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# THE UNIVERSITY OF MICHIGAN

# Studies in Language and Language Behavior

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CENTER FOR RESEARCH ON LANGUAGE AND LANGUAGE BEHAVIOR

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II. STUDIES IN PROGRESS

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# The Patterns of Air Flow During Pronunciation: A Feasibility Study for Automatic Recognition and Evaluation of Speech

J. C. Catford, H. L. Lane, Ruth Oster, & S. Ross

The Patterns of Air Flow during Pronunciation:

a Feasibility Study for Automatic Recognition

and Evaluation of Speech

J. C. Catford, H. Lane, R. Lehman, R. Oster

T. Rand, and S. Ross

Center for Research on Language and Language Behavior

Since the latter half of the nineteenth century the kymographic recording of air flow out of the mouth has been a basic tool of phonetic research. Originally using rubber diaphragms and tracings on smoked paper wrapped around a clockwork-driven drum, kymography now uses electronic equipment; but the objects and results are essentially the same, namely to record variations in air flow which are diagnostic of phonatory and articulatory events in the vocal tract.

The linear trace of the kymograph, however, gives, in effect, information about only one dimension of vocal activity; namely the varying durations and degrees of constrictions of the tract, as indicated by the variations through time of the volume-velocity of air flow out of (or into) the mouth and nose.

The present research project is an attempt to introduce a second dimension into recordings of air flow out of the mouth, namely, to add at least some indications of the location and cross-sectional shape of constrictions of the vocal tract.

The hypothesis is that articulatory constrictions at different locations and of different cross-sectional shape and area should in many cases produce differences in the location and cross-sectional area of the total mass of air flowing out of the mouth. Thus, it might be predicted that air flowing through a lateral channel (as for /l/) would show a more laterally located outflow than air flowing through a central channel (as for /z/), that air flowing through narrowly rounded lips, as for /u/, would show a more concentrated and centrally located outflow than air flowing through a vertically wide opening as for /a/, and so on. It was further hoped that finer discriminations might be obtained. For instance, there might be characteristic differences in the cross-sectional flow pattern for such pairs of sounds as /s/ and /š/; the latter, perhaps, having the flow directed somewhat more downwards than the former.

It was realized from the start that there might be at least three possible sources of problems. First, the subjects were to produce isolated sounds representing as far as possible certain English phonemes. However, phonemes cannot be defined absolutely but only relative to other phonemes; the articulators are allowed some degree of freedom in their placement. Thus an English /t/ is recognized as such whether the tongue is touching the teeth or the back part of the alveolar ridge. In another language these two positions might define two rather than just one phoneme. Thus, when a subject attempts to say a sound twice, representing the same phoneme, a slight change in articulation might change the air flow pattern but not the phoneme. This factor would be even more apparent between subjects because each person tends to develop his own characteristic way of producing each phoneme. Second, the size and shape of the vocal tract varies from person to person. Thus, because of physiological limitations, even approximately identical articulatory positions in different people may not produce identical airflow patterns. Third, the initial air flow, usually from the lungs, may vary without changing the quality of the sound. This variation could also contribute to a variation in air flow pattern.

Despite all these possible complications, it must be remembered that for the present purposes it is not necessary that a given phoneme result in exactly the same airflow pattern each time. It is only necessary that the pattern be distinguishable from the patterns formed by all other phonemes in the set employed.

Initial experiments using a moveable hot-wire anemometer in front of the mouth were inconclusive, not only because of the problems mentioned above, but also for two other reasons.

First, the necessity of placing the anemometer probe successively in four different positions meant that for each sound studied we obtained recordings of four different utterances. It was therefore difficult to draw conclusions from these data about the air-velocity distribution over the four probe-locations for any one utterance of a sound.

Secondly, in using only four probe-locations it was impossible to tell if these locations were optimal. In any given case we might, in fact, have been missing the locus or loci of maximal flow velocity, or otherwise failing to get a reliable picture of the cross-sectional pattern of the flow.

It became necessary, therefore, to find a way of obtaining a more general visualization of the location of the whole mass of air flowing out of the mouth.

## A Method Using Liquid Nitrogen

Several methods of flow-visualization were considered. These included the Schlieren technique (a method using the deflection of parallel light-rays by a density gradient, provided in this case by articulating after inhaling helium) and methods using infra-red heat and moisture-sensitive chemicals.

Finally, a method using liquid nitrogen was selected.[1] A copper screen was dipped in liquid nitrogen and then placed on a rigid frame. Because of the rapid evaporation of the liquid nitrogen, the screen became quite cold and moisture from the air formed a frost layer on it. The gradual return of the screen's temperature toward that of the room was monitored with a circuit including a constantan wire soldered to the center of the copper screen at one end and to a copper lead, submerged in ice-water, at the other. A VTVM measured the voltage between the lead and the screen, which was the sum of the emf generated at the two thermocouple junctions, and was proportional to the temperature of the screen referred to that of the ice water. Through experimentation a temperature was selected at which the screen appeared to be most sensitive to the air flow from the mouth ($-5^{o}C$). Although this threshold was low, its effect on the measured pattern can probably not be neglected.

The subject approached the screen just before it reached threshold temperature. He placed his nose against a wire projection, which positioned his lips approximately 1.5 centimeters from the screen, and then he produced the given phoneme. The screen began to defrost from the warmth of the air flowing from his mouth. By use of a voice-operated relay, a photograph of the pattern on the screen was taken exactly 1.5 seconds after the subject began to phonate (cf. Fig. 1). This time lapse allowed the pattern to develop but was not so long

Insert Fig. 1 about here

that defrosting from other factors had much chance to alter the pattern. Each observed pattern of air flow is, therefore, time integrated; it is not the pattern at any given moment during production of the sound. The utterance was simultaneously recorded on a tape recorder for later measurement of relative sound levels.

Seven sounds, representing approximately isolated utterances of the English phonemes /a/, /u/, /l/, /s/, /š/, /z/, and /ž/ were used as samples. In a given session a subject spoke each of the seven sounds twice in succession; he tried to duplicate each sound as closely as possible in articulatory position and effort. Subjects One and Two each served in two sessions a week apart, while Subject Three served only once.

## Results and Discussion

Figures 2-4 present tracings of the photographs of the air flow patterns. Because the photographs were the same size as the original patterns, these tracings are life-size. The + represents that point in the subject's mouth where the lower edges of the two upper front teeth come together. The patterns

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Insert Figs. 2-4 about here

---

marked by ——— and - - - - - were obtained in the first session; those marked by -.- and -+- were recorded in the second. An incomplete tracing indicates that the pattern extended beyond the edge of the photograph.

Examination of the tracings reveals that the pattern of air flow is quite consistent over utterances of the same phoneme by one subject. In this respect, the vowels are the most consistent. Their patterns are very much like those that might be predicted from general phonetic knowledge. The patterns for /a/ followed very closely the outline of the shape of the mouth. The absence of a record here for Subject Two is understandable because the velocity of air flow from the mouth during this sound is low. However, it should be noted that no systematic relation was observed between the area of the air flow patterns and the sound pressure level of their correlated sounds. The patterns for /u/ for all subjects were small and centered about the mouth. This type of pattern is consistent with the rapid air flow, the rounding of the lips, and the small oral opening that occur during this sound.

The /l/ and the voiced fricatives seem to be the next most consistent within a subject. The voiceless fricatives show the widest variation, which may be partly the result of their very turbulent air flow. The patterns for /l/ are particularly interesting. Subjects Two and Three show clearly unilateral patterns--with the difference that Two's /l/ appears to be left-sided, Three's /l/ right-sided. Subject One's /l/ is apparently bilateral, and hence not so distinct from /z/ and /ž/ as that of Two and Three.

There seems to be enough variati[illegible] patterns of different sounds for a given subject for purposes of differentiation. The variations between sounds seem to be greater than the variations within a sound.

In contrast to the intra-subject consistency, there is very little inter-subject consistency for a given phoneme. Only the vowels show any consistency at all. There appears to be no simple transform, such as reduction or enlargement or change of position, which would make two subjects' data congruent. Differences in anatomy, articulation, and breath-stream control may obscure such regularities as exist across subjects. Therefore, it appears that an efficient pattern-matching method for the differentiation of phonemes is quite possible, based on their correlated patterns of air flow, for a given subject. However, because of the extensive inter-subject variation, the standard patterns would have to be modified for each new subject.

## Figure captions

Fig. 1. A photograph illustrating how patterns of air flow were detected using a frosted screen.

Figs. 2-4. Tracings of air flow patterns taken from photographs like that in Fig. 1.

## Footnotes

1. The assistance of Mr. K. Lanini in developing this technique is gratefully acknowledged.

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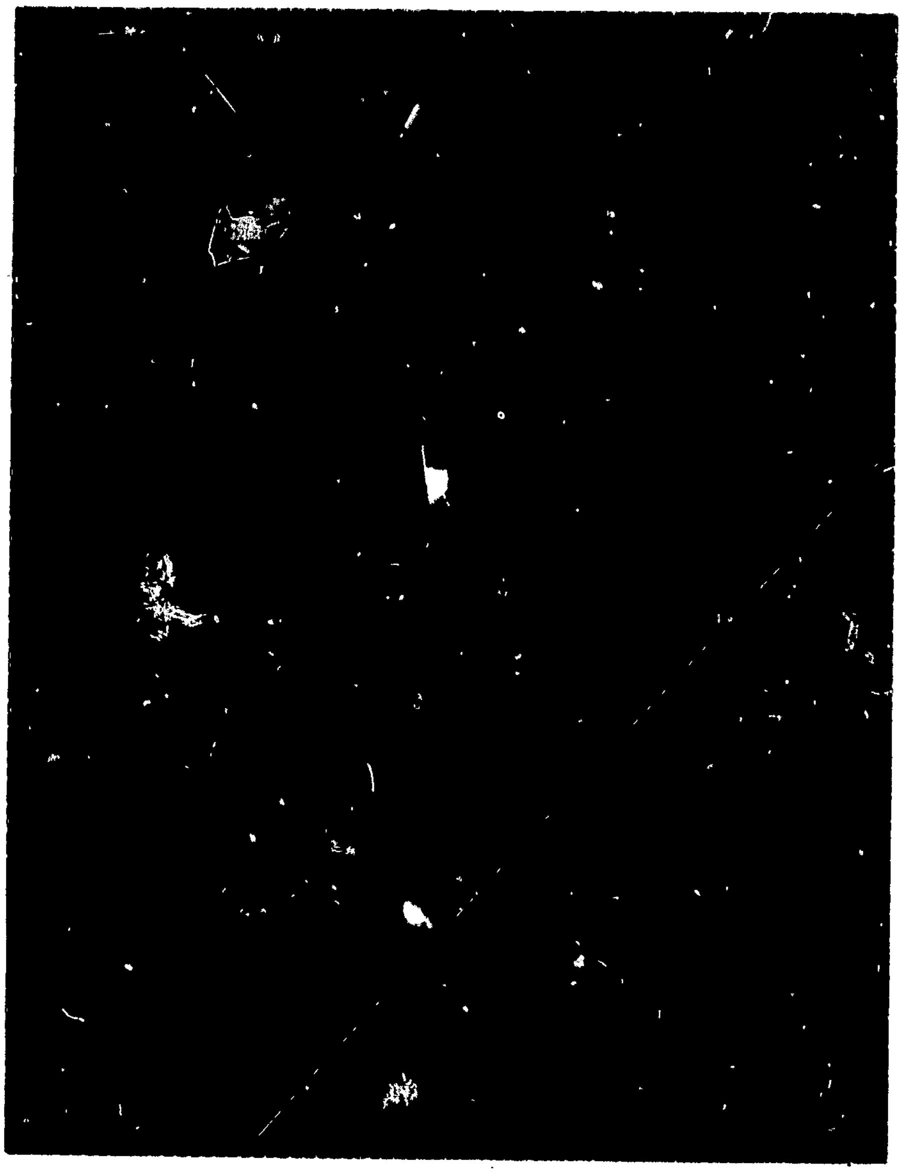

Figure 1

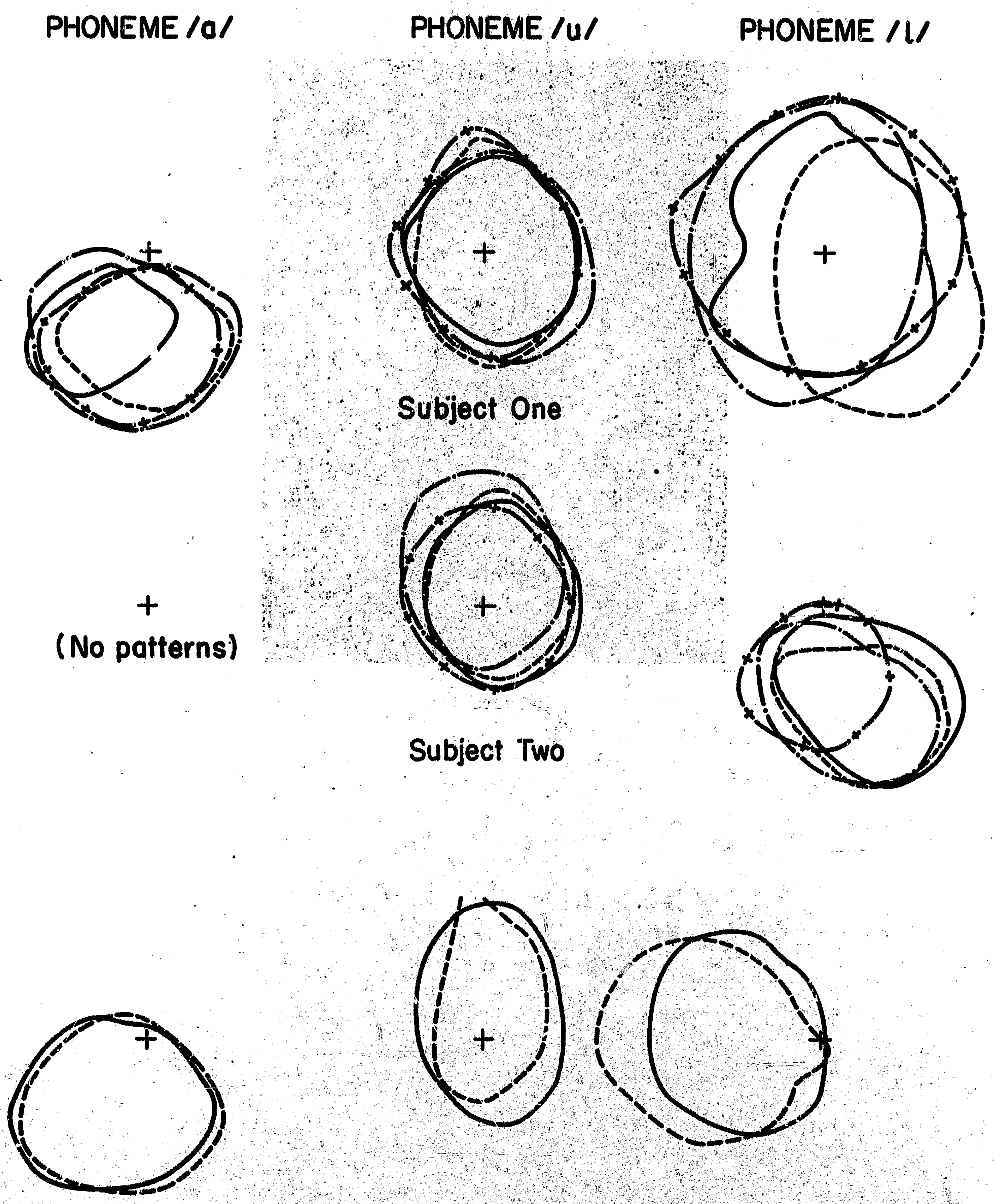
PHONEME /a/
PHONEME /u/
PHONEME /l/
Subject One
(No patterns)
Subject Two

Figure 2

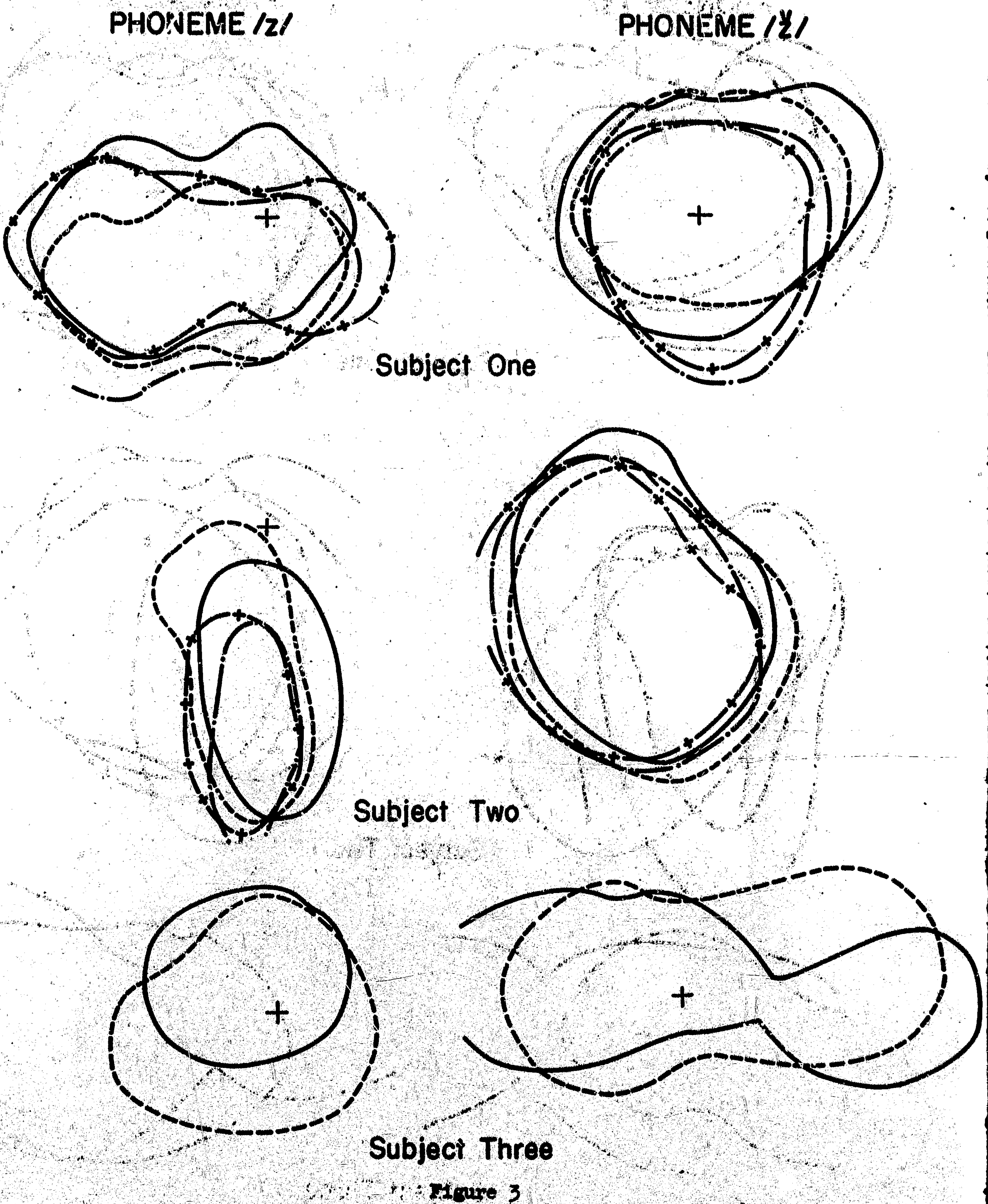


Figure 3

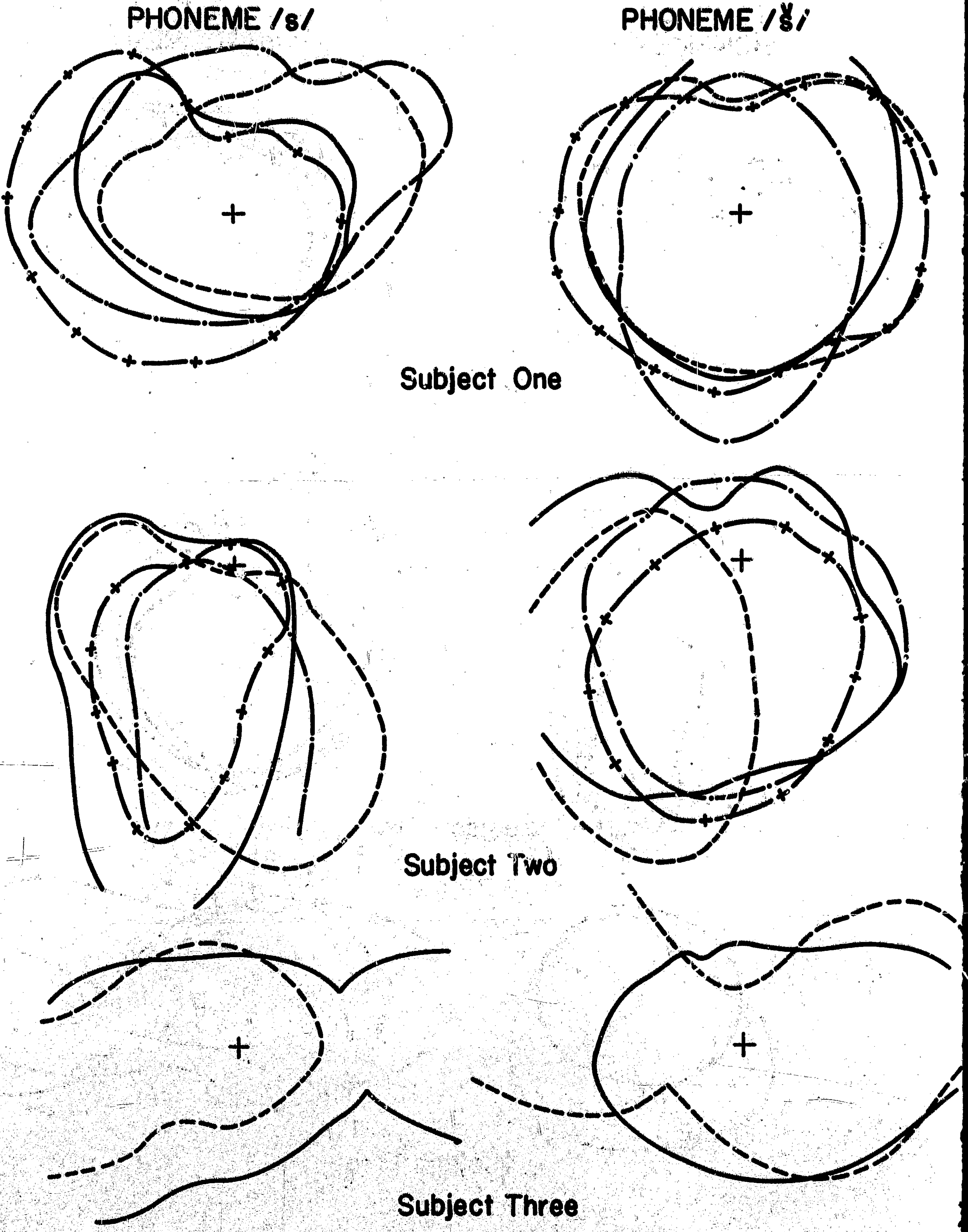


Figure 4

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# An Application of Digital Inverse Filtering to the Systematic Variation of Vowel Parameters

J. Hemdal

# An Application of Digital Inverse Filtering to the Systematic Variation of Vowel Parameters

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Abstract

The Levin time-domain method for the least-squares determination of impulse functions and filter characteristics has been applied to the measurement and systematic variation of vowel parameters. This technique determines the optimum filter that equalizes or transforms a given time series into a related or derived series. For example, when given a typical vowel waveform and an estimate of the corresponding laryngeal excitation, the method produces the impulse response of the vocal tract during the production of that vowel. This results in a time-domain approach to analysis-by-synthesis. Alternately, this method may be used for the systematic variation of certain vowel parameters. In this instance, one vowel waveform of a given speaker and a second vowel waveform of the same speaker are considered as input and output waveforms; the impulse response obtained from this equalizing technique exhibits the characteristic difference between the vocal tract configurations of the two vowels. In addition, this filter impulse-response may be systematically varied and convolved with different vowel waveforms, producing quasi-natural vowels. These quasi-natural vowels, in turn, may be useful in charting perceptual regions in vowel spaces such as the formant one-formant two plane. This paper describes the mathematical formulation, its implementation on a digital computer and some preliminary results.

One of the factors which has provided impetus to studies in speech synthesis is the need for the systematic control of acoustic parameters for studies in speech perception. Since we are mostly concerned with perception of natural speech, every effort is made to increase the naturalness of the sounds of synthetic speech. The extent to which perceptual behavior may be "non-lingual" if the listener is presented with speech-like sounds, is difficult to determine. On the other hand, it is also difficult to systematically vary a given acoustic parameter of a naturally-produced vowel in order to provide perceptual stimuli.

To avoid the possibility of obtaining misleading or shifted perceptual boundaries when using unnatural speech-like sounds, a study was undertaken to

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test the feasibility of varying a single pole of a natural vowel. It was suspected that multiplication of a pole and zero transfer function by the vocal tract transfer function would achieve the desired result, but only at a great expense of computing time. Therefore, an investigation was conducted into the Levin time-domain extension of Wiener's classic least-squares prediction and smoothing procedure (Levin, 1960).

To review the method, consider the block diagram in Fig. 1.

---

Insert Fig. 1 about here

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If $f_A(t)$ is a stationary process with both random and deterministic components, then the Wiener method provides a frequency domain, least-squares determination of a linear, time-invariant filter-response $g_{AB}(t)$ which will produce a desired output $f_B(t)$. The method requires only the correlation functions of the input and output. This process requires knowledge of the infinite past of a stationary process and therefore cannot be used for non-stationary pulses.

Levin, however, was able to relax the conditions on stationarity and knowledge of the infinite past and was able to perform the transformation in the time-domain. Therefore, his approach is applicable to a single glottal pulse or pitch period of the speech waveform. Furthermore, this transformation is sufficiently general that the input and output functions need not be related.

This technique determines the impulse response of a suitable filter which, if convolved with the function $f_A(t)$, will produce the desired output $f_B(t)$. The method may be examined more closely with Fig. 2.

---

Insert Fig. 2 about here

---

A linear integral equation in the correlation functions of the input and output is presented in line (1). The solution of this equation yields the linear least-squares convolution operator $g_{AB}(t)$. The conditions for the existence of this solution require $f_A(t)$ be a stationary random process and that the integration be carried out for a semi-infinite extent.

In line (2), however, a discrete version of the integral equation appears, for which Levin has shown the existence of a solution. If the correlation functions (or more properly, the lagged cross-products) are finite, then the summation takes place over a finite extent. Furthermore, the condition of stationarity of the input and output is not required. The solution $g_{AB}(t)$ is the least-squares convolution operator for a finite-length signal $f_A(t)$.

The solution to the equation (2) can be obtained most easily by writing this equation as a matrix operation, as shown in Fig. 3.

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Insert Fig. 3 about here

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The discrete operator may then be obtained as a solution of N simultaneous linear equations in N unknowns.

Figure 4 shows the matrix equation alongside the equation for a direct solution for the convolution operator.

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Insert Fig. 4 about here

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The latter approach, requiring the discrete input and output time-series themselves rather than the lagged cross-products or empirical correlations, is not attempted because the input and output may be incompatible--i.e., there may exist no exact operator for arbitrary $f_A$ and $f_B$. When using the lagged cross-products, however, we are assured that a solution of equation (3) does exist and that this solution is the least-squares approximation to the exact solution. Thus, unrelated time functions may be used without prior testing for compatibility.

This feature makes the method attractive for studying vowel acoustic waveforms. If the vowel waveform is considered to be the output and the glottal pulse waveform the input, then the solution to the matrix equation (3) is the convolution operator or the time-domain impulse response of the vocal tract. To check this result, a single pitch period of the vowel /ɔ/ was chosen as $f_B(t)$, the assumed output. The approximate glottal pulse shown in Fig. 5 is considered the input.

Insert Fig. 5 about here

A solution of the matrix equation by digital computer yields the convolution operator or impulse response of the vocal tract during a single pitch period of the vowel /ɔ/.

A Fourier analysis of this impulse response should exhibit the poles or formants of the vocal tract, but not the zeros of the glottal pulse. This time-domain operation is aquivalent to cancellation of the zeros of the input function. Since the input pulse-spectrum is known to drop off with frequency at about 12 db per octave, the result is similar to pre-emphasizing the vowel spectrum at the higher frequencies. It has more significance than simple pre-emphasis, however, since extraction of the glottal-source characteristics from the acoustic waveform is performed. It is possible to gain an advantage other than just making higher order formants more apparent. To illustrate, the spectrum in Fig. 6 is determined from a single pitch

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Insert Fig. 6 about here

---

period from the vowel /ɔ /, and no frequency pre-emphasis was performed. On a linear scale, the higher formants are barely detectable. Figure 7 shows the spectrum obtained by a time-domain cancellation of the effects of the

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Insert Fig. 7 about here

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glottal pulse. Note particularly the absence of the fundamental and second harmonic, and the increase of energy at the higher frequencies. It was not possible to obtain the exact shape of the glottal pulse that was present at the production of this vowel; therefore, it was impossible to obtain complete cancellation of the glottal zeros. This results in the presence of extraneous peaks in the spectrum. Closer approximations to the correct source would "clean up" the spectrum.

A second example of the effects of time-domain cancellation of the contribution of the glottal spectrum to the vowel spectrum is given in Figs. 8 and 9 for the vowel /æ/. Note the apparent narrowing

Insert Figs. 8 and 9 about here

of the first formant, which arises from the removal of the effect of harmonics of the source in shaping the spectrum. Again, we see the removal of harmonics, the accentuation of the second and third formants, and, unfortunately, the incomplete cancellation of some source zeros. Notice also the possible ambiguities in the location of formant three. If a different glottal pulse is assumed for the calculations, the spectrum shown in Fig. 10 results. Here the ambiguity in the locus of the third formant is resolved,

Insert Fig. 10 about here

but incomplete cancellation of the sixth harmonic obscures the first formant, implying that both of the assumed glottal-pulse shapes were inadequate representations of the actual source waveform.

The preceding discussion is not aimed primarily at adding to the numerous methods already available for determining transfer functions of the vocal tract. Rather, we are interested in the feasibility of determining this transformational technique, using the least-squares digital inverse operator which would remove a specified formant from a vowel waveform and replace it by an alternate formant. In its simplest form, the waveform of a vowel, say /ɯ/, may be considered the filter input and another vowel waveform /ɔ/ may be considered its output. The solution, which always exists, may be considered as that convolution operator which transforms the /ɔ/ vowel into an /ɯ/. The predominant action of this operator would be to remove the relatively high first formant of /ɔ/ and replace it at a lower frequency. It would be expected that other poles and zeros would require some shifting and, since this may well interfere with the primary movement of the first formant, it was thought best that the operator be determined for shifting a single pole. One such convolution operator is shown in Fig. 11. A series of such operators was calculated; it was designed to progressively

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Insert Fig. 11 about here

---

shift the first formant frequency of the vowel /ɔ/ by 100 cps steps.

The effect of the convolution operator on one pitch period of the vowel /ɔ/ is shown in Fig. 12. The dotted line represents the spectrum of the

---

Insert Fig. 12 about here

---

vowel /ɔ/ before shifting the first formant; the solid line shows the vowel spectrum after the shift. The resulting decrease in the height of the second formant peak is in accord with the measurements of formant amplitude performed by Fant and others (1963).

It was mentioned earlier that a hoped-for result was the systematic variation of vowel parameters which did not destroy the naturalness of the sound of the vowel. Presumably, this naturalness is a result of variations in pitch, glottal-pulse shape, formant transitions and the spectral shaping resulting from higher-order formants. In this preliminary study it was possible to examine only a single vowel pitch period at a time; consequently the vowels were reconstructed from repeated pitch periods and most of the factors contributing to naturalness were eliminated. Nevertheless, this is not a limitation of the transformational method and studies in progress overcome these constraints in order to assess the naturalness of vowels manipulated by digital inverse filtering.

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## Figure Captions

Fig. 1. A block diagram illustrating the filtering process for vowels.

Fig. 2. The linear integral equation in exact (1) and discrete (2) forms.

Fig. 3. A matrix equation which is equivalent to the discrete version of the integral equation.

Fig. 4. For comparison, the matrix equation and the intergral equation for solving for $g_{AB}(t)$ directly.

Fig. 5. A free-hand approximation to the glottal pulse waveform.

Fig. 6. The frequency spectrum of a single pitch period extracted from the middle of the vowel /ɔ/ (Speaker DVY). No high frequency pre-emphasis or other spectral preshaping was performed.

Fig. 7. The spectrum of the same pitch period of /ɔ/ after removing the effects of the glottal pulse by inverse filtering.

Fig. 8. The frequency spectrum of a single pitch period from the vowel /ɝ/ (speaker DVY). Again no spectral preshaping was performed.

Fig. 9. The spectrum of the pitch period of /ɝ/ after removing the effects of the glottal pulse by inverse filtering. The assumed glottal pulse shown had approximately a 60 per cent duty-cycle.

Fig. 10. The spectrum of the vowel /ɝ/ after removing the effects of a different glottal pulse. This glottal pulse had approximately a 95 per cent duty-cycle.

Fig. 11. An example of the waveform of a digital inverse operator. This operator shifts a pole at 1600 cps to a pole at 3200 cps. The lack of symmetry in the operator results from truncation errors and the inharmonic relation between the repetition rate (fundamental) of the waveform and the

pole at 3200 cps.

Fig. 12. An example of the change in the spectrum of the vowel /ɔ/ resulting from inverse digital filtering. The first formant of the vowel /ɔ/ (dotted line) was removed from 660 cps and replaced at 500 cps (solid line).

## Bibliography

Note: Many variations of the basic Wiener theory exist as a result of relaxing some or all of the conditions on the signal and/or noise. Also, more complete derivations and existence proofs, as well as application in other areas, have been reported. The following sources discuss most of the extensive work in this area.


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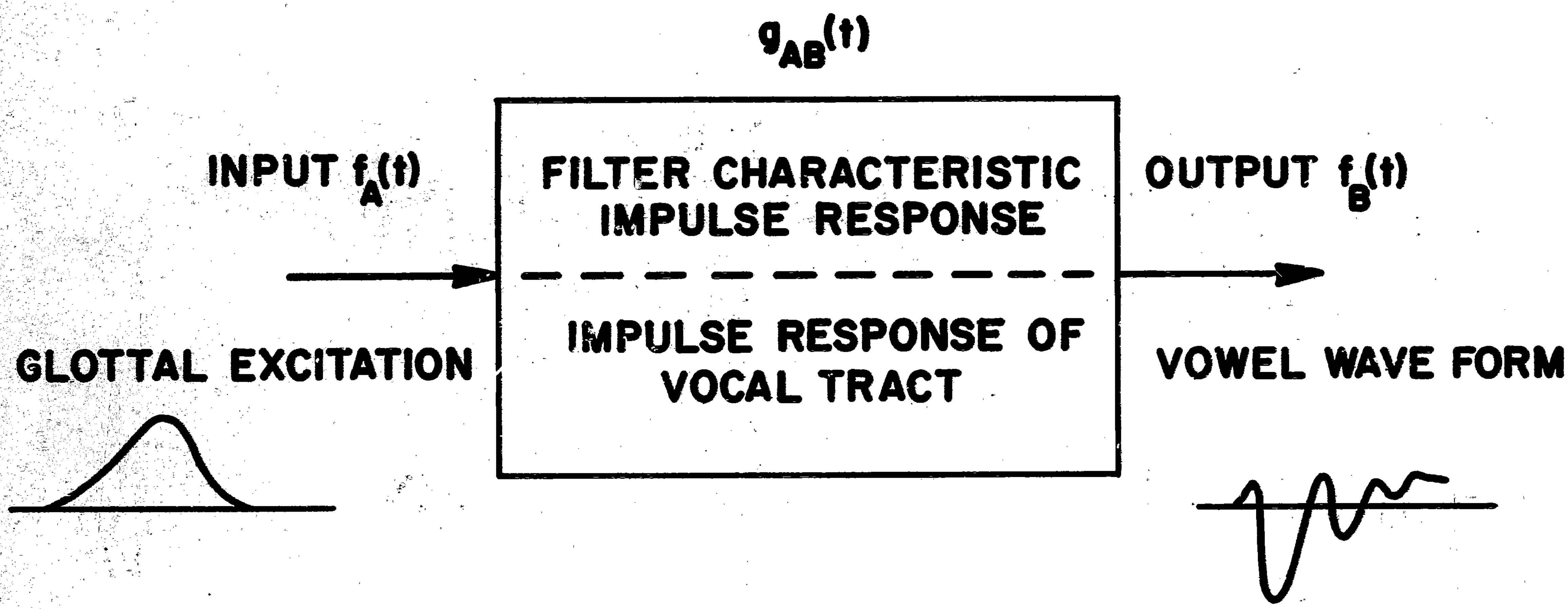


$g_{AB}(t)$
INPUT $f_A(t)$
GLOTTAL EXCITATION
FILTER CHARACTERISTIC IMPULSE RESPONSE
IMPULSE RESPONSE OF VOCAL TRACT
OUTPUT $f_B(t)$
VOWEL WAVE FORM


Fig. 1

$$\phi_{BA}(\tau) = \int_0^\infty g_{AB}(t)\phi_{BB}(\tau - t)dt \tag{1}$$

$$\phi_{BA}(\tau_n) = \sum_{n=0}^{n-1} g_{AB}(t\ )\phi_{BB}(\tau_n - t_n)\,\Delta t \tag{2}$$

Fig. 2

$$
\begin{bmatrix} \phi_{BA}(0) \\ \phi_{BA}(1) \\ \phi_{BA}(2) \\ \vdots \\ \phi_{BA}(N-1) \end{bmatrix}
=
\begin{bmatrix} g_{AB}(0) \\ g_{AB}(1) \\ g_{AB}(2) \\ \vdots \\ g_{AB}(N-1) \end{bmatrix}
\times
\begin{bmatrix}
\phi_{BB}(0) & \phi_{BB}(1) & \cdots & \phi_{BB}(N-1) \\
\phi_{BB}(1) & \phi_{BB}(0) & \cdots & \phi_{BB}(N-2) \\
\phi_{BB}(2) & \phi_{BB}(1) & \cdots & \phi_{BB}(N-3) \\
\vdots & \vdots & & \vdots \\
\phi_{BB}(N-1) & \phi_{BB}(N-2) & & \phi_{BB}(0)
\end{bmatrix}
$$

Fig. 3

$$\underset{\text{Column}}{\left[\phi_{BA}(\tau)\right]} = \underset{\text{Column}}{\left[g_{AB}(\tau)\right]} \times \underset{N \times N}{\left[\Phi_{BB}(\tau)\right]}$$

EQUATION THREE - MATRIX EQUATION

$$f_B(t) = \int_0^{\infty} g_{AB}(t)\, f_A(\tau - t)\, dt$$

EQUATION FOUR - CONVOLUTION OPERATION

Fig. 4

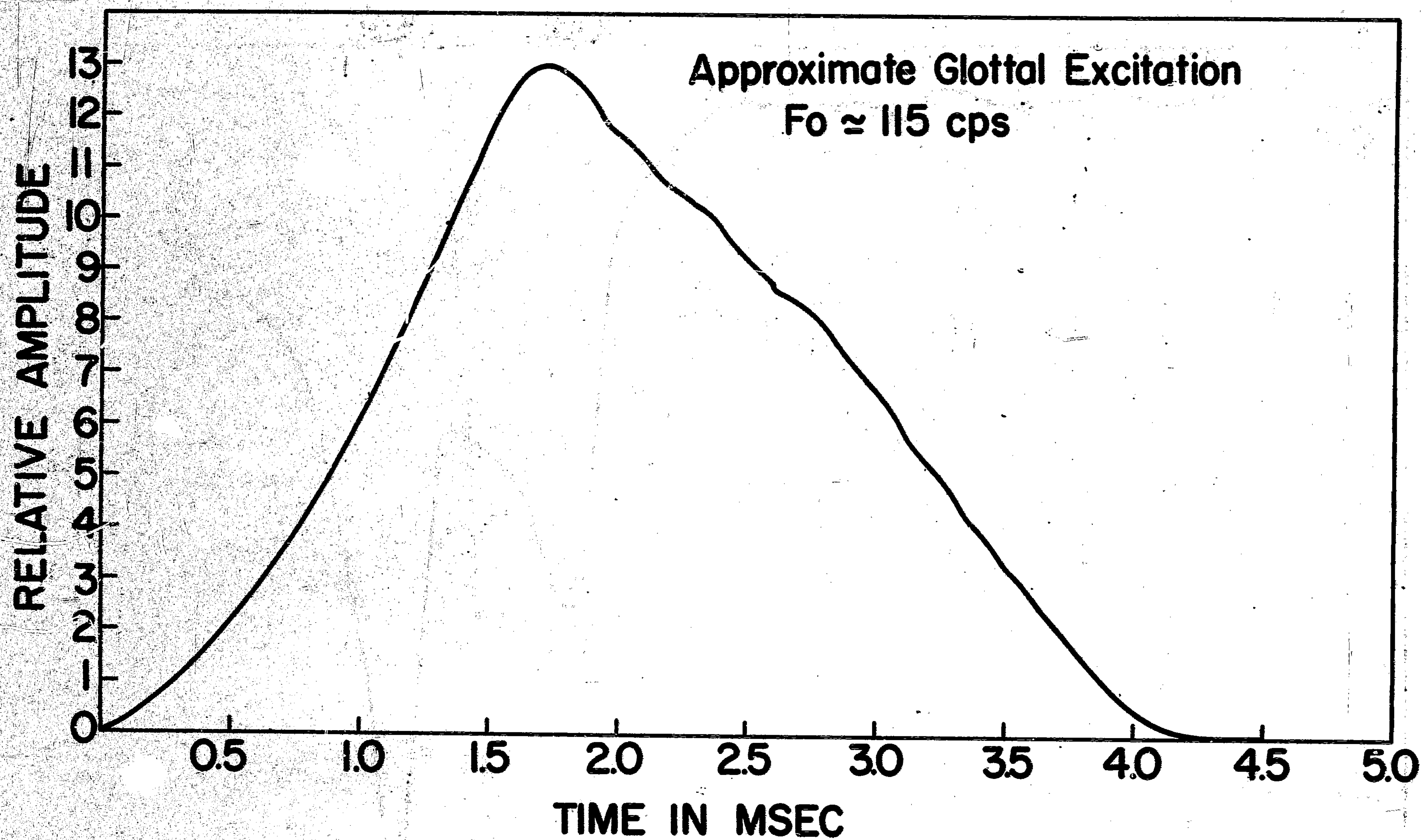

Approximate Glottal Excitation
Fo ≃ 115 cps
RELATIVE AMPLITUDE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
TIME IN MSEC

Fig. 5

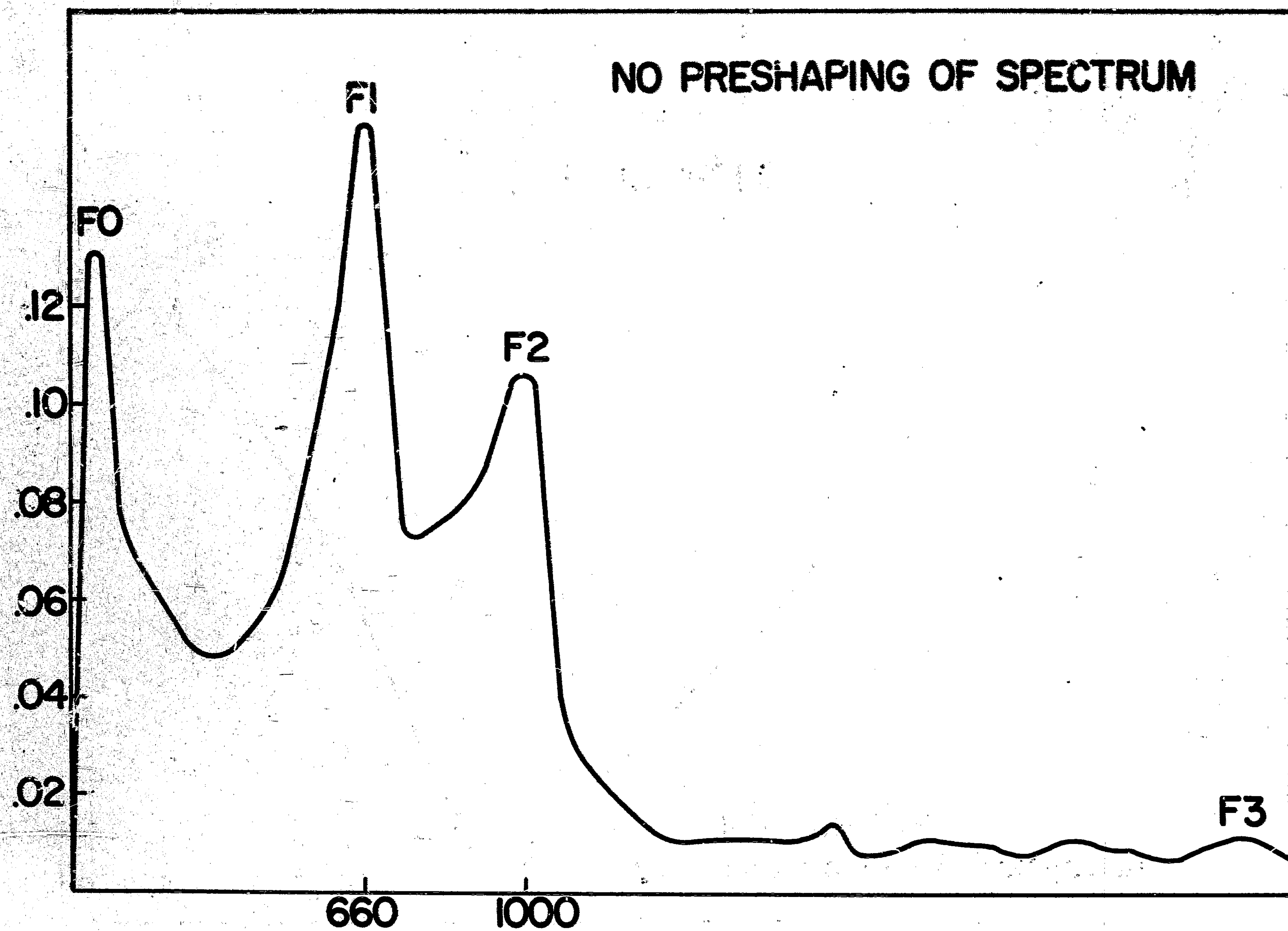

NO PRESHAPING OF SPECTRUM
F0
F1
F2
F3
.12
.10
.08
.06
.04
.02
660
1000
FREQUENCY

Fig. 6

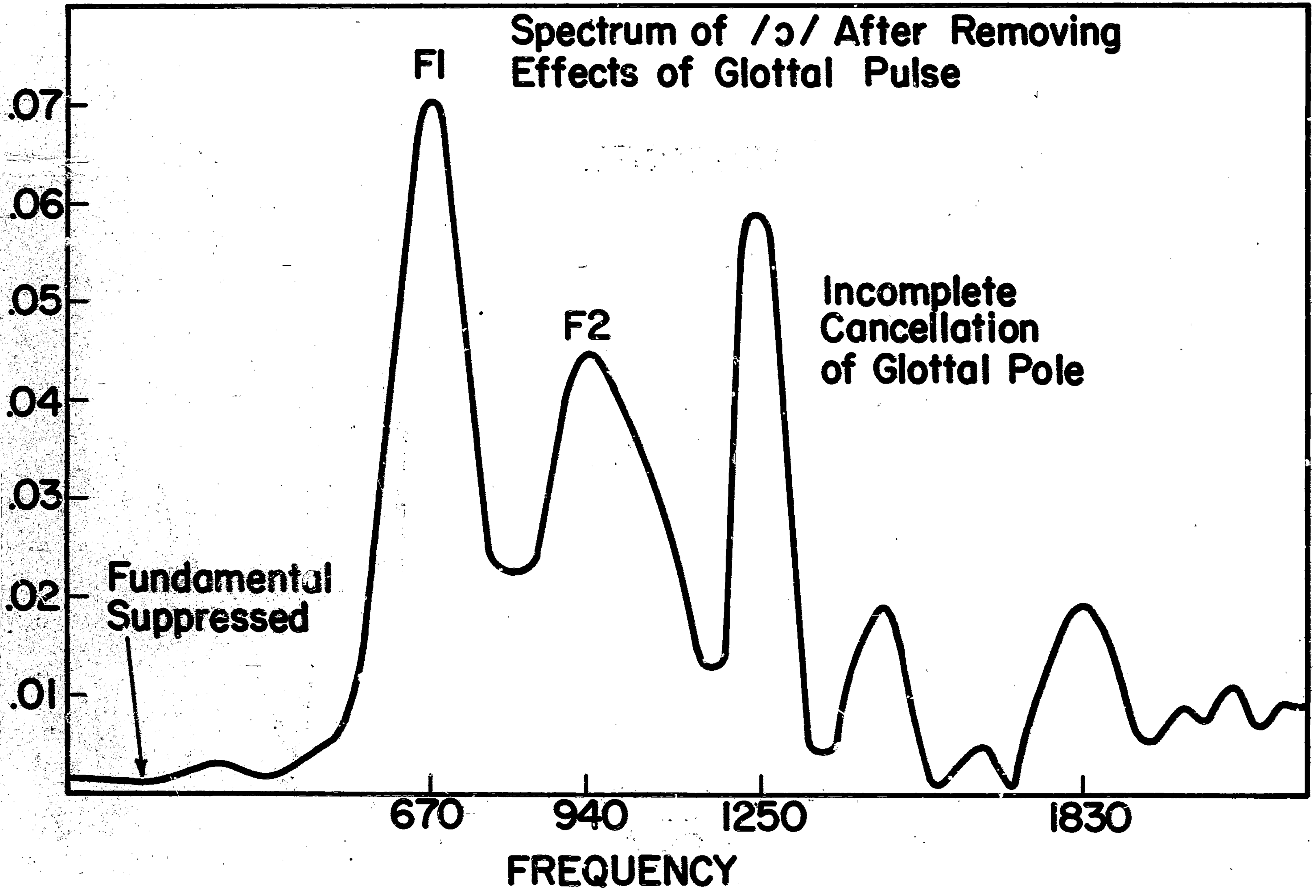
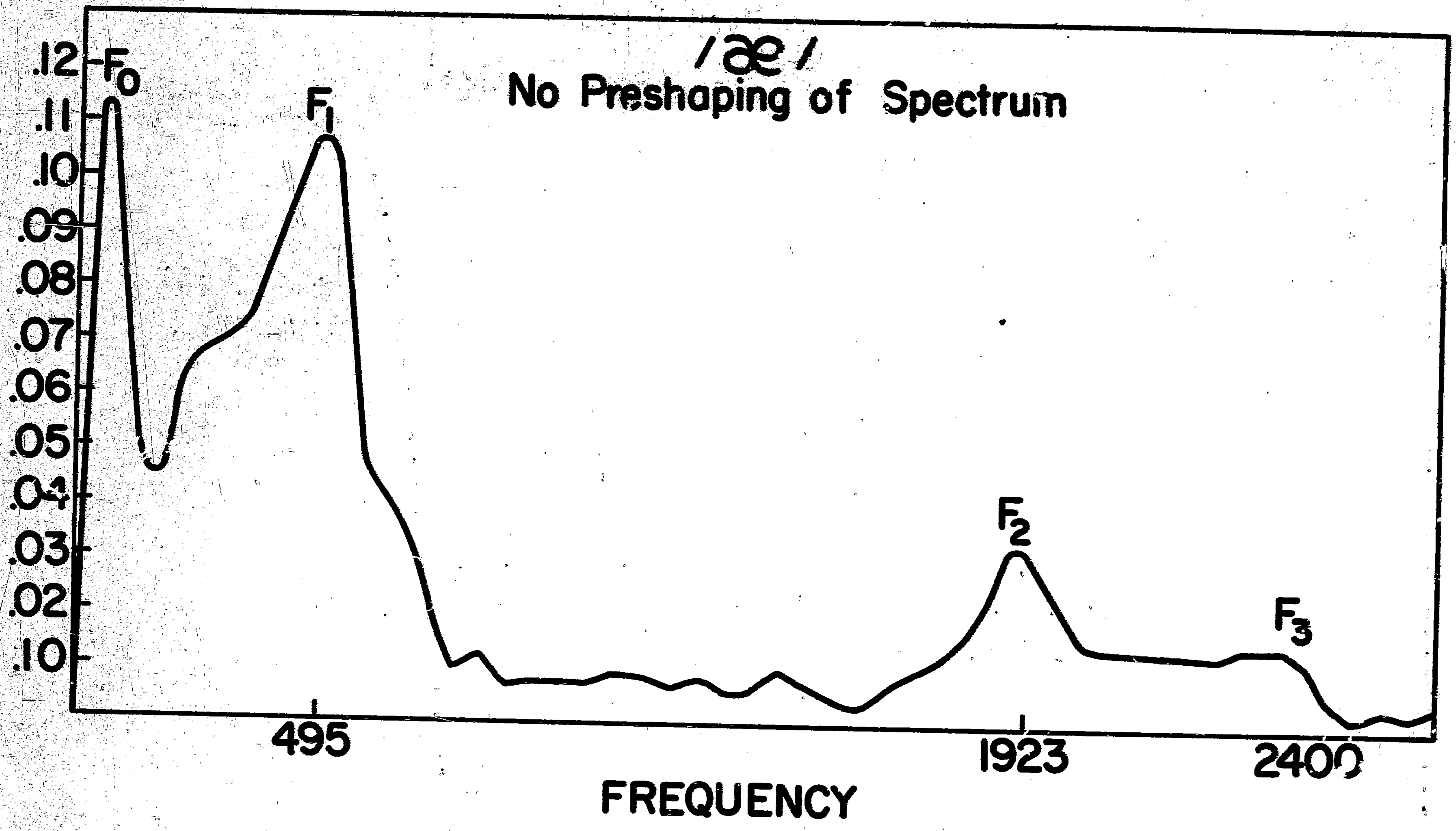

Spectrum of /ɔ/ After Removing
Effects of Glottal Pulse
F1
F2
Incomplete
Cancellation
of Glottal Pole
Fundamental
Suppressed
.07
.06
.05
.04
.03
.02
.01
670
940
1250
1830
FREQUENCY

Fig. 7



/æ/
No Preshaping of Spectrum
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.10
F0
F1
F2
F3
495
1923
2400
FREQUENCY


Fig. 8

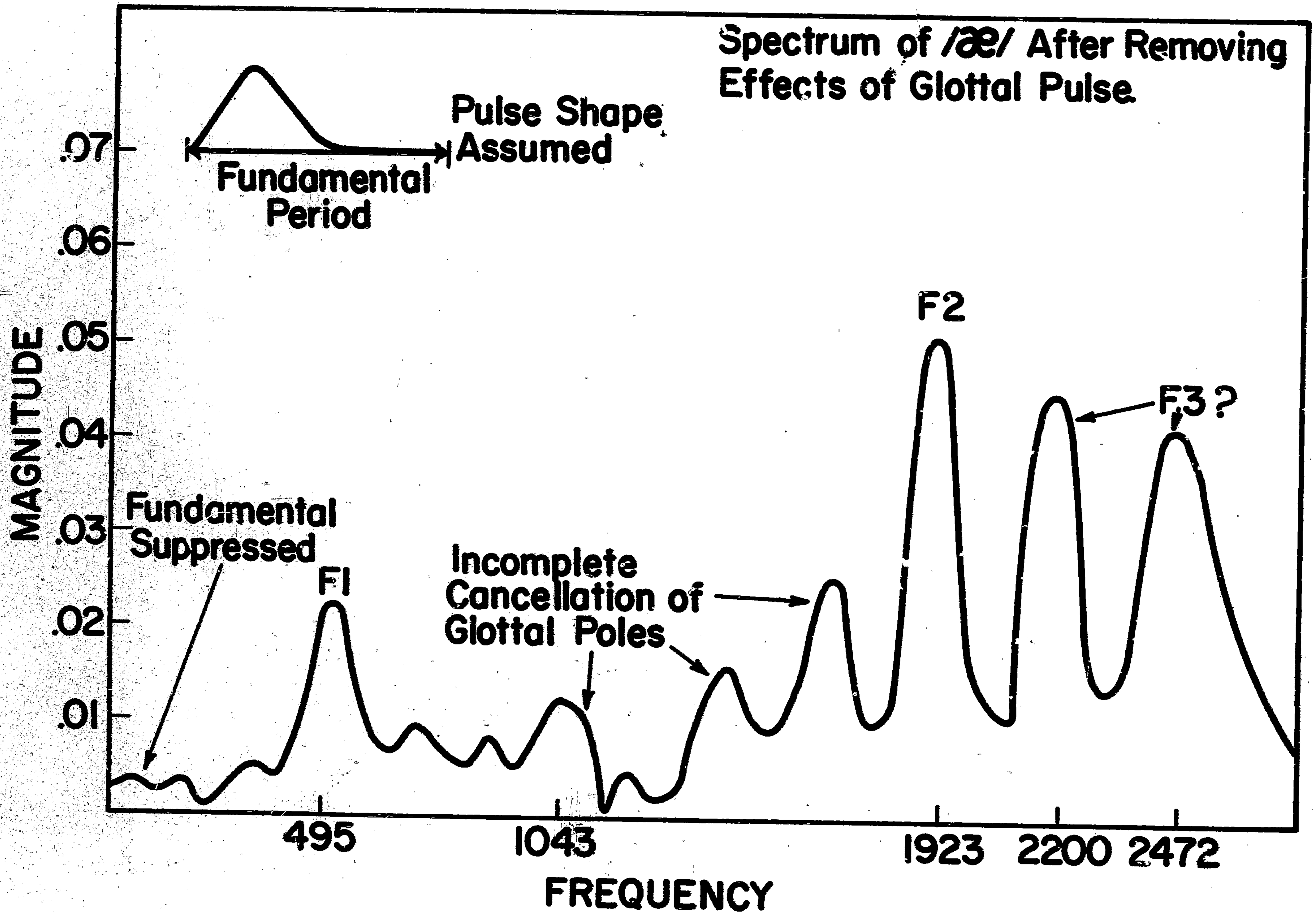

Spectrum of /æ/ After Removing
Effects of Glottal Pulse
Pulse Shape
Assumed
Fundamental
Period
MAGNITUDE
.07
.06
.05
.04
.03
.02
.01
Fundamental
Suppressed
F1
Incomplete
Cancellation of
Glottal Poles
F2
F3 ?
495
1043
1923
2200
2472
FREQUENCY

Fig. 9

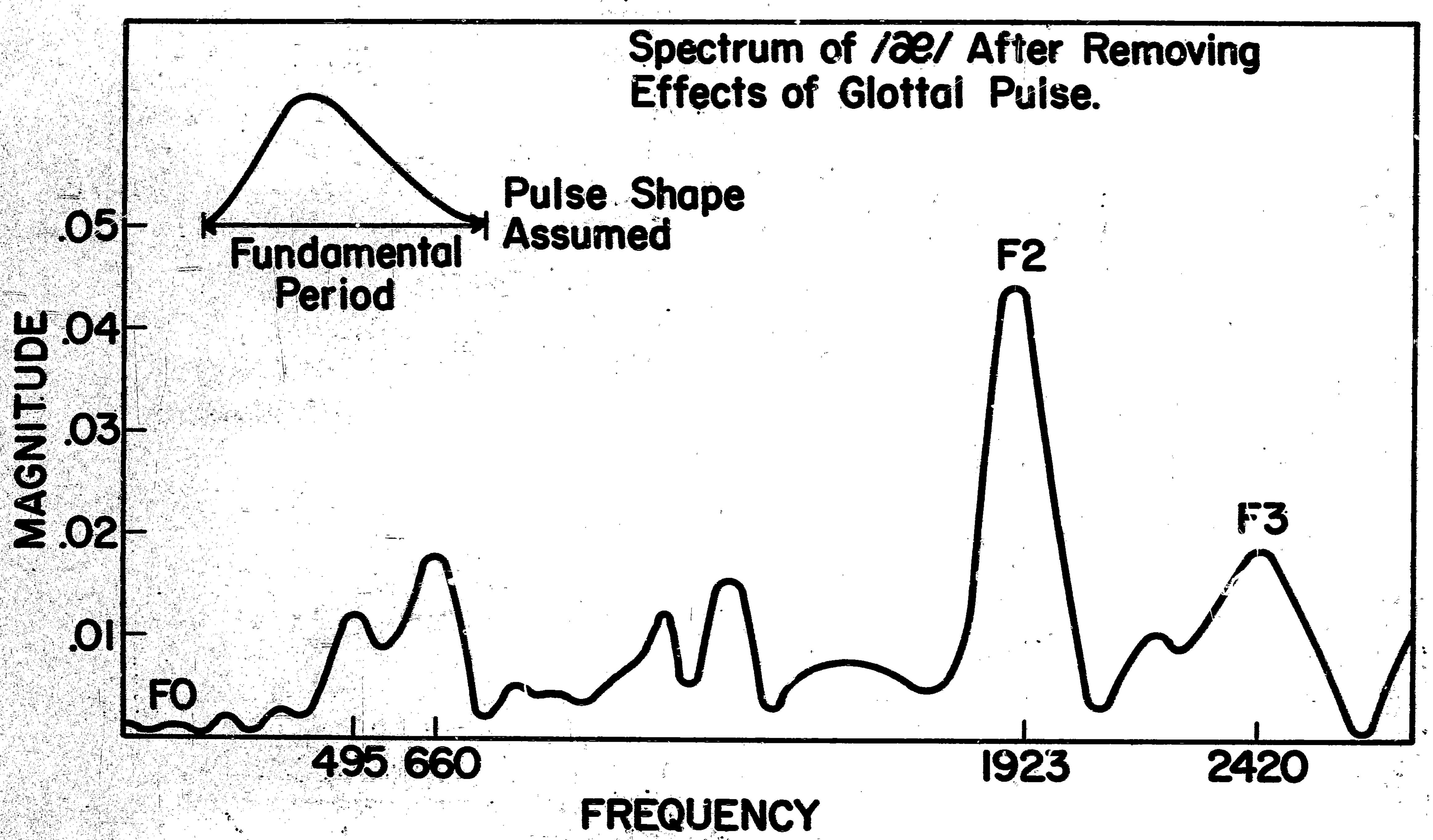
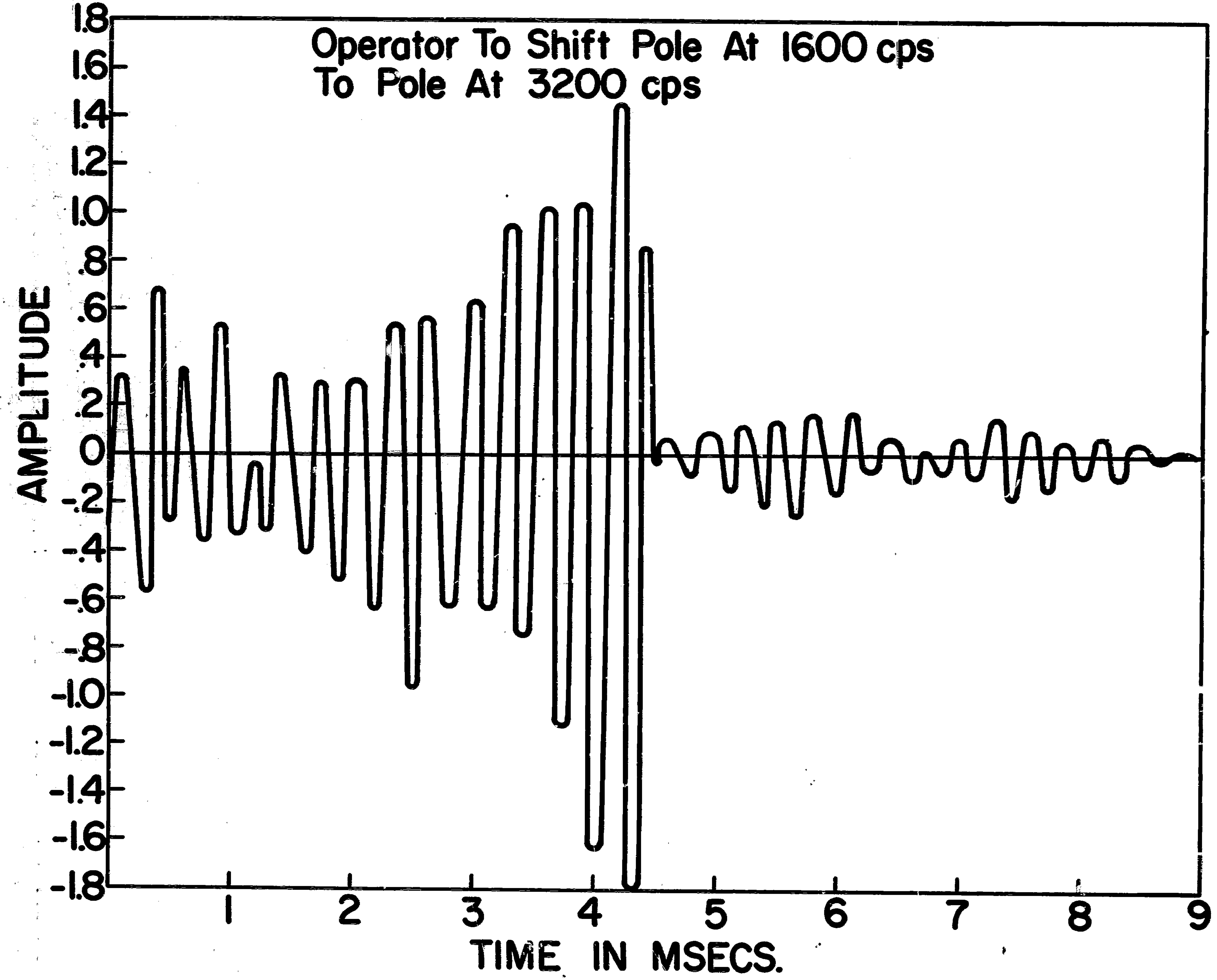
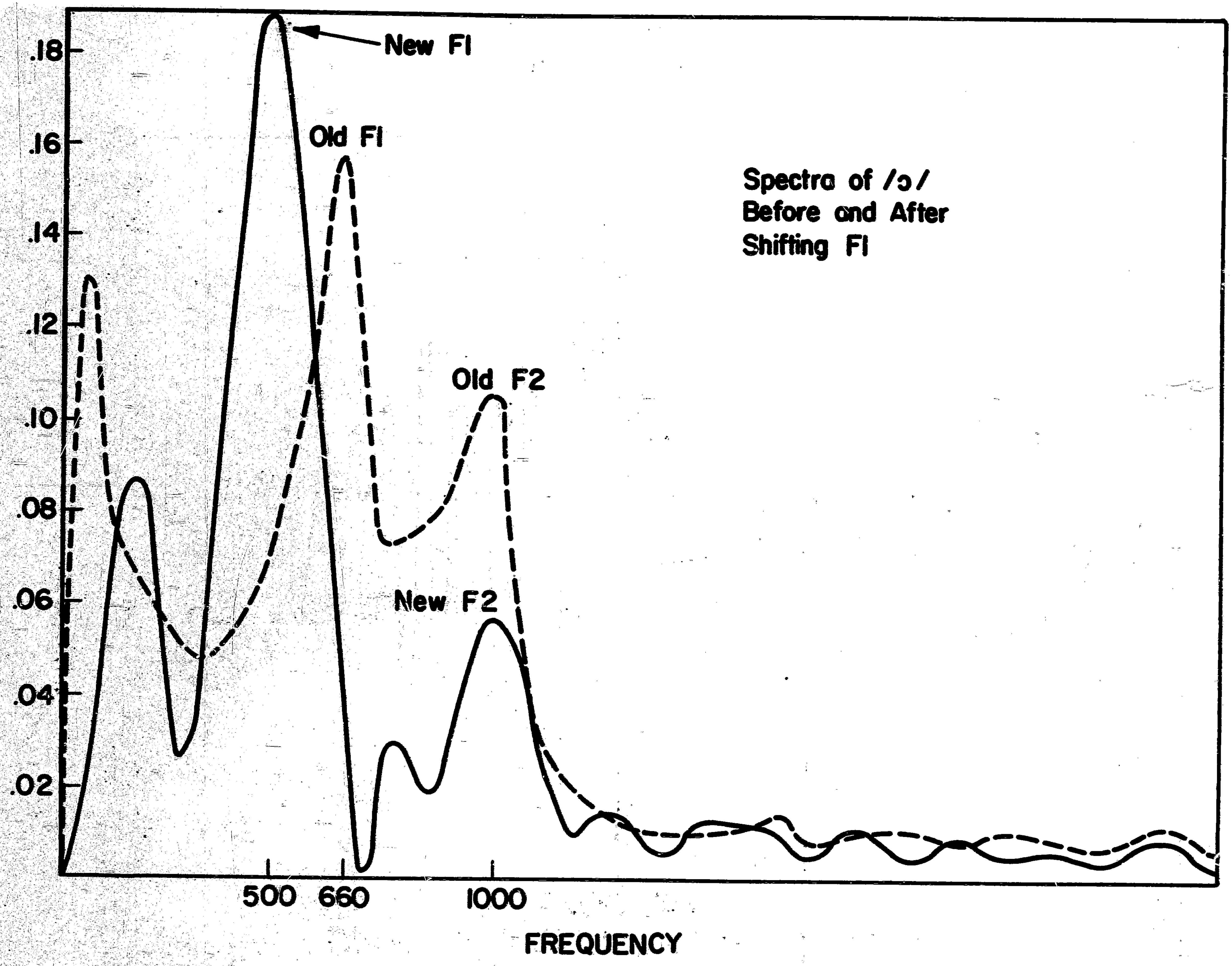

Spectrum of /æ/ After Removing
Effects of Glottal Pulse.
Pulse Shape
Assumed
Fundamental
Period
MAGNITUDE
.05
.04
.03
.02
.01
F0
F2
F3
495
660
1923
2420
FREQUENCY

Fig. 10



Operator To Shift Pole At 1600 cps
To Pole At 3200 cps
AMPLITUDE
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4
-1.6
-1.8
1
2
3
4
5
6
7
8
9
TIME IN MSECS.


Fig. 11



.18
.16
.14
.12
.10
.08
.06
.04
.02
New FI
Old FI
Old F2
New F2
Spectra of /ɔ/
Before and After
Shifting FI
500
660
1000
FREQUENCY


Fig. 12

# The Relation between Arousal and the Recall of Verbal Material in Connected Discourse

F. M. Koen

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# The Relation Between Arousal and the Recall of Verbal Material in Connected Discourse: A Preliminary Report

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Abstract

In previous studies, measures of galvanic skin response (GSR) have been related to the recall of words in paired-associate learning. The generality of the relation between GSR and recall is examined in this study using verbal elements in messages that have the form of logical arguments. The experiment also explores (a) the relation between S's agreement or disagreement with message content and recall, and (b) the relation between both GSR and personal agreement on the one hand, and judgments of validity on the other. One group is used to obtain data on validity judgments, while four others provide information on the effects of the recall interval and instructions to remember the material. Twelve experimental items have been developed, consisting of three syllogisms in each of four logical forms, equated in difficulty as well as length of words and position of item to be recalled, but varying in judged emotionality.

Kleinsmith and Kaplan (1963, 1964) and Walker and Tarte (1963) found a relation between physiological arousal, as measured by GSR, and the recall of individual words in a paired-associate learning paradigm. Words which are associated with high arousal showed relatively poor immediate, but good long-term, recall; low arousal items exhibited a reverse pattern. Alper and Korchin (1952) and Kamano and Drew (1961), among others, have found a general relationship between an individual's values and belief systems, and his recall of material relating to these opinion areas. Ss tend to recall material with which they are in agreement and to forget that with which they disagree. The same kind of relation has been found (Janis and Frick, 1943; Thistlethwaite, 1950) between individual values and judgments involving logical inference. Again, arguments with which Ss agree tend to be seen as valid; those with which they disagree, as invalid. To date, there have been no studies of the relation between GSR and logical inference.

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The present experiment seeks to extend previous results by asking three general questions: (a) Is arousal related to the recall of elements (words) which are part of normal language construction? (b) Is arousal (as measured by GSR) related to accuracy of logical inference? and (c) Will a continuous record of the direction and degree of agreement/disagreement relate to recall and to validity judgments?

In addition, the study is expected to introduce methodological improvements in research involving the use of GSR, inasmuch as the reading and interpretation of the records will be carried out by the PDP-4 computer.

## Method

### Development of the stimuli

Establishing the difficulty of logical forms. Sixteen syllogisms were composed--one-half valid, one-half invalid. They were presented to 80 Ss in counterbalanced order in both symbolic (i.e., "If p is the case, then q is the case"), and in translated terms (i.e., "All members of Phi Beta Kappa must be college students"). The Ss were instructed to indicate their personal agreement (disagreement) with each of the three sentences in each syllogism, then to judge the validity of the argument as a whole. Four forms were obtained which were very similar in level of difficulty.

Establishing affective properties of the syllogisms. Six translations were made of each of the four selected forms. Nine Ss then performed a six-category Q sort which ranged from "most positive emotionally" to "most negative". An average value was obtained for each syllogism-translation. Three translations were chosen for each of the four forms--including a "most positive" instance, a "neutral" instance, and a "most negative" instance. These 12 messages constitute the experimental stimuli. All sentences included in instances of the same form were equated in number of words and in general grammatical form.

Determining effect of E's presence in experimental room. Eight female students served in an experiment to compare the average GSR and immediate recall scores obtained when E was in the experimental room with those obtained when he was in an adjacent room, communicating with the S only by intercom. It was found that GSR tended to be lower when E was absent, but the effect was only marginally significant. There was no difference in recall scores.

Establishing the probability of guessing the recall word from context. The word chosen for testing recall was deleted from the last sentence of each of the experimental items. These truncated sentences were then presented to 10 Ss with instructions to supply five words which would be most probable and appropriate for completing the sentences. Weights were then assigned to the (pre-determined) recall words on the basis of the percentage of correct guesses that were made from context alone.

During experimental sessions with Group I Ss (validity judgments), it was found that the greatest GSR deflections occurred most frequently to the first sentences of the items, rather than the third (last) sentences, as had been expected. In order to provide maximum opportunity for the effect of the arousal variable, it was decided to ask for recall (in Groups II-V) of specific words in first sentences. Therefore, one word was deleted from the first sentence of each experimental item, and these incomplete sentences were then presented to 10 Ss with instructions to supply five words which would be the most probable and appropriate for completing each sentence. Weights were determined as before.

Establishing exposure times for experimental stimuli. The 12 experimental and 15 practice items were put on 2" x 2" slides. Leads to the GSR equipment were attached to each of 10 Ss. The S then saw the first sentence of an item, and she registered agreement-disagreement by displacing the spring-loaded arm of a potentiometer; then the second sentence of the item was exposed, followed by the third. The complete syllogism was then shown and a judgment of validity made. The measures of GSR and agreement, and the judgment of validity were recorded automatically. The average interval required for the Ss to respond to each sentence of each item was determined.

Apparatus

After the S had become practiced in the task, presentation of the stimulus items was automatic. An electronic timer fed pulses into a Grason-Stadler E 783B counter which controlled the slide changes of a Kodak Carousel projector. The GSR was obtained through the use of a Fels Model 22A Dermohmmeter; the agreement (A) or disagreement (D) of the subjects with the content of the items was collected by a locally-fabricated spring-loaded potentiometer connected through a DC source to the recording devices. Slide changes, A-D responses, and continuous GSR values were recorded on a Honeywell 1508 Visicorder and on an Ampex SP 300 FM direct recorder/reproducer.

Subjects

All Ss were paid female undergraduate volunteers, except in the pretest designed to establish the difficulty of the logical forms, and the test used to determine the probability of guessing the recall word from context.

Procedure

Validity judgments (Group I). Ss were seated in a sound-attenuating booth; GSR electrodes were attached to the first and third fingertips of the left hand. Instructions were read over an intercom. The first sentence of a syllogism was projected onto a screen on the front wall of the booth for 15 seconds, and the S registered the direction and intensity of her agreement or disagreement with the facts alleged in the sentence by moving the control of the A-D meter. The second sentence was then projected for 15 seconds; and the third for 16 seconds, with continuous recordings being made of both GSR and A-D responses. The entire syllogism was then projected for 45 seconds, during which S stated her judgment of the validity of the item. The next slide projected nine circles of color for 12 seconds, and S was required to name each one. S was trained in the task with three self-paced illustrative items, before the automatic timing mechanism took over control of the presentation of stimuli. These were followed by four automatically-paced practice items, and then by the 12 experimental items in one of four differnt random orders.

Design. There will be five groups of experimental Ss, with 16 in each group. One group will judge the validity of the arguments while the remaining four groups will constitute a 2 x 2 factorial design, with Instruction (instructed vs. non-instructed) and Recall Interval (immediate vs. one-week) as the main effects.

## Results

Eighteen experimental Ss in Group I have been run, although the data have not yet been analyzed. A program is being written to permit the evaluation of all responses by the PDP-4 computer. Each S will próvide her own baseline on both GSR and A-D dimensions. For each S in Group I, the accuracy of her judgmént of validity will be examined as a function of the arousal (GSR) and the agreement (A-D) evoked concurrently by the messages. There will be comparisons of the accuracy of recall of Ss in Groups II-V, with instructions and elapsed interval between exposure and recall as independent variables, and arousal and agreement with content as parameters.

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# Identification, Discrimination, Translation: The Effects of Mapping Ranges of Physical Continua onto Phoneme and Sememe Categories

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Identification, Discrimination, Translation: The Effects of Mapping Ranges of Physical Continua onto Phoneme and Sememe Categories

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In a recently-published book entitled "A Linguistic Theory of Translation" Professor J. C. Catford writes:

"Language...is patterned behavior. It is, indeed, the pattern which is the language... The precise quality of [a speaker's] vocal movements and [consequent] sound waves will be found to differ on different occasions, even when the speaker is 'saying the same thing.' From the linguistic point of view, the important thing is that, on each occasion of 'saying the same thing' the vocal activities of the speaker conform to the same pattern" (1965, p. 2).

The interesting question arises, what is invariant--what is 'same'--when we perceive the speaker to be 'saying the same thing' or when the speaker, always as speaker-hearer, understands <u>himself</u> to be 'saying the same thing'? It is not the object of perception, the utterances that are invariant--these change from one occasion to the next. Instead, as the preceding quote states, the important thing is that the speaker conforms to the same pattern--and this pattern is language. Thus we have a many-to-one relationship between the changing utterances (the phonic substance) and the invariant pattern. And the criterion for this many-to-one mapping of a range of phonic substance into one pattern is function: the different bits of phonic substance function equivalently in social interaction--the hearer perceives the speaker to be 'saying the same thing.'

Professor Catford continues:

"There are specific objects, events, relations and so on, in the situation, which lead the [speaker] to produce these particular vocal movements, and no others. The precise nature of the situational features which are relatable to the performer's linguistic behavior will [also] be found to differ on different occasions, even when he is 'saying the same thing.'

"From the linguistic point of view, however, the important thing again is that, in each case, the situational features which lead to 'the same' utterance conform to the same general pattern" (p. 2).

The question arises again, what is invariant in a set of situations all of which lead a speaker to 'say the same thing'? It is not the situation substance itself that is invariant--this changes from one occasion to the next. Instead, as the preceding quote states, the important thing is that the situational features conform to the same pattern--and this pattern is language. Thus, we have a many-to-one relation between the changing situational substance and the invariant pattern, and the criterion for this many-to-one mapping of a range of situation substance into one pattern is function. The different bits of situation substance function equivalently in their control over the speaker--they all lead him to say functionally 'the same thing.'

Thus, the pattern that is language is bounded at both sides by a one-to-many relation to substance. On the one hand, we find classes of functionally-equivalent bits of distinct phonic substance; on the other hand, we find classes of functionally equivalent bits of distinct situation substance.

In this paper these two kinds of Psycholinguistic classes will be examined, and in each case some implications for translation will be considered.

Categories of phonic substance

The smallest class of functionally equivalent bits of phonic substance is the phoneme. Figure 1 shows in detail how a range of phonic substance is mapped into one language pattern. Seven distinct bits of phonic substance were presented recurrently in scrambled order to a group of naive listeners. All of the sounds consisted of the same two formants, with the same transitional and steady-state frequencies, but the sounds differed in the time of onset of the first formant with respect to the second. At the one extreme, there was a sound whose formants began at the same instant; at the other extreme, the first formant did not begin until 60 msec after the second formant had begun. The listeners were told to identify the distinct bits of phonic substance. The figure shows that three of the bits were functionally equivalent and belong to one phoneme class, whereas another three belong to a second class.

It is important to note the complete equivalence within classes and complete contrast between classes, the near dichotomizing of the continuum of phonic substance, the absence of a continuous phonemic scale. This brings to mind a quote from Charles Hockett:

"No phonologically relevant contrasts are of the continuous scale type. In a language where voicing and voicelessness are phonologically functional, a given bit of speech is either voiced or voiceless--not, structurally, half voiced or three-quarters voiced.... If we find continuous scale contrasts in the vicinity of what we are sure is language, we exclude them from language...." (1955, p. 17).

Instead of finding a continuous scale in which, say, the first bit of phonic substance was heard as /do/ 100 per cent of the time, the second 85 per cent, the third, 70 per cent, and so forth, we find almost perfect polarity. This is reminiscent of Jakobson and Halle's statement that the dichotomous scale is inherent in the structure of language; and it is consonant with C. L. Ebeling's description of the mapping of phonic substance into language patterns. Ebeling wrote:

"A sound dimension running from A to Z when parcelled out phonemically consists of...A-P allotted to a phoneme, a no-man's-land P-Q, and Q-Z allotted to another phoneme...The function of a point is wholly defined by the mere fact that it belongs to one of the segments" (1962, p. 45).

It is one thing to show that listeners assign to distinct bits of phonic substance the same linguistic label, and another to claim that these bits are mapped into one point in language structure and are indistinguishable for the speaker-hearer. Figure 2 illustrates the latter finding. If two bits of distinct phonic substance are presented to a listener and he is asked to tell whether they are the same or whether they differ in any respect whatsoever, it turns out that he is virtually reduced to guessing when the bits of substance come from the same phoneme class. Figure 2 shows the mapping function again and above it the present findings for discrimination. Note that the first two bits of phonic substance, which fall within the range of the first phoneme class, are not discriminated with more than chance accuracy--50 per cent. The same is true of the second two bits of phonic substance. Comparable results obtain for the second phoneme class. However, two bits of phonic substance drawn from different phoneme classes, in this case the bits labelled 20 and 30, are highly distinguishable and are discriminated nearly 100 per cent of the time.

Thus we have functional equivalence within classes and contrast between them. Without indulging in a digression to explain the following statement, I would say that this is the behavioral basis for the utility of the Pair Test in phonological investigations.

Figure 3 presents once again the mapping function and the discrimination function and displays one more consequence of mapping a range of phonic substance into one linguistic pattern. The graph at the upper right shows the latency with which a subject identifies the various bits of phonic substance,

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that is, the time between the presentation of the sound and his identifying response. Within the range of phonic substance in one phoneme class, latencies are relatively short and uniform. However, the bit of substance at the boundary of the phoneme classes--in "no-man's land," to use Ebeling's term--takes a long time to identify.

It should be noted that the identification, discrimination, and latency functions shown above are representative; comparable findings have been obtained for many other ranges of phonic substance, entailing such contrasts as rapid-rabid, slit-split, ba-da, and so forth. Thus, the earlier statements concerning the polarity of the mapping, the lack of discrimination within classes and its acuteness between classes, and the equivocation in identifying boundary substance, are broadly based on empirical studies.

Before turning to a similar analysis of the categorizing of situation substance, these observations at the level of phonology may be extended to the problem of translation, as discussed by Professor Catford in his book.

To begin with, we may take as a broad definition of translation "the replacement of textual material in one language (called the source language) by equivalent textual material in another language [the target language]" (p. 20). Now Translation may be restricted to a single level. Catford writes:

"In phonological translation, SL phonology is replaced by equivalent TL phonology. There are no other replacements except such grammatical or lexical changes as may result accidentally from phonological translation... The basis for translation equivalence in phonological translation is relationship of SL and TL phonological units to 'the same' phonic substance" (p. 56).

To illustrate this, Professor Catford gives a phonological translation from English to Greek. Translating the English /had/, we ask first what phoneme in Greek has a range of phonic substance closest to the English /h/. Lacking convenient descriptive terms for the ranges of phonic substance, they are referred to with the terms appropriate to their correlated articulations. What phoneme in Greek, then, shares the most substance with the voiceless glottal fricative in English? Probably /x/, a voiceless fricative which is, however, not glottal. The English /a/ is a low front vocoid and the same phonic features are largely present in Greek /e/ (although the Greek vowel is not so low). English /d/ is a voiced apical stop, so the Greek phoneme with the greatest common range of phonic substance is probably the Greek apical stop /t/. It is, however, voiceless unless preceded by a nasal, so the best translation equivalent for /d/ may be /nt/.

The basis of translation equivalence here is the relation of SL and TL phonological units to the same phonic substance. The degree of translation equivalence between two phonological units is equal to the degree to which their separate one-to-many mappings onto phonic substance overlap. This overlap may be judged informally by ear, or it may be inferred from a knowledge of the articulatory patterns associated with the two phoneme classes; or, best of all, it may be assessed directly and quantitatively from the mapping functions associated with the two phoneme classes. To illustrate, Fig. 4 shows the ranges of phonic substance that map onto certain English consonant phonemes and those that map onto certain Spanish and Thai consonant phonemes, and how these ranges overlap. In this case, 30 bits of phonic substance, all with the same two formants but differing in the relative onset-time of these formants, were presented recurrently in scrambled order to listeners who were native speakers of English, Spanish or Thai.

Comparison of the mapping functions reveals that /d/ phonemes in English, Spanish and Thai are reasonable translation equivalents. However, they certainly do not encompass identical ranges of phonic substance since the range of English /d/

includes some bits of phonic substance perceived by speakers of Spanish and Thai as /t/. Turning to the voiceless stops, the English and Spanish /t/ are good translation equivalents, but the Thai phoneme with which they share the greatest range of phonic substance is the voiceless aspirated stop /$t^h$/.

Although, for the sake of simplicity, we have examined the mapping of bits of phonic substance that vary in only one physical property, it should be noted that the analysis is not changed except in complexity if we consider the mapping of language categories onto several ranges of substance along several concurrent dimensions. For example, it is quite common to examine the mapping of vowel phonemes onto the concurrent ranges of phonic substance of first-formant frequency and second-formant frequency. The same generalization applies to the mapping of language categories onto ranges of situation substance.

Categories of situation substance

At the other boundary between language and the physical world--the boundary between pattern and situation substance--essentially the same state of affairs exists: from the linguistic point of view, the important thing is the invariance of language despite the variability of substance. In particular, we find the one-to-many mapping between a pattern and its range of situation substance. Thus it is that distinct bits of situation substance may comprise one class by virtue of their functional equivalence for the speaker.

To illustrate this, it is useful once again to examine the mapping into language of distinct bits of substance that can be deployed along a single physical continuum. The ranges of situation substance that lead an English speaker to say one color name or another may be examined in Fig. 5. Fifty bits of situation substance were presented recurrently in scrambled order to a group of speakers. The displays were identical in size, brightness, and so forth, but they differed in the wavelength of light coming from them--that is, they differed in hue. At the one extreme, a bit of situation substance was presented with a wavelength of 400 millimicrons; at the other, one with a wavelength of 700 millimicrons. The speakers were told to identify the distinct bits of situation substance. Figure 5 shows that nine of the bits were functionally equivalent and belong to one class--one "sememe" class--namely, red. Another range of distinct bits of situation substance is mapped into another class, namely green; and so forth.

As in the case of phonic substance, it is important to note the high degree of equivalence within classes and contrast between classes; the absence of a continuous scale and the presence, instead, of successive partitionings of the visible continuum. Also paralleling the findings for phonic substance, distinct bits of situation substance that map into a single sememe are less discriminable than those that map into different categories. This is shown by the discrimination function superimposed on the mapping function. Note the high levels of discrimination accuracy for comparisons of bits of substance drawn from different sememe classes, and the low levels of discrimination accuracy for comparisons of bits of substance drawn from within one sememe class. (Comparable discrimination functions have been obtained by numerous investigators; see the review by Graham, 1959.)

The properties of classes of situation substance parallel these for phonic substance in yet a third respect, namely, latency of identification. Figure 6 shows, superimposed on the mapping functions, the average latency of identifying each bit of situation substance. Within the range of situation substance in one sememe class, latencies are relatively short. However, the bits of substance at the boundaries of the sememe classes--in no-man's-land--take a longer time to identify.

These observations may be extended to the problem of translation, now at the level of lexis. Recalling Professor Catford's definition of translation, "the replacement of textual material in one language by equivalent textual material in a second language," we note that in lexical translation "the [source language] lexis of a text is replaced by the [target language] lexis, but with no replacement of grammar. The basis of equivalence again is relationship to the same situation substance" (p. 72). To illustrate this, Professor Catford gives a lexical translation of the English sentence "this is the man I saw" into French: "this the homme I voi-ed." Clearly, he considers quite reasonably that the lexical item in the target language that has the greatest overlap of situation substance with "man" is "homme." This overlap is usually judged informally; typically, we ask a person who has been in both environments and who speaks both languages.

We can bring to light what is involved in this kind of judgment and can make the judgment directly and quantitatively when it is possible to determine the mapping functions of sememes in two languages.

To illustrate this, Fig. 7 shows the ranges of situation substance that map onto certain sememes in English, Eskimo and several other languages, and it makes clear how these ranges overlap. As we have seen earlier, sememe classes partition the hue continuum rather than scale it continuously. Therefore the classes can be shown in a table instead of by mapping functions. In the first column are shown the English sememe classes for hue, examined previously. To illustrate the process that underpins lexical translation, take English as the source language and Eskimo as the target language. English "red" has a reasonably good lexical translation equivalent in Eskimo, although the latter sememe includes much of the range of situation substance that maps into English "orange."

The best translation equivalent for English "yellow" is equivocal, while English "green" and "blue" have the same lexical translation equivalent.

Summary

The pattern that is language makes contact with the environment at two points: phonic substance and situation substance. The nature of this contact is a one-to-many relationship, in which one language pattern is mapped onto a range of distinct bits of phonic or situation substance. There are several properties of this relationship or mapping. First, it is functional. The distinct bits of substance that belong in one language category cause the speaker-hearer to behave in ways that are functionally equivalent from the point of view of social interaction. Second, it is nearly absolute. Each point of substance along a continuum that maps into language categories belongs unequivocally to one of those categories. Third, the mapping renders distinct bits of substance that are in one class largely indistinguishable, while those that are in different classes are contrastive and highly distinguishable. Fourth, it causes some bits of substance, those within one class, to be readily and rapidly identified, whereas it causes similar bits of substance located just at category boundaries to be identified only with difficulty, relatively slowly. Fifth, the mapping of language categories onto substance is the basis for translation; two phonemes or two sememes are translation equivalents to the degree that their corresponding ranges of substance overlap.

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## Figure Captions

Fig. 1. Identification functions for a synthetic speech continuum, illustrating how a range of phonic substance is mapped into phoneme categories. (After Liberman et al., 1961)

Fig. 2. A comparison of discrimination and identification functions for a synthetic speech continuum. (After Liberman et al., 1961)

Fig. 3. Distributions of discrimination accuracy and identification probability and latency for the /d/ - /t/ continuum. (From Lane, 1965)

Fig. 4. The ranges of phonic substance that map on to certain consonant phonemes in English, Spanish and Thai. (From Abramson & Lisker, 1965)

Fig. 5. Identification and discrimination functions for the hue continuum. (After Beare, 1963, and Laurens & Hamilton, 1923, respectively)

Fig. 6. Distributions of identification probability and latency for the hue continuum. (From Beare, 1963)

Fig. 7. The ranges of situation substance that map onto certain hue sememes in English and nine other languages. (From Ray, 1953)

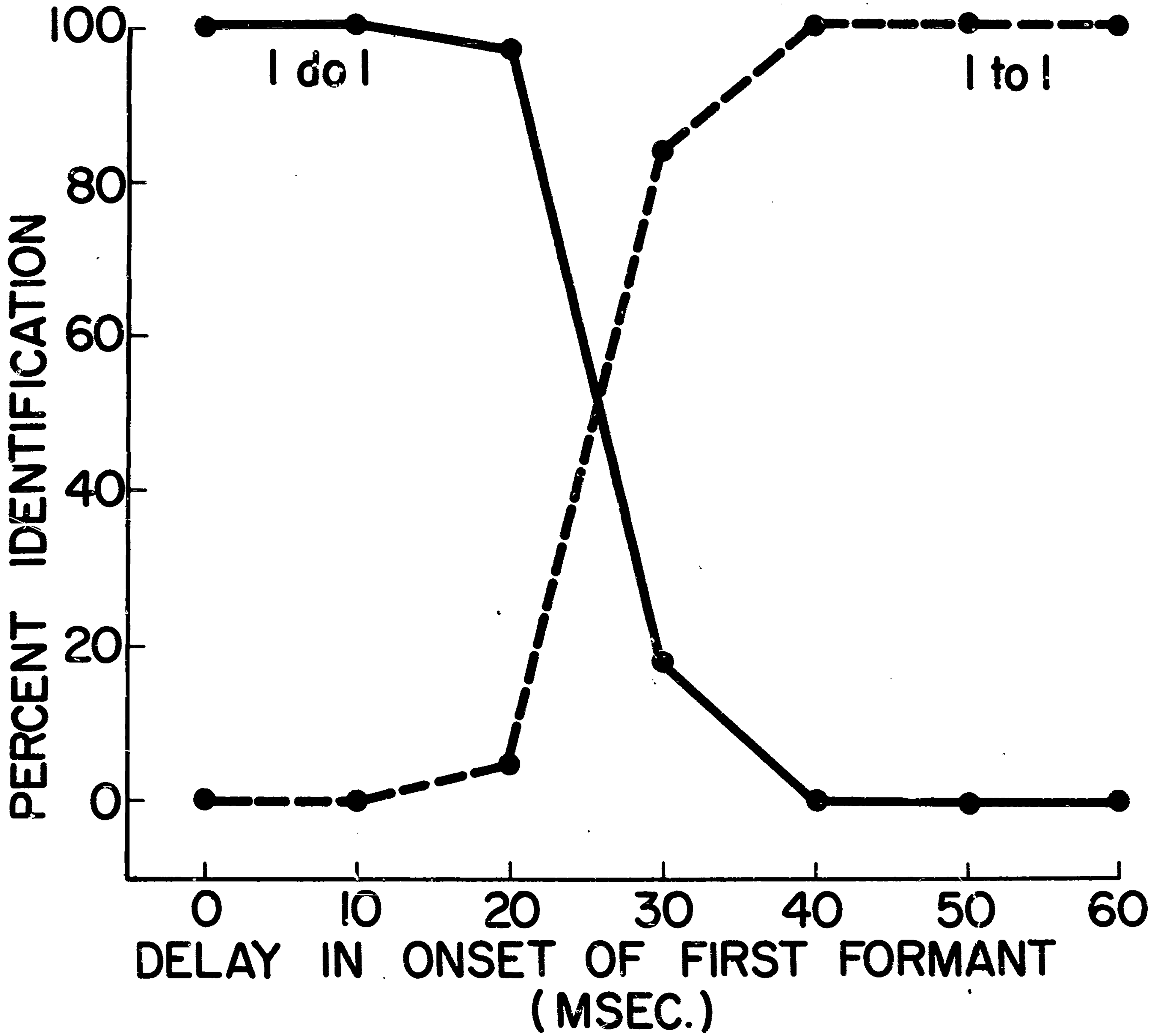

100
80
60
40
20
0
PERCENT IDENTIFICATION
| do |
| to |
0
10
20
30
40
50
60
DELAY IN ONSET OF FIRST FORMANT
(MSEC.)

Fig. 1

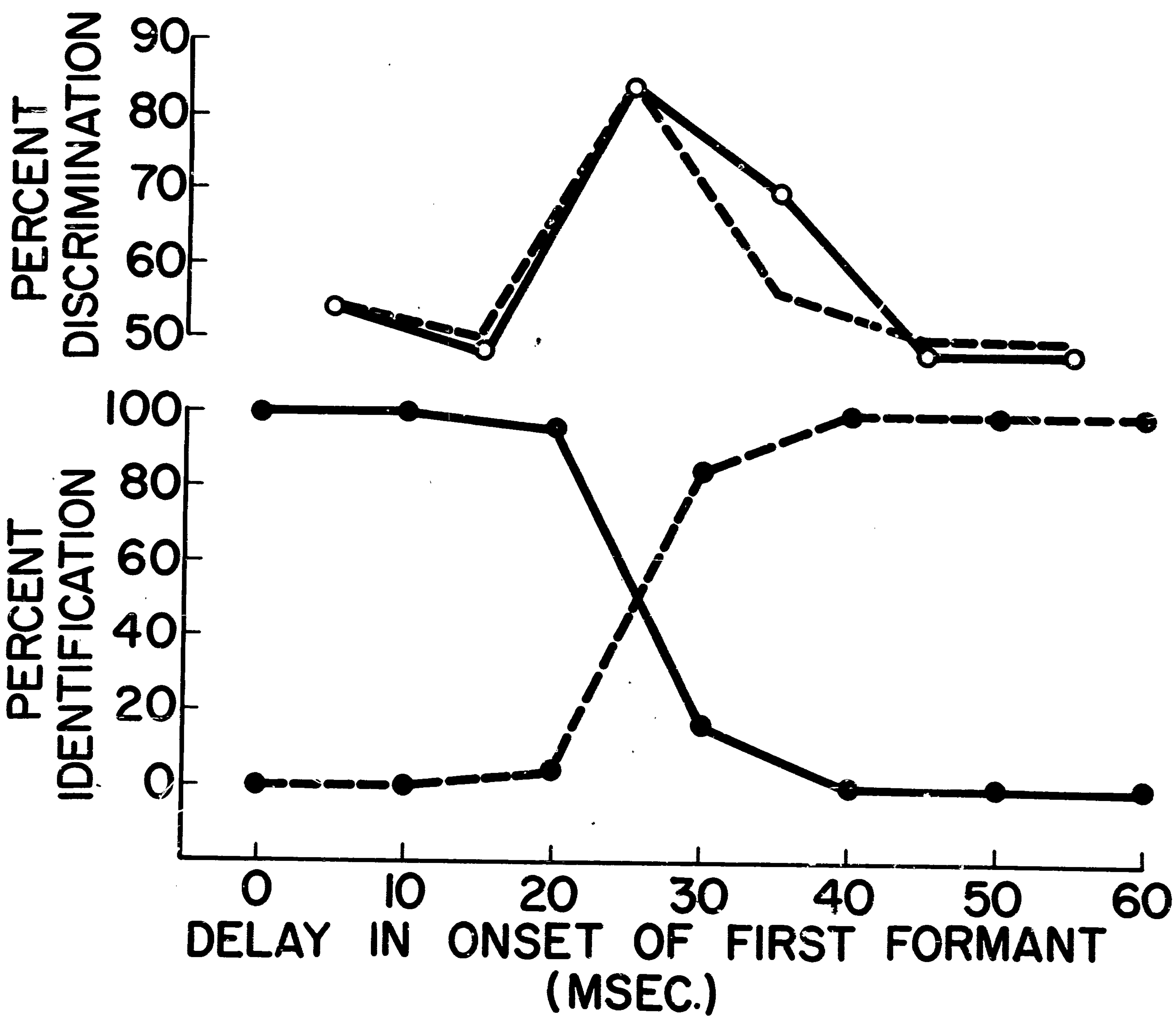
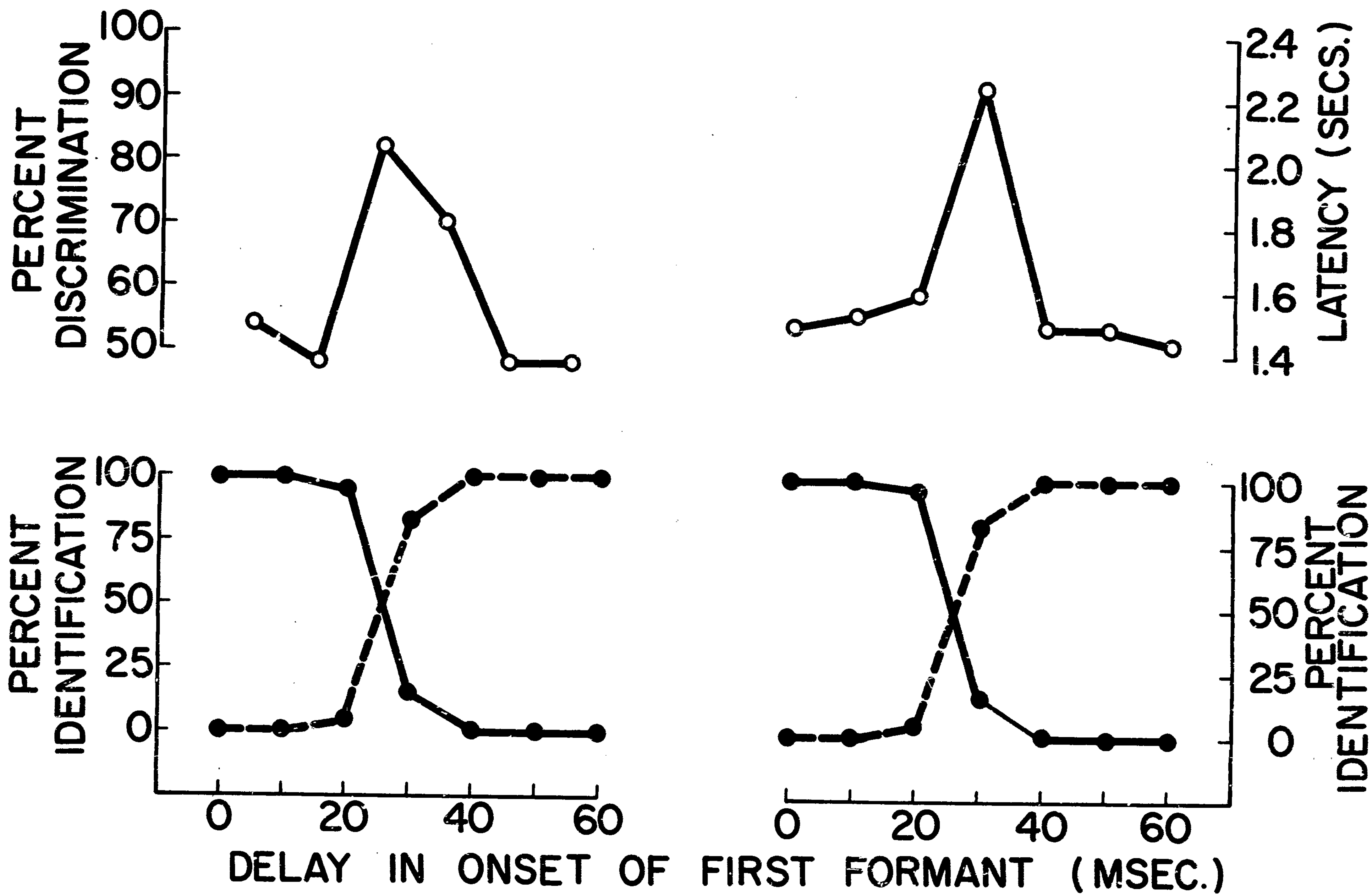

PERCENT DISCRIMINATION
90
80
70
60
50
PERCENT IDENTIFICATION
100
80
60
40
20
0
0
10
20
30
40
50
60
DELAY IN ONSET OF FIRST FORMANT (MSEC.)

Fig. 2



PERCENT DISCRIMINATION
100
90
80
70
60
50
LATENCY (SECS.)
2.4
2.2
2.0
1.8
1.6
1.4
PERCENT IDENTIFICATION
100
75
50
25
0
0
20
40
60
DELAY IN ONSET OF FIRST FORMANT (MSEC.)


Fig. 3

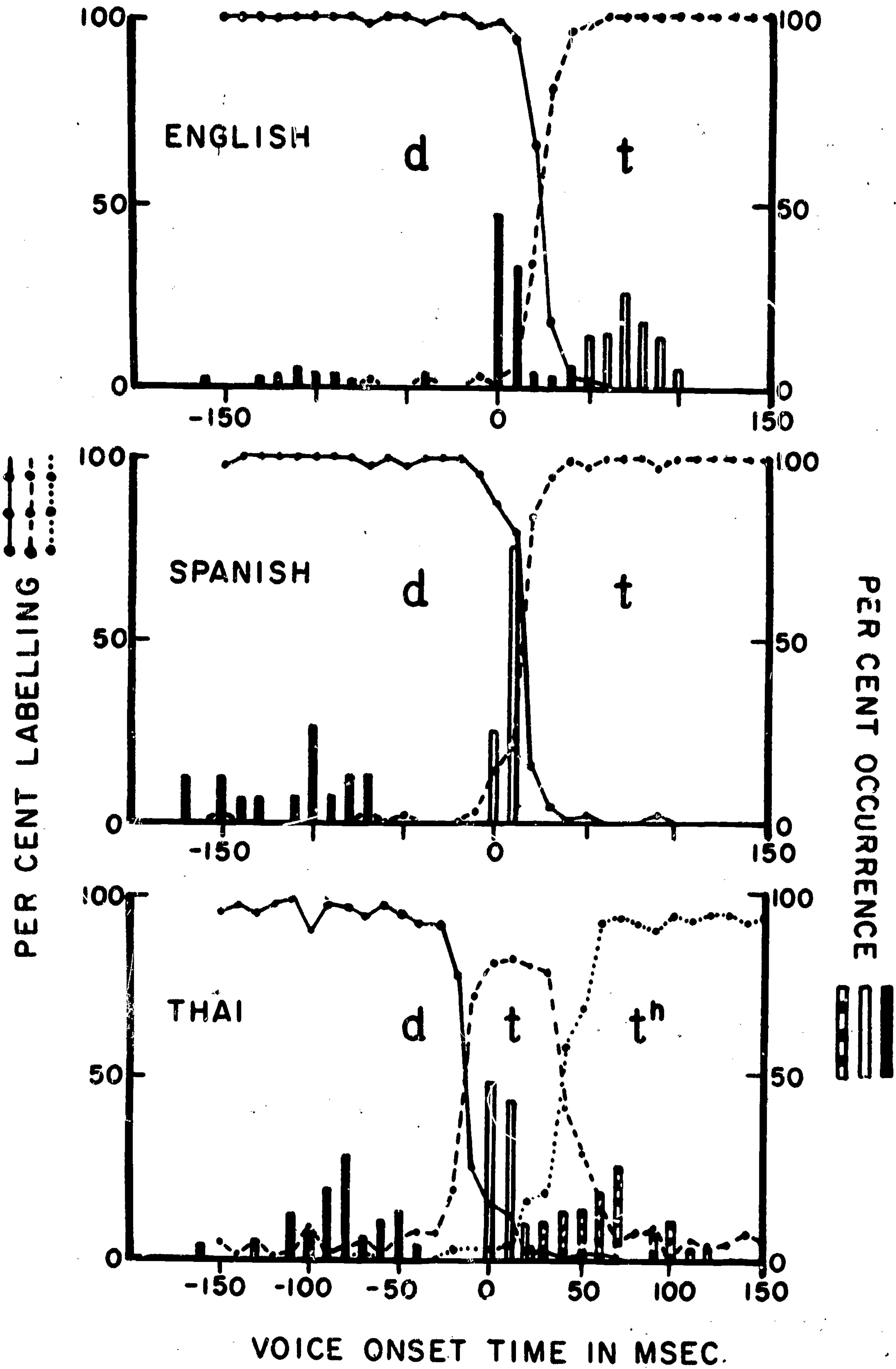
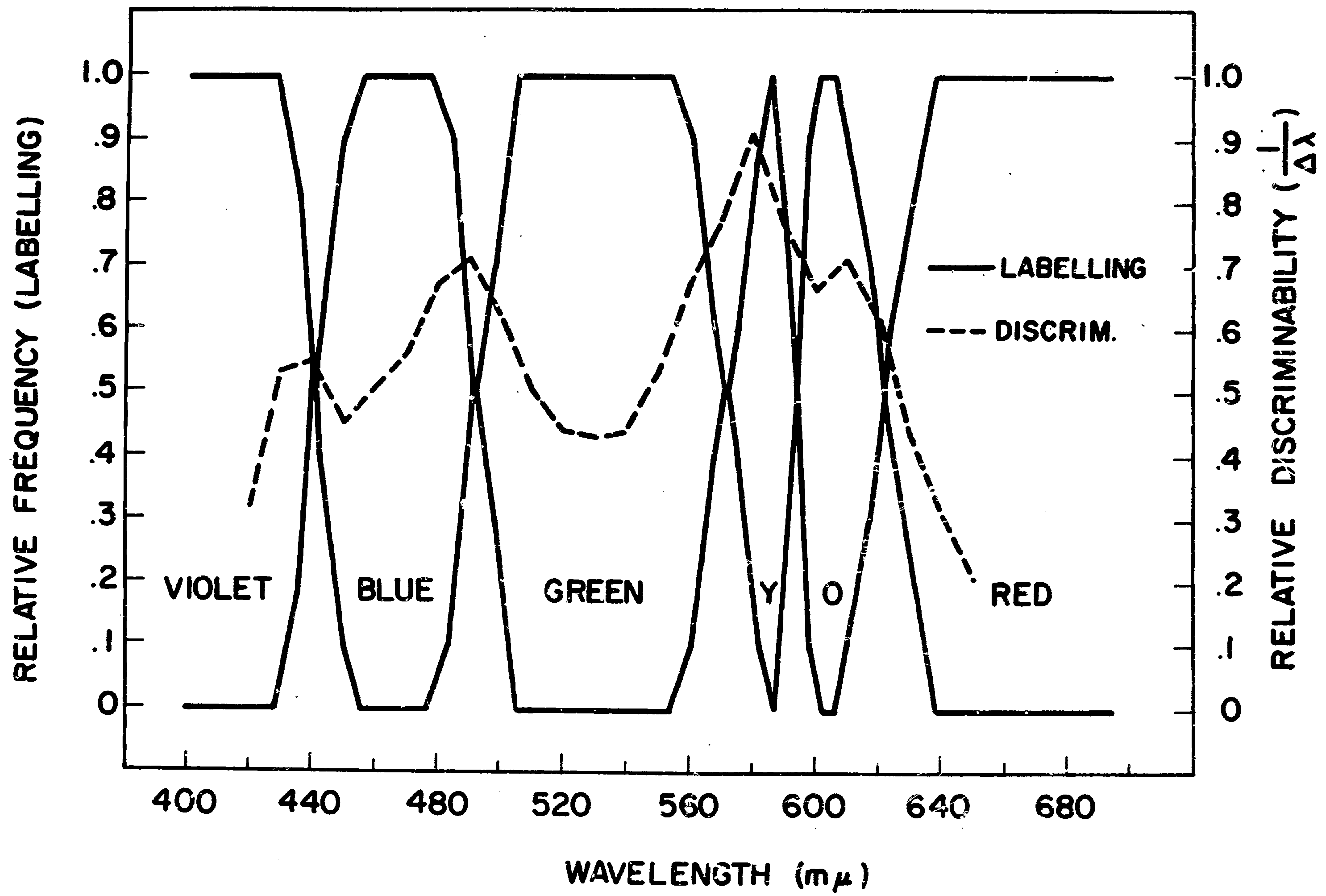

ENGLISH
SPANISH
THAI
d
t
$t^h$
PER CENT LABELLING
PER CENT OCCURRENCE
VOICE ONSET TIME IN MSEC.
100
50
0
-150
-100
-50
150

Fig. 4



RELATIVE FREQUENCY (LABELLING)
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
VIOLET
BLUE
GREEN
Y
O
RED
LABELLING
DISCRIM.
RELATIVE DISCRIMINABILITY ($\frac{1}{\Delta\lambda}$)
400
440
480
520
560
600
640
680
WAVELENGTH (mμ)


Fig. 5

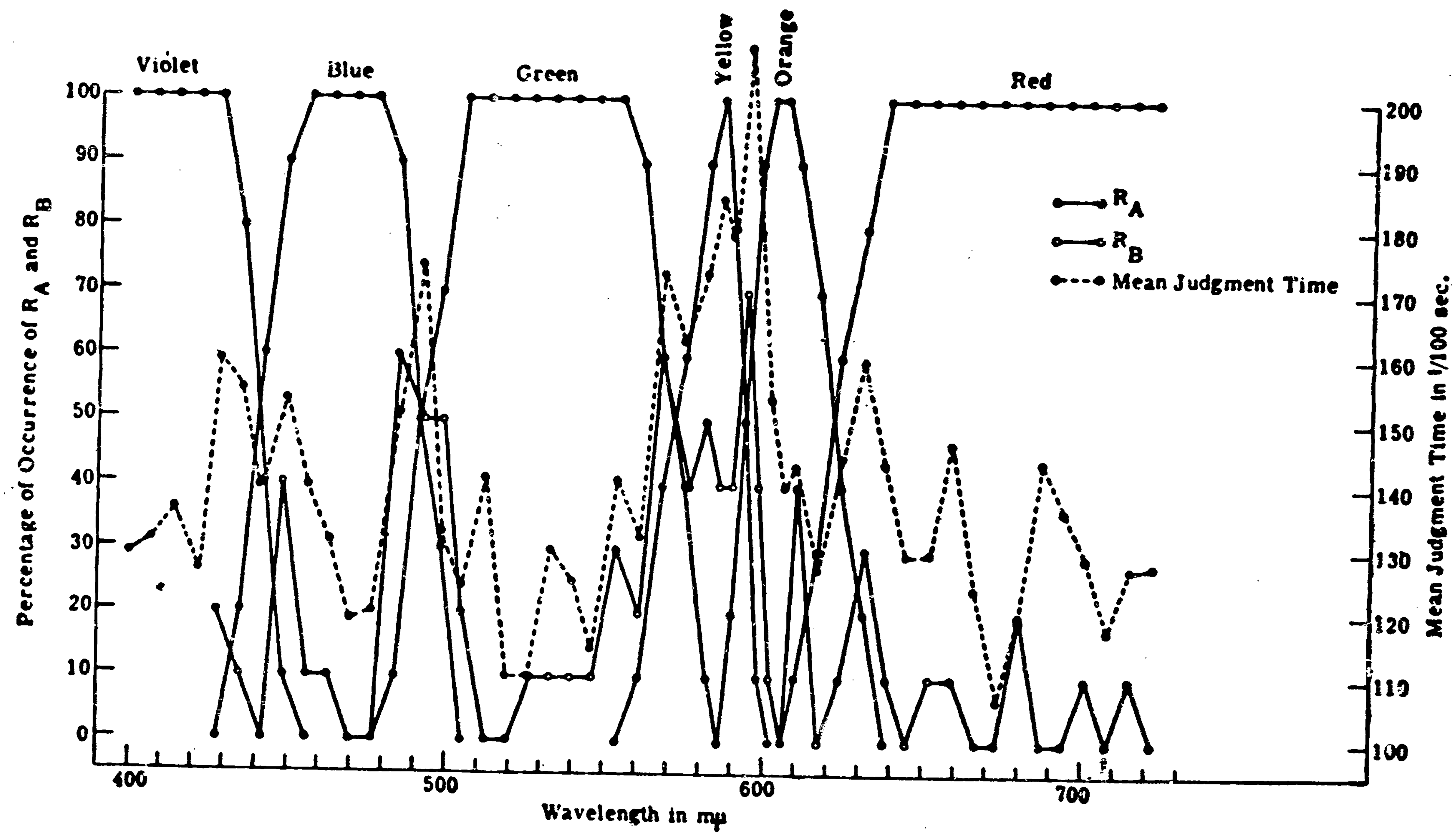

Violet
Blue
Green
Yellow
Orange
Red
$R_A$
$R_B$
Mean Judgment Time
Percentage of Occurrence of $R_A$ and $R_B$
Mean Judgment Time in 1/100 sec.
Wavelength in mμ
100
90
80
70
60
50
40
30
20
10
0
200
190
180
170
160
150
140
130
120
110
100
400
500
600
700

Fig. 6

| | Wave length | English<br>Northwest U. S. | Salish<br>Sanpoil | Sahaptin<br>Tenino | Chinook<br>Wishram | Salish<br>Songish | Athapaskan<br>Chilcotin | Eskimo<br>Atka | Athapaskan<br>Chetco R. | Takelma<br>Rogue R. | Kalapuya<br>Santiam |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Violet-red | comp 5600 | X | X | | X | | X | X | | | sa'kwala |
| Red | 6571 | red | | | | | | | tsi'k | | utsa·'la |
| Orange-red | 6340 | | qu'l | | dalbá'l | nəsə'qu | | u'lu·'δax | | àlči'l | |
| Red-Orange | 6230 | | | lut'sa' | | | TəlTə'l | | | | t'sə·'lılω· |
| Orange | 6085 | orange | | mə'kc | | | | | | | |
| Yellow-orange | 5390 | | | | | | | | | | |
| Orange-yellow | 5870 | | | | dagá'c | lələ'č | | | xa'dəgi | | ва'lamı |
| Yellow | 5793 | yellow | kuya'i | pa'a'x | | | | ču'mnu'γıx | | ва'uəx | |
| Green-yellow | 5710 | | | | | iələčalıs | Təltso'' | | | | tskı'Tkwu |
| Yellow-green | 5600 | | qwı'n | | | | | | | Gwa'camt | |
| Green | 5164 | green | | | qa'naptsu | nəkwa'i | | čı'δγıx | | | |
| Blue-green | 5050 | | | | | | | | tsu' | tGicə'mt | pčı'x |
| Green-blue | 4985 | | | | | | | | | | |
| Blue | 4695 | blue | | | daptsá'x | či'ı'alıs | | | | | |
| Violet-blue | 4455 | | | lə'mt | | sqwa'iux | | | | kiyə'x | X |
| Blue-violet | 4350 | | qwa'i | | | | Ti·lča'n | X | | | X |
| Violet | 4210 | violet | | pu'u'x | | nəkwa'i | | X | xa'dətsu' | | X |
| Red-violet | comp 4990 | | | | | kwi'ıməl | | X | X | X | X |
| Violet-red | comp 5600 | | xı'n | X | iyaquitsabəl | X | | X | X | X | X |

Fig. 7

# Contrastive Analysis of the Prosody of Spoken American English and Colloquial Jordanian Arabic

R. Rammuny

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# Contrastive Analysis of the Prosody of General American English (GAE) and Colloquial Jordanian Arabic (CJA)

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Center for Research on Language and Language Behavior

Abstract

This study is concerned with an instrumental contrastive analysis of the prosody of General American English (GAE) and Colloquial Jordanian Arabic (CJA). The main purpose of this study, the first specifically contrastive linguistic analysis of the prosodic features of GAE and CJA, is to identify the areas of difficulty involved in the teaching of prosodic features of GAE to native speakers of CJA. A distinctive feature of this research is the use of the Speech Auto-Instructional Device (SAID) for analyzing and teaching prosodic features of both the native and target languages. The effectiveness of the SAID system as an electro-mechanical device for describing and measuring prosodic features (amplitude, pitch, tempo) of languages will be tested. The corpus prepared was recorded and developed through the cooperation of two groups: English informants and Jordanian subjects. The final set of recorded tapes was used in sorting out the utterances where the production of prosodic features of GAE by the Jordanian subjects was incorrect. The process of sorting was based on judgment of the SAID system, judgment of linguistically trained listeners and judgment of the authors. The results obtained have pointed out some major areas of interference between the two languages. One of the significant points, found in this research, is the fact that CJA rhythm is not syllable-timed, although its effect is something like syllable-timing.

In recent years, quite a few materials and dissertations concerned with the phonology, morphology and syntax of Arabic have been written. However, there are very few works dealing wholly or partly with the prosodic features of the language in particular ( Arabic Dialect Studies Sobelman, 1962). The only major modern work ( that we know of) devoted wholly to this subject is that of George Abdallah (1960). With the exception of this work, there is no specifically modern linguistic treatment of the prosodic features of either colloquial or classical Arabic.

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1. The author wishes to acknowledge the assistance of Prof. J.C. Catford in the design, execution, and report of this research.

It is also worthwhile noting that no satisfactory contrastive studies have been done of the prosody of American English and Arabic dialects, especially from a pedagogical viewpoint. There are two works that deal partly with the contrastive analysis of the prosody of the two languages (Kennedy, 1960; Nasr, 1955), both of which offer only limited details. Therefore, it is apparent that the present study will be of interest to both language teachers and linguists, since it is wholly concerned with an instrumental analysis of the prosodies of GAE and CJA.

The main purpose of the research reported here is not to give a full description of the prosody of CJA, but to identify the areas of difficulty involved in the teaching of prosodic features of GAE to native speakers of CJA. However, for the convenience of contrastive analysis of these aspects of the two languages, and to arrive at the areas of interference between them, it seems necessary to give an initial description of the prosody of CJA, restricted to the corpus of data. Perhaps this work will open the way for further research in the field with the expectation of predicting some problems that are involved in the teaching of prosodic features of Arabic to native speakers of English. A distinctive feature of this research is the use of the Speech Auto-Instructional Device (SAID) (Lane & Buiten, 1965) for analyzing and teaching the prosodic features of both the native and target languages.

## Method

### Informants and subjects

The corpus was recorded and developed through the cooperation of two groups: English informants and Jordanian subjects. The first group consisted of John C. Catford and Alton L. Becker. Becker was selected as the speaker of General American English (GAE). The second group was selected from five Jordanian students, four of whom recently arrived in the United States. The members of this group represent the educated class in Jordan; have lived in towns all their lives; and have received their elementary and secondary education in Jordanian governmental schools. Their speech habits constitute one of the two major CJA dialects--the dialect of the Eastern bank of Jordan. Although these subjects had spent 5 to 8 months studying in the United States before the start of this project, their knowledge of English was not good enough to enable them to use the language correctly and efficiently in their speech and writing.

### Procedure

The corpus collected for recording consists of five English dialogues, especially prepared for the study of intonation, stress and rhythm. These dialogues contain 54 utterances to be selected for analysis including examples of affirmative and negative statements, yes-no questions, wh- questions, requests and commands, as well as greetings--in each case using a variety of intonations.

The English and Jordanian subjects were requested to produce the normal speech of daily conversation, while recording on magnetic tape, and to act out the dialogues in a natural way.

In addition, the English informants were asked to record 30 of the 54 utterances selected for analysis which were to serve as models. The Jordanian

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subjects, in turn, recorded their imitation of these model utterances, so that recognition and production versus production without recognition could be studied. For comparative analysis the CJA translation-equivalents of the 54 English utterances mentioned above were recorded by the Jordanian subjects.

Analysis of the corpus

The recorded tapes were played back and the 54 utterances for each informant and subject (to be selected for analysis) were picked out of the recorded dialogues and copied on another set of tapes. This new set of tapes held the selected utterances for all the informants and subjects arranged according to their occurrence in the dialogues. This created the need for making a third set of tapes on which the utterances were arranged in the following order: first, the category of greetings with its various intonation patterns; second, the category of matter-of-fact statements, etc. Finally, a new set of tapes was prepared so that a listener could first hear a model recording as performed by the English informant, and then the recording of the same utterance by one of the Jordanian subjects. This was done with each pair of utterances.

First we listened to the tapes, taking each pair of utterances as they were copied on the final set of listening tapes. The performance of the model was compared with that of the subject for amplitude, pitch and tempo. If the two utterances appeared to have different stress, rhythm, or intonation patterns, they were marked to be singled out. Otherwise, they were left unmarked. The resultant list was then classified into three major categories pertaining to stress, rhythm and intonation.

Following this, a listening experiment was run in which six native English speakers, all linguistically trained, participated. The listeners were first given a sheet of instructions, explaining what was involved in the experiment. They were asked to listen to the tapes of English utterances by Jordanians and then mark the primary stress points and intonation contours. This marking was done on an attached form which included all the utterances arranged in order. A final consensus of the listeners' reactions was then made.

Finally, using the SAID system (pitch and intensity analyzer and pen-writer), charts of the selected utterances were completed for analysis as they were copied on the final tapes. The charts were very helpful in showing variation, in connection with amplitude, pitch and tempo, between the performance of the English informants and the Jordanian subjects.

The results obtained from an analysis of these charts were then compared with the results from the listening experiment, as well as with the judgment of the authors. Eventually, a final consensus of the three judgments was established. This consensus became the foundation upon which prediction and illustration of the areas of difficulty between the two languages were based.

The difficulties pinpointed were then classified into three groups of problems: stress, rhythm and intonation. Finally, the problems of each category were presented in the following manner: indication of the problem involved, its description, and its interpretation, in relation to any differences found in this research between GAE and CJA prosodic patterns.

It is important to add that the findings of the comparative analysis will be utilized later on in preparing a programmed unit, for use with the SAID system. The program, to increase fluency in the prosodic features of GAE, will be used by an experimental group of Jordanian students. This will provide an evaluation of the SAID system as an electro-mechanical teaching device of the prosody of the target language under study.

## Results and Discussion

This section consists of two parts: first, a summary and discussion of the tentative description of CJA prosody as restricted to the corpus of data, and, second, examples of some major areas of interference (found in this research) between the prosodies of GAE and CJA.

Summary and discussion of the tentative description of the prosody of CJA

Stress. In CJA, three degrees of stress may be identified, which occur with great regularity in words. These three degrees of stress are not phonemic, however, since their occurrence is determined by the syllabic structure of the word or its consonant-vowel sequence.

For comparative purposes, these stresses are labeled: primary (´), secondary (`) and weak (˘). The following common patterns in the stress system of CJA are given for illustration:

1. Words consisting of only one syllable take primary stress whether the syllable is short or long. The latter contains a long vowel vv, or a short vowel and two consonants, vcc.

| | |
|---|---|
| bás | 'but' |
| báʕd | 'after' |
| kíif | 'how' |
| šáay | 'tea' |

2. Words consisting of two syllables (short and long) take primary stress on the long syllable and weak stress on the short one:

| | |
|---|---|
| ṣăbáaḥ | 'morning' |
| ʕĭšríin | 'twenty' |
| katábt | 'I wrote' |

3. Words containing two long syllables take primary stress on the second syllable and secondary stress on the first:

| | |
|---|---|
| bàarúud | 'gunpowder' |
| kàatábt | 'I corresponded with' |

4. The first combination of vcc or vv from the end of the word receives primary stress.

| | |
|---|---|
| ʔăʕárfàk | 'I introduce you' |
| băṣáddìq | 'I believe' |
| nìtʕăllámhă | 'we learn it' |

In the CJA sentence, however, stress is significant, and any word may carry the main sentence stress. This is always a reinforcement of the primary word stress. It is worth adding here that in CJA, under the influence of sentence stress, most primary word stresses, other than the one receiving the sentence stress, are reduced to secondary stresses. There are very few cases where primary word stress is reduced to weak stress as in the case of GAE:

mùmkin ʔàaxuð kubbàayit šàay θáanya làw samàḥt.

'May I have anóther cup of tèa, plèase.'

Sentence-stress and pitch are interrelated, in that the nuclear tone or change-point of an intonation pattern is normally located at the place where sentence-stress occurs. However, there is some evidence that sentence-stress and pitch are independently variable, and both are therefore phonemic. Notice how, in the first pair of the following examples, there is change of pitch, but no change of sentence-stress, whereas in the second pair there is change in location of tone, but no change in location of sentence-stress. This is represented graphically in Fig. 1.

Insert Fig. 1 about here

1. a) ʔistánna daqiiqa (normal request)
3- 2-3- -3||

'wait a minute'

b) ʔistánna daqiiqa (spoken with annoyance)
3-″1-3- -3||

2. a) (ʔi)šš́úu ʔisim ʔaxuu
3-″2-3- ″3-3||

'What is his brother's name?' (normal question)

b) (ʔi)šš́úu ʔisim ʔaxuu
3-″2-3 ″3-2||

'What is his brother's name?' (question repeated with surprise)

Pitch levels. Three relative pitch levels function in the CJA intonation system. They are fixed by their height, relative to one another. For convenience of comparison with GAE pitch levels, they are referred to as follows:

a) Pitch level /1/. This is the starting point of an intonation contour indicating great attention, surprise or unexpectedness.

b) Pitch level /2/. This is the starting point of a contour used for special attention; it is less intense in contrast than "extra-high /1/."

c) Pitch level /3/. This is the lowest pitch in CJA, used by speakers for normal conversation.

An important phonetic feature of CJA pitches is that they are not at equal intervals of each other as is the case of GAE pitch levels.

Rhythm. Like GAE, CJA is stress-timed; the time is approximately equal between stress groups (Pike, 1947, p. 13, 251-252). However, they differ importantly since in CJA every word in an utterance has a primary or secondary stress, whereas in GAE, many words (so-called "structure words" or "grammatical words"), e.g., articles, pronouns, auxiliary verbs, prepositions, are normally weak-stressed in conversational speech. These weak-stressed English words cluster together in GAE with the strong-stressed words (so-called "content" words).

These word-clusters are often translation-equivalents of single Arabic words, consisting of a stem plus one or more bound morphemes. Note the translation-equivalents of the underlined parts in the following:

1. What's <u>hǐs brɔ̀ther's</u> náme? (normal question)

   ʔaxúu

2. Whére did you say <u>hě pùt thěm</u>? (inquiring about the place)

   ḥáṭhum

3. <u>I'm hòping</u> | <u>to gó back</u> | this year. (matter-of-fact statement)

   batʔámmal | ʔárjaʕ |

It was stated above that CJA is stress-timed like GAE; but that in CJA every separate word has either primary or secondary stress. Therefore, it might also be said that CJA is "word-stress timed". Consequently, the CJA subject, speaking GAE, follows the CJA pattern of giving primary or secondary stress to every word. This results in many GAE grammatical words receiving a stress.

It is very important to repeat that CJA rhythm is not syllable-timed, though its effect often is something like syllable-timing. For example:

Model: || fáhd had lived a |còmfortable |lîfe |but his bróther |hàdn't ||

Subject:||fáhd|hàd|lîved|à |comfòrtable |lîfe |bùt|hîs|bróther |hàdn't ||

If CJA were truly syllable-timed, the word <u>comfortable</u> would be pronounced [còm|fór|tà|blè]. The stress-shift from <u>còmfortable</u> to <u>comfòrtable</u> is related to CJA habits of word stress (see CJA stress pattern no. 4 above).

Pause. An analysis of the corpus reveals two significant contrastive pauses in CJA:

a) Poised non-final pause /|/. This type of pause signals tentativeness, incompleteness and unexpectedness (in some cases). It is normally short in duration and marks the end of segments of incomplete utterances.

b) Relaxed, final pause /||/. This is of longer duration than the first type. It marks the end of complete utterances used in conversation. After falling contours at the end of utterances, this kind of pause implies completeness and finality, whereas after rising or level contours of the type 2-2, it indicates surprise, unexpectedness or requires an answer. Example:

Fahd ʕaaš ḥayaa mliiḥa bas ʔaxuuh maʕ ašiš
3- ´2-2 3- ´2-3 |3- ´2-3 ´2-3 ||

'Fahd had lived a comfortable life, but his brother had not.'

Examples of some major areas of interference between the prosody of GAE and CJA

Stress problems. First, the Jordanian subjects tend to substitute the secondary stress for a weak stress when they produce GAE utterances (see Fig. 2a).

Insert Fig. 2a about here

Model: May I have anóther cup of tèa, plèase.

Subject: Mày Ì hàve anòther cùp òf téa plèase.

CJA pattern: mùmkin ʔàaxùð kubbàayit šàay θáanya làw samàḥt.

(In Fig. 2b note how the GAE utterance as produced by the Jordanian subject has relatively even, high stress when compared with the model.)

Insert Fig. 2b about here

Second, the Jordanian subjects tend to place primary stress on the second syllable and secondary stress on the first syllable of disyllabic GAE compound words, because of the influence of their native language stress patterns:

màilmán

ròommáte (see Fig. 3, and CJA stress pattern no. 3 above).

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Insert Fig. 3 about here

---

Rhythm problems. First, CJA habits of word-stress influence the Jordanian subjects to pronounce the words of a GAE utterance clearly and loudly, giving each word its citation value in terms of length and stress. This resulted in "word-stress timed" rhythm (see Fig. 4).

---

Insert Fig. 4 about here

---

Model: ||Will yòu be|hére next se|mèster||

Subject: ||Wìll|yòu|bè|hére|nèxt|sèmester||

CJA pattern: ||ràayḥi~| tkùun|hóohi|~ʔfàṣli|~jjàay||

Second, the speaker of CJA has difficulty in recognizing and producing reduced forms in GAE connected speech (see Fig. 5).

---

Insert Fig. 5 about here

---

Model: He's been studying English for eleven years.

Subject: He <u>has</u> <u>been</u> studying English <u>for</u> <u>eleven</u> years.

[hii haaz biin studiying engliš foor ilevin yiirz]

CJA pattern: ṣaarlu byudrusi ~ ngliizi ~ ḥdaʕšar sana.

These word-stress habits of CJA make English utterances, produced by Jordanian speakers, sound tense and unrelaxed to native speakers of GAE who may think that Jordanians are somewhat irritated when they speak GAE.

Intonation problems. First, all the Jordanian subjects have trouble in producing GAE intonation patterns "2--3, "2-1-4 and "2-4, which are used for greetings. They tend to substitute their intonation pattern ⁄⁄2-3 instead, which makes them sound somewhat curt to GAE speakers. This may be seen by reference to Fig. 6.

Insert Fig. 6 about here

Model: Good morning, Sami (lively and cheerful)
⁄2- -3 | -3 ||

Subject: Good morning, sami
3- ⁄2-3- | -3 ||

CJA pattern: ṣabaahilxeer saami.
3- ⁄2-3 | -3 ||

b) The Jordanian subjects transfer their rising intonation ⁄3-2 when they produce GAE utterances signaling attached questions, because such questions are expressed by the rising intonation ⁄⁄3-2 in CJA, whether or not the question asks for confirmation or information. This is verified in Fig. 7.

Insert Fig. 7 about here

Model: Doesn't he? (asking for confirmation)
⁄2- -4 ||

Subject: Doesn't he?
3- ⁄3- -2 ||

CJA pattern: mišheek.
3- ⁄3-2 ||

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## Figure captions

Fig. 1. Graph (a) shows change in pitch, but no change in CJA sentence-stress. Graph (b) shows change in location of tone, but no change in location of sentence-stress.

Fig. 2. a) An illustration of the fact that the CJA subject, speaking GAE, follows the CJA pattern of giving primary or secondary stress to every word. b) Data taken from Fig. 2(a) showing amplitude relative to highest value, on same scale for Model and Subject.

Fig. 3. The difference, with respect to changes in loudness, between Model and Subject in pronouncing the syllables of the compound word roommate.

Fig. 4. An illustration of CJA "word-stressed timed" rhythm.

Fig. 5. An example showing how GAE reduced forms are produced in their full forms by the Jordanian subject.

Fig. 6. Nonresemblance of the two graphs, for Model and Subject, illustrates how the Subject produces the GAE greeting with a different pitch contour from the Model.

Fig. 7. The graphs show the difference, with respect to changes in pitch, between Model and Subject in producing the GAE attached question, "Doesn't he?," asking for information.

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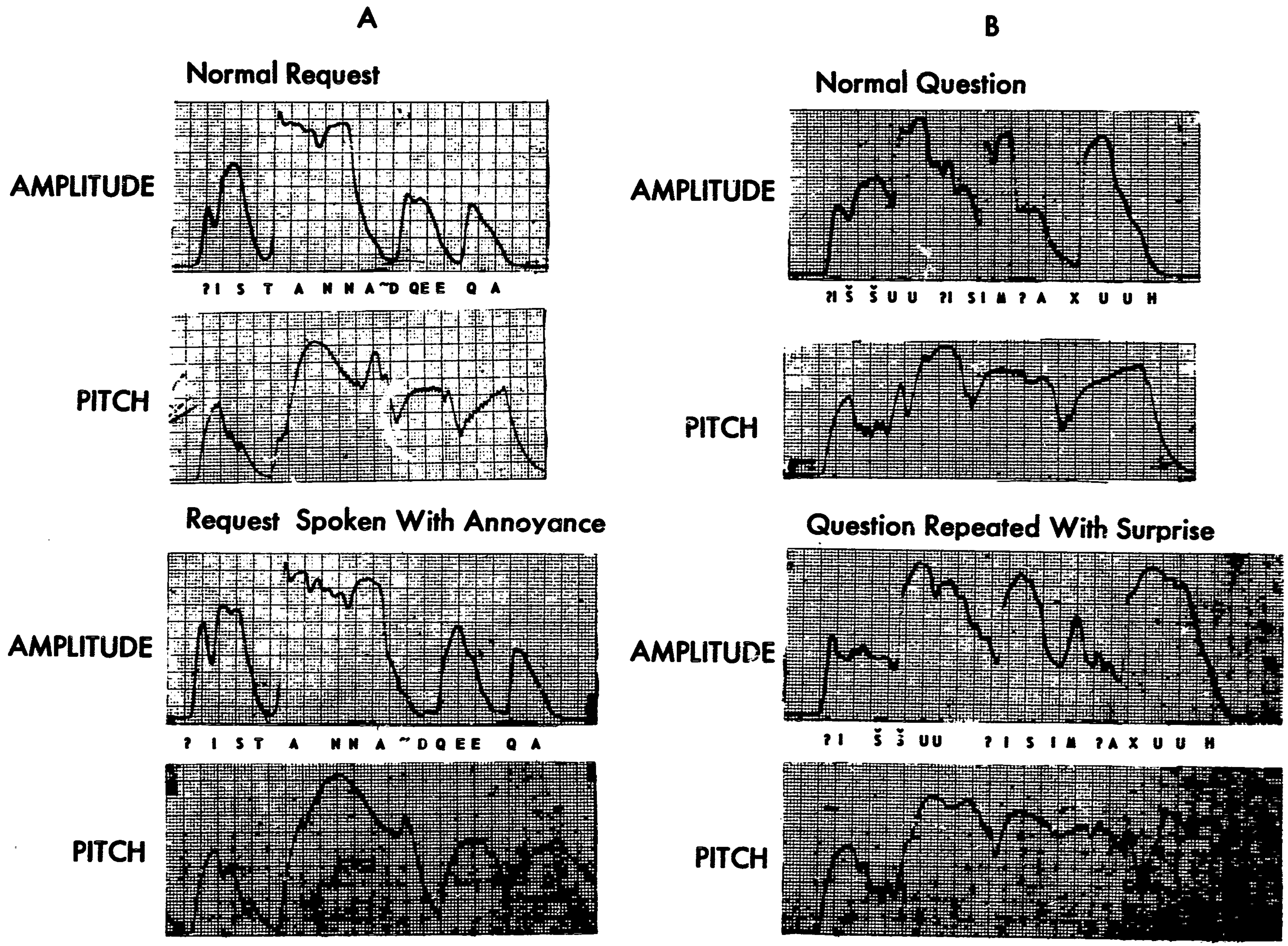
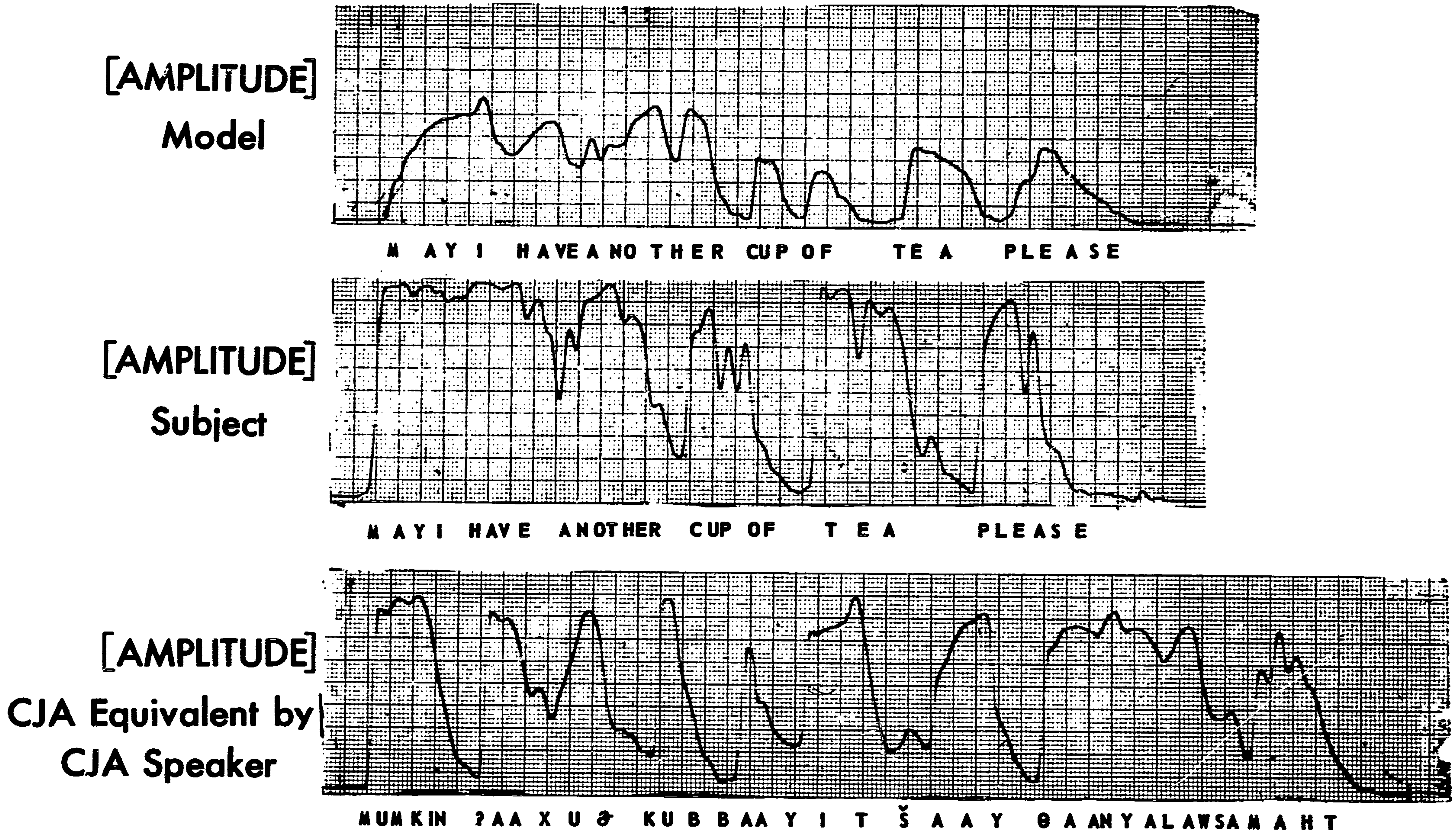
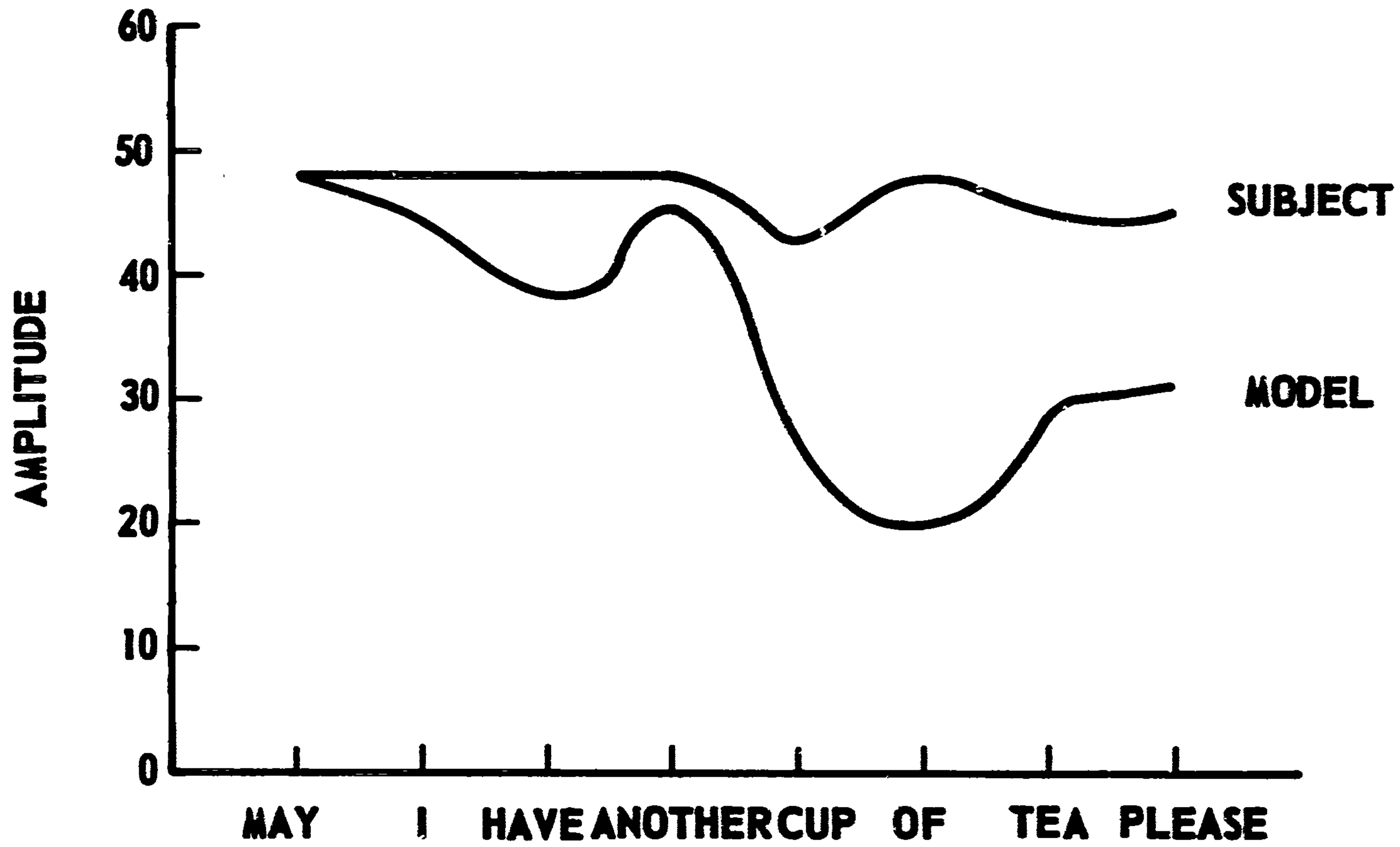

A
Normal Request
AMPLITUDE
?I S T A N N A ~D QEE Q A
PITCH
Request Spoken With Annoyance
AMPLITUDE
? I S T A N N A ~ D Q E E Q A
PITCH
B
Normal Question
AMPLITUDE
?I Š Š U U ?I S I M ? A X U U H
PITCH
Question Repeated With Surprise
AMPLITUDE
? I Š Š U U ? I S I M ? A X U U H
PITCH

Fig. 1


[AMPLITUDE]
Model
M AY I HAVE A NO THER CUP OF TE A PLE A SE
[AMPLITUDE]
Subject
M A Y I HAVE ANOTHER CUP OF T E A PLEAS E
[AMPLITUDE]
CJA Equivalent by
CJA Speaker
MUMKIN ?AA X U ə KU B B AA Y I T Š A A Y θ A ANY AL AWSA M A H T



60
50
40
30
20
10
0
AMPLITUDE
SUBJECT
MODEL
MAY
I
HAVE
ANOTHER
CUP
OF
TEA
PLEASE


Fig. 2b

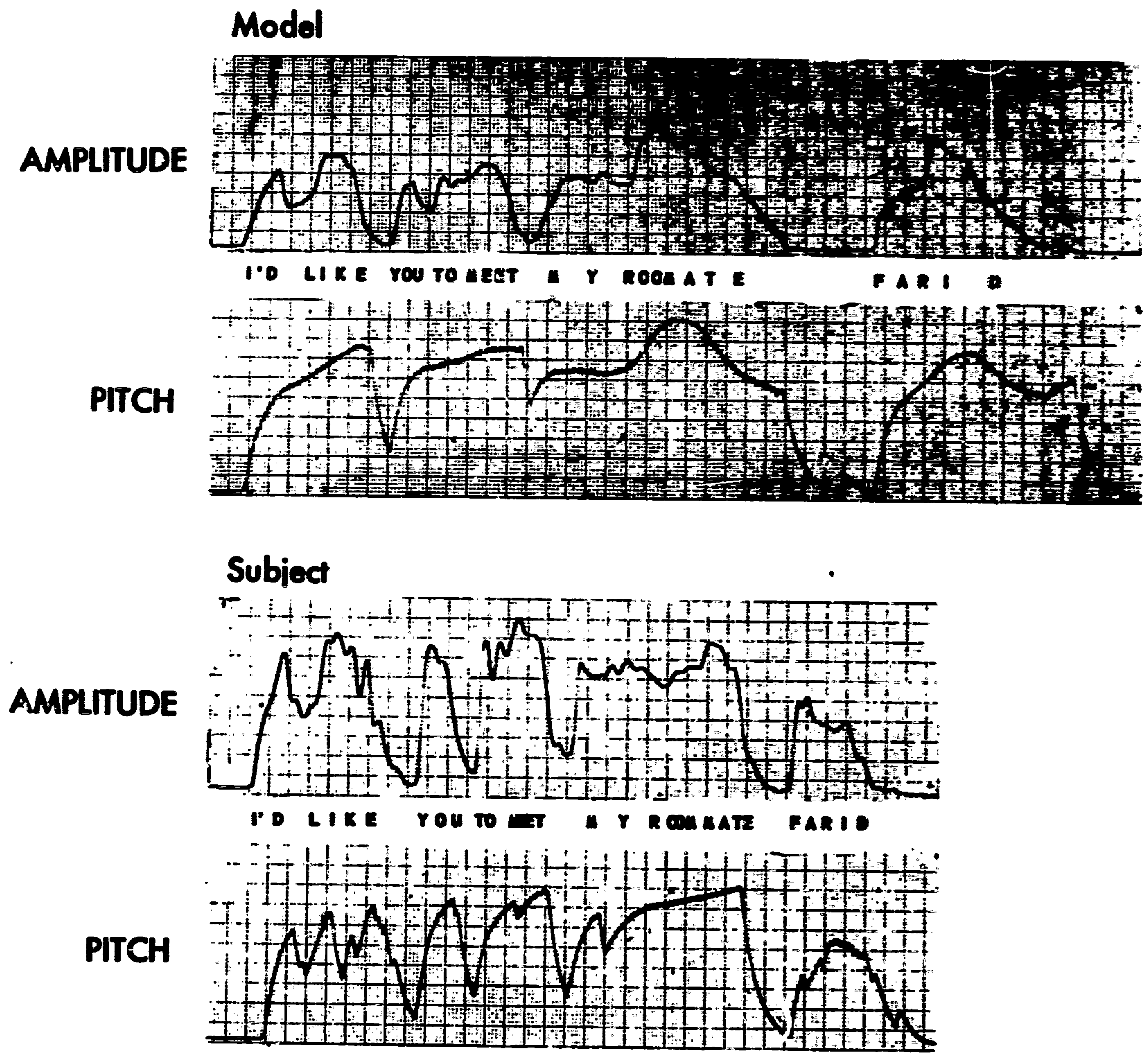
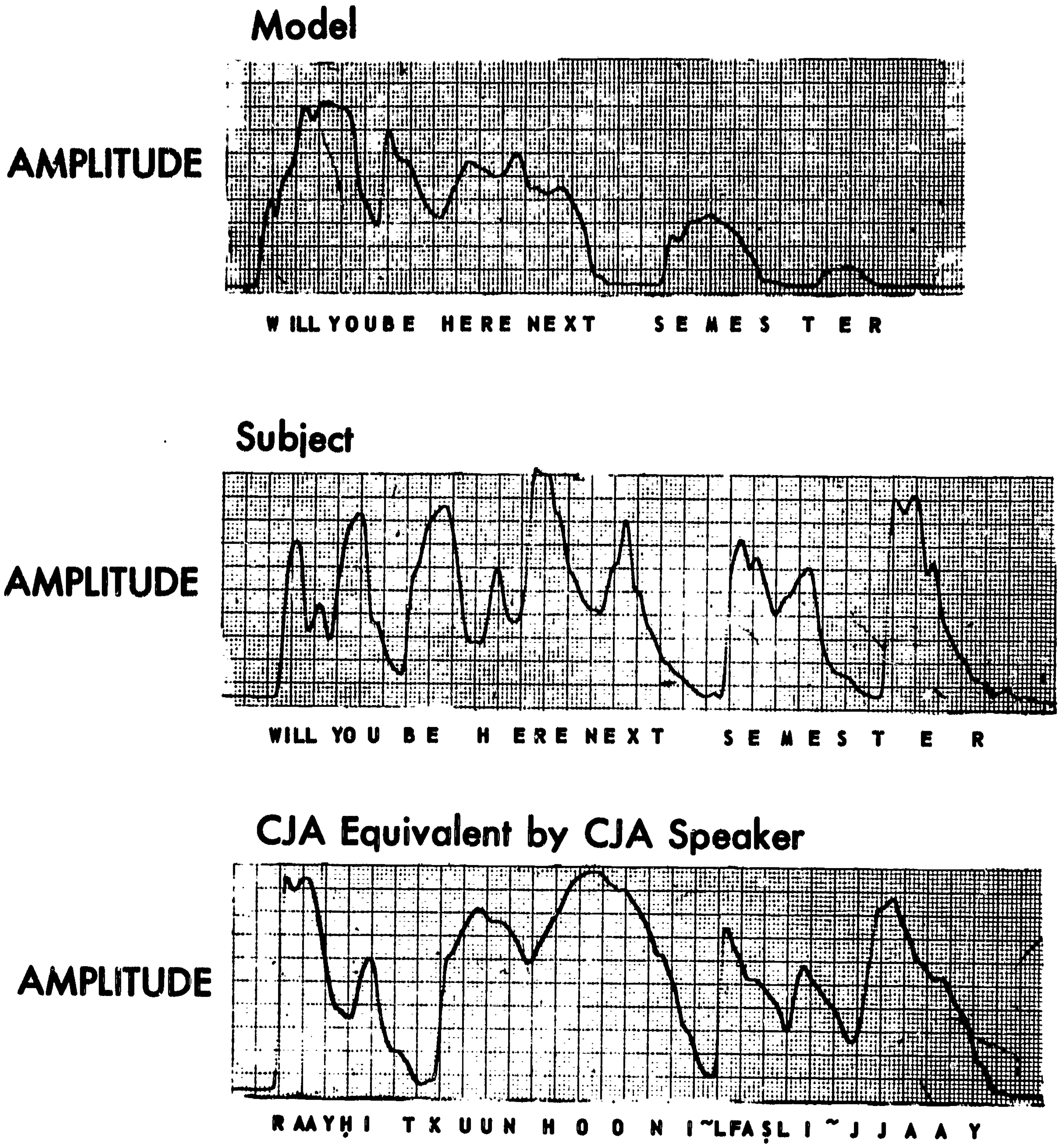

Model
AMPLITUDE
I'D LIKE YOU TO MEET MY ROOMATE FARID
PITCH
Subject
AMPLITUDE
I'D LIKE YOU TO MEET MY ROOMMATE FARID
PITCH

Fig. 3



Model
AMPLITUDE
WILL YOUBE HERE NEXT SEMES T E R
Subject
AMPLITUDE
WILL YO U BE H ERE NEXT SEMES T E R
CJA Equivalent by CJA Speaker
AMPLITUDE
RAAYḤI TXUUN H O O N I~LFAṢL I ~ J J A A Y


Fig. 4

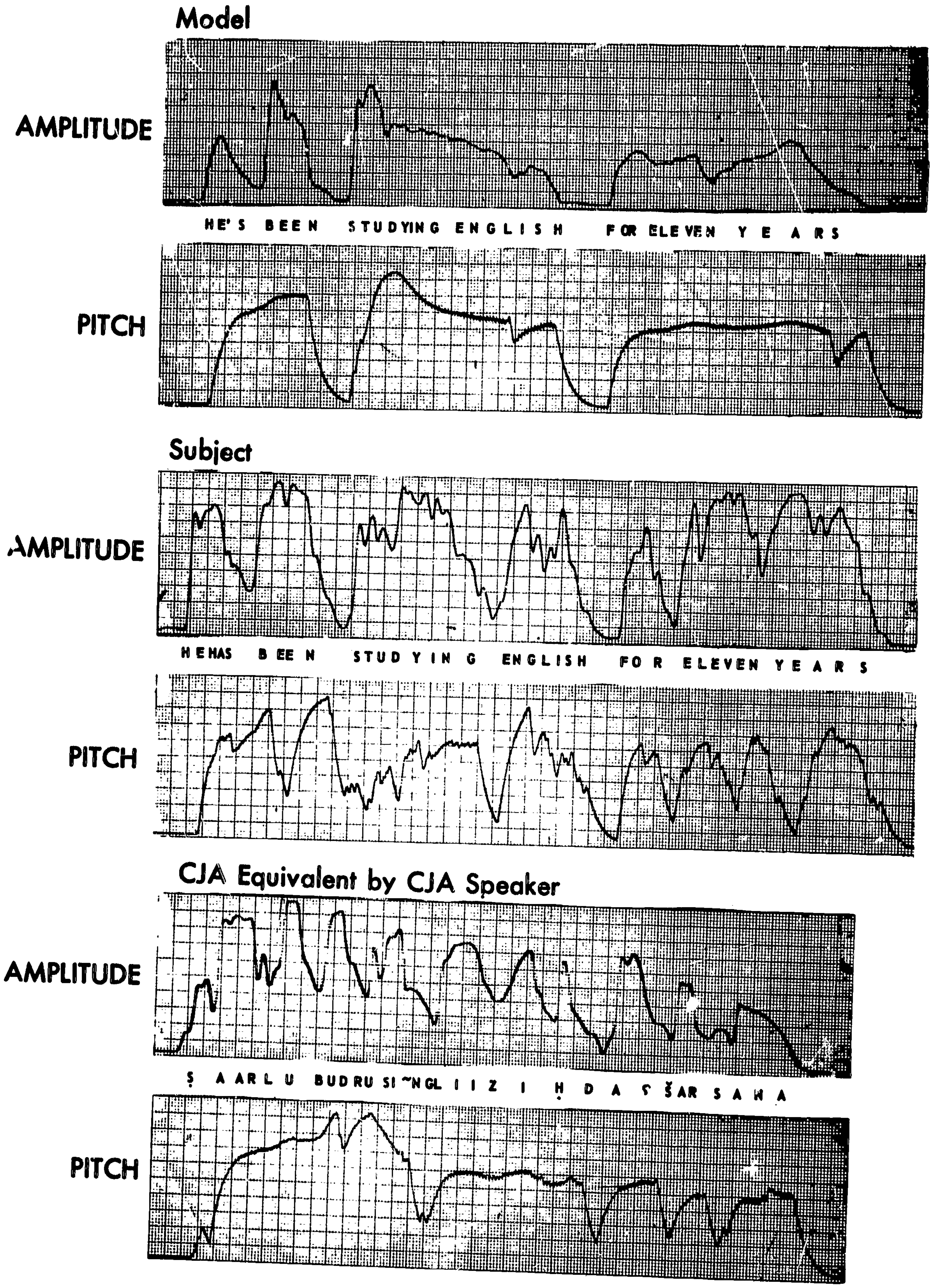

Model
AMPLITUDE
HE'S BEEN STUDYING ENGLISH FOR ELEVEN YEARS
PITCH
Subject
AMPLITUDE
HE HAS BEEN STUDYING ENGLISH FOR ELEVEN YEARS
PITCH
CJA Equivalent by CJA Speaker
AMPLITUDE
Ṣ A ARL U BUDRU SI ~NGL I I Z I Ḥ D A ʕ ŠAR SAHA
PITCH

Fig. 5

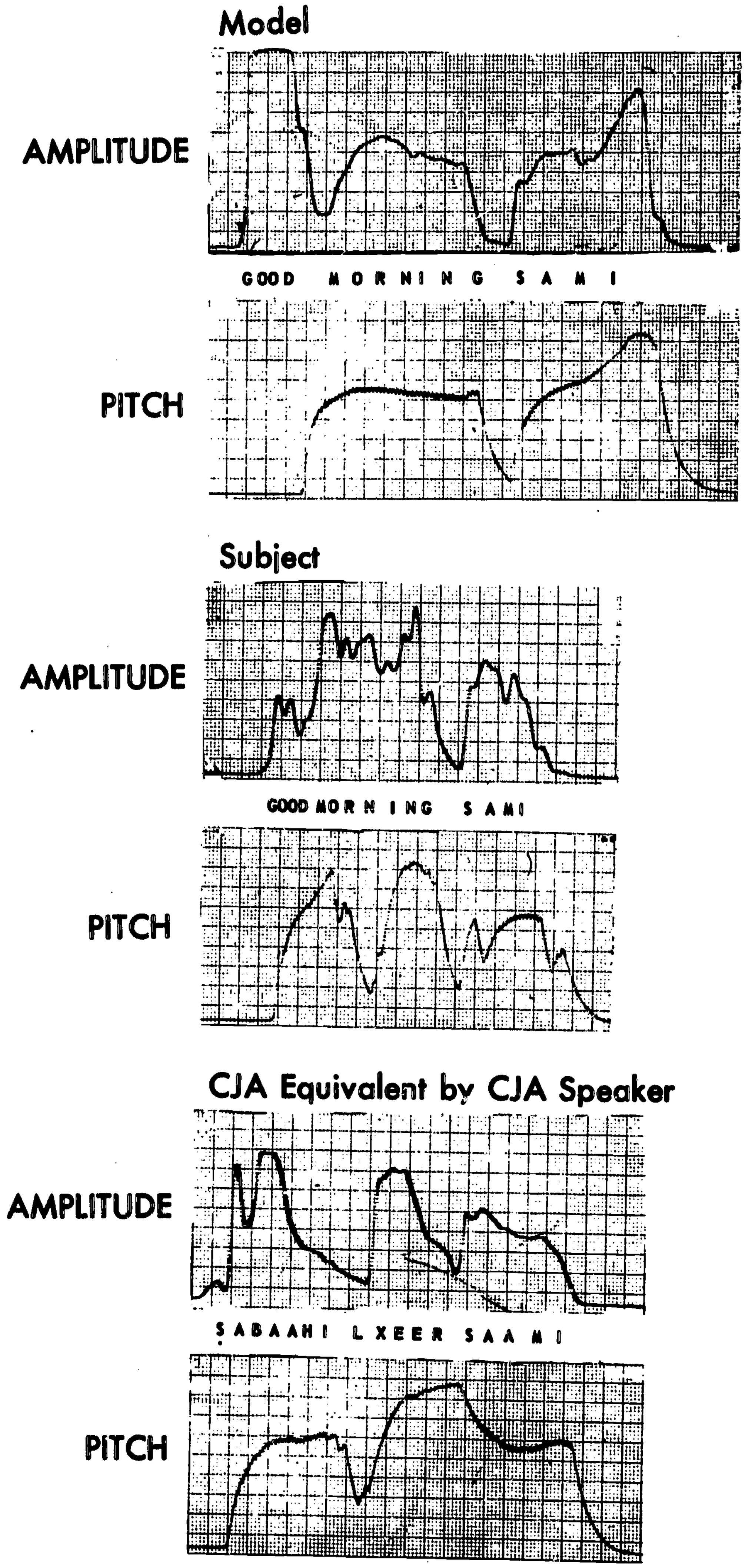

Model
AMPLITUDE
GOOD MORNING SAMI
PITCH
Subject
AMPLITUDE
GOOD MORNING SAMI
PITCH
CJA Equivalent by CJA Speaker
AMPLITUDE
SABAAHI LXEER SAAMI
PITCH

Fig. 6

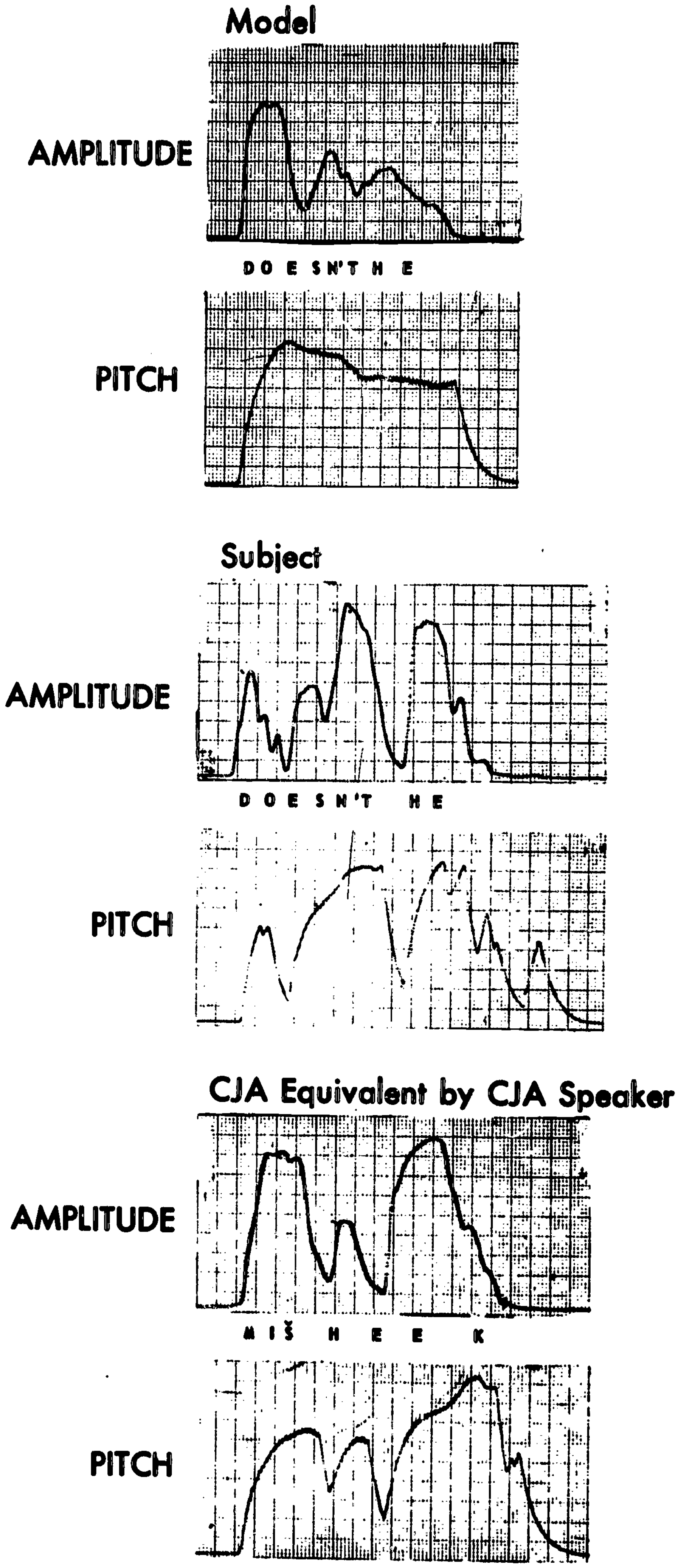

Model
AMPLITUDE
DO E SN'T H E
PITCH
Subject
AMPLITUDE
D O E S N'T H E
PITCH
CJA Equivalent by CJA Speaker
AMPLITUDE
M I Š H E E K
PITCH

Fig. 7

Loudness of Pure Tones as a Function of Frequency, Intensity, and Middle Ear Mechanics

Part II

S. Ross

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# Loudness of Pure Tones as a Function of Frequency, Intensity, and Middle-Ear Mechanics

## Part II

## Acoustico-Mechanical Properties of the Middle Ear at Low Stimulating Sound Intensities

Strange Ross

Center for Research on Language and Language Behavior

Abstract

Acoustic impedance at the eardrum was measured for three Ss as a function of intensity and frequency of a tone stimulating the ear under measurement. An analog network for the middle ear developed by Zwislocki is discussed, and the parameters of the network are adjusted to obtain the best possible match between input impedance of the network and acoustic impedance at the eardrum, for each S. The transfer characteristic of the network is calculated for each set of parameter values, and the relation between this characteristic and the equal-loudness contours arrived at in Part I of this report is examined. Possible sources of a peculiar kind of variability in the measures of acoustic impedance are investigated by means of the analog networks.

## Introduction

In Part I of this report a set of equal-loudness contours for each of three Ss was presented. The analysis of these contours suggested that their general shape, as well as some local perturbations, might be better understood if the transmission characteristic of each middle ear under consideration were known. The recent work of Zwislocki (1962, 1965) indicates that this transmission characteristic may be recovered through the measurement of the acoustic impedance at the eardrum. In the above-mentioned papers, Zwislocki has provided the necessary theoretical foundation for such a venture by working out a model of the functioning of the middle ear. Further, he has developed the tool that makes possible the actual measurements, in the form of an acoustic bridge.

In addition to its relevance for the analysis of the above-mentioned equal-loudness contours, the measurements of acoustic impedance at the eardrum to be reported in this and a later part of the present report may be of interest in their own right due to two innovations in technique relative to previous studies. One of these is concerned with the frequency range employed. By means of a technique to be described later in this report, it was possible to push the lower frequency limit of the measurements from the previous value of approximately 100 cps down to 20 cps. Secondly, the acoustic impedance at the eardrum was measured as a function of the parameters of the tone stimulating the same ear, rather than stimulating the opposite ear as has previously been the case.

As the intensity of the stimulating tone reaches a certain level, depending on the frequency of the tone and on the S, the acoustic impedance at the eardrum begins to change. In the present part of this report all impedance measures collected will be presented, but only the "static" impedance that obtains up to the critical intensity level will be discussed. In Part III of this report the "dynamic" impedance will be treated.

## Method

### Apparatus and techniques

The Zwislocki Acoustic Bridge (Grason-Stadler Co., Type E 8872A, Model 3, Serial No. 26) was employed for obtaining measurements of the acoustic impedance at the eardrum. In its intended mode of operation this bridge works as a Schuster bridge. In this mode a built-in symmetrical transducer radiates acoustic energy into a variable acoustic impedance, as well as into the unknown impedance (the eardrum). By means of a Y-tube whose branches are connected to symmetrical points in the two paths of sound within the bridge and a stethoscope connected to the stem of the Y-tube, a null is obtained by adjusting appropriately the variable impedance.

In the present application it was desired to utilize the acoustic output of the bridge as the sound stimulating the ear under test. It was further desired that these stimulating sounds cover as wide a frequency and intensity range as possible. Owing to the difficulties of constructing a symmetrical transducer, the output of the built-in transducer is sufficiently distortion-free only for measurements at rather low output intensities. Difficulties in detecting the null (either by stethoscope, or by monitoring by means of a microphone followed by selective amplification) further set a lower limit to the frequency employed at about 100 cps. (Resonance effects in the bridge set a higher limit at about 1500 cps.)

In order to overcome these limitations the Zwislocki Acoustic Bridge was employed as a Robinson bridge, rather than as a Schuster bridge. In this mode of operation an externally generated acoustic signal is fed to the stem of the Y-tube. Through the symmetrical branches of this Y-tube signals of equal amplitude and phase are delivered to the two halves of the bridge. When the variable impedance equals the unknown impedance (of the eardrum), the sound pressures on both sides of the built-in symmetrical transducer are of equal amplitude and phase. By employing this transducer as a microphone, a null may be detected under this condition.

Details of the experimental set-up are as follows (see Fig. 1). A

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Insert Fig. 1 about here

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speaker (University Driver Type ID-40), driven by an audio oscillator (Bruel & Kjaer Type 1014), was employed as external sound source. After removing the protective screen from the neck of the driver, a rubber stopper provided with a piece of 1/4" dia. brass tubing was fitted in its place. A 20 cm long 1/4" dia. rubber tube connected the driver with the Y-tube of the bridge. This arrangement provided acoustic outputs of the bridge with a distortion of not more than 1.5 per cent at the following levels and frequencies: 140 db SPL at 20 cps; 150 db SPL at 32 cps; 140 db SPL at 50 cps; 145 db SPL at 80 cps; 135 db SPL at 125 cps; 150 db SPL at 200 cps; 135 db SPL at 320 cps; and 125 db SPL at 500, 800, and 1250 cps.

The built-in transducer was connected via a transformer (UTC Type LS-14X; primary 10 ohms, secondary 50,000 ohms) to a low-noise, selective pre-amplifier (General Radio Tuned Amplifier and Null Detector Type 1232-A), which fed another amplifier (Bruel & Kjaer Microphone Amplifier Type 2603). The output from the latter amplifier was filtered (60 cps filtering by means of Bruel & Kjaer Frequency and Distortion Measuring Bridge Type 1607; filtering of signal frequency by Krohn-Hite Band-Pass Filter Model 310-AB) and monitored either by phone or by meter, depending upon signal frequency. By means of this arrangement nulls could be detected for the following minimum sound pressure levels at the eardrum: 110 db SPL at 20 cps; 105 db SPL at 32 and 50 cps; 90 db SPL at 80 cps; 80 db SPL at 125 cps; 70 db SPL at 200 and 320 cps; and about 60 db SPL at 500, 800, and 1250 cps. Only for the latter three frequencies does the Schuster mode of operation provide an approximately 10 db better sensitivity, while distortion due to the built-in transducer--as already mentioned--prevents this mode of operation below about 100 cps. (Filtering of the monitored signal greatly facilitates the null adjustment of the bridge in either mode of operation.)

In coupling the acoustic bridge to the ear under investigation a speculum is employed (shown in Fig. 3). This funnel-shaped device is fitted at its tip with a plastic collar of appropriate size. When the speculum (with vaseline applied to the plastic collar) has been properly seated in the meatus, the tip of the acoustic bridge is inserted into the speculum, thus providing an airtight seal between meatus and bridge. Since the volume of air enclosed between the tip of the speculum and the eardrum contributes to the total impedance measured by the bridge, this volume is independently measured, and a compensating volume adjusted on the bridge. After this adjustment the reading of the bridge reflects only the impedance at the eardrum.

It has been repeatedly emphasized, in the Instruction Manual, as well as in the literature concerning the Zwislocki Bridge, that an accurate determination of the volume enclosed between speculum and eardrum is of utmost importance if accurate absolute impedance measures are desired. This implies that the coupling between bridge and ear, as well as the volume measurement itself, be carefully controlled. Unfortunately, no standardized techniques for these purposes have as yet been developed. Previous investigators using the Zwislocki bridge have supplied only very scant information concerning their procedures in this respect. Thus, one group of investigators states that "the examiner hand-held the acoustic bridge in an approximately horizontal position" (Tillman et al., 1964), while another author states that the S was positioned in a dental chair, and "the bridge was rigidly held in position by appropriate clamps and rods" (Dallos, 1964). Neither does the Instruction Manual accompanying the bridge recommend any specific procedure.

In an attempt to introduce some measure of control in the application of speculum and bridge the following procedure was adopted in the present investigation (see Fig. 1). During impedance measurements the S was resting on a cot, with his head thus positioned that the speculum when inserted correctly, i.e., so that the eardrum was visible through the speculum, was oriented vertically. After this positioning was obtained, the bridge was inserted into the speculum and allowed to exert its own weight on the speculum. All adjustments of the controls of the bridge were carried out so as to maintain this condition as closely as possible. During volume measurements the speculum was positioned in the same manner as just described, and a bar suspended at one end and so adjusted that its other end exerted a downward force equal to the weight of the bridge (240 grams) was positioned over the free end of the speculum (see Fig. 2). In this way the downward force applied to the speculum was constant and equal during both kinds of measurements.

Insert Fig. 2 about here

The recommended procedure for determining the volume between tip of speculum and eardrum is to insert the speculum in a vertical position and inject alcohol from a calibrated syringe into the ear canal until the alcohol reaches the level of the tip of the speculum. Due to difficulties in determining when the alcohol (even when colored) reaches the proper level, this method does not seem the most suitable one for laboratory measurements. Therefore, as suggested by Tillman et al. (1964), an electrical method was employed. An insert which fitted snugly into the funnel-shaped part of the speculum was moulded from resin glue, and this insert was fitted with a piece of insulated wire and a piece of 1 mm diameter tubing (see Fig. 3). Initially,

Insert Fig. 3 about here

the length of the wire was so adjusted that one end was flush with the tip of the speculum. The other end of the wire was connected to one terminal of an ohmmeter, and the other terminal was brought in contact with the S's body. A relay operated by the meter circuit of the ohmmeter activated an acoustic signal when alcohol injected through the tube in the insert reached the level of the wire, and, thus, the level of the tip of the speculum. Quite often,

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however, unwanted short-circuits between the wire and the wall of the ear canal were encountered. This situation was bettered to some extent by shortening the wire protruding from the insert. In this case, of course, a greater amount of alcohol had to be injected before contact occurred between alcohol and wire, and a corresponding correction of the volume injected was made. (A different arrangement for measuring the volume between tip of speculum and eardrum was conceived later, but not actually tested. By providing a snugly-fitting insert for the speculum with two narrow tubes, alcohol can be injected through one tube until overflow is observed at the other tube. The necessary correction for the amount of alcohol injected is easily measured. It is felt that this method would provide a highly reliable measure of the desired volume, and at the same time be extremely simple to perform. The use of colored alcohol might even further facilitate this procedure.)

During impedance measurements at the ear, the electrical input to the driver connected to the bridge was measured and recorded. In order to convert these measures to the sound pressures generated at the eardrum during these measurements, the following technique was employed. After the completion of impedance measurements on the ear, the bridge was terminated by a variable impedance constructed from a syringe. The narrow tip of this syringe had been removed, and its open end was connected to the tip of the speculum by means of a short piece of flexible tubing (see Fig. 4). By varying the volume of the air space enclosed by the syringe the compliance of this termination was

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Insert Fig. 4 about here

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varied, and by inserting various amounts of more or less compressed cotton into the syringe the resistance of the termination was varied. By means of a calibrated probe microphone inserted through the wall of the flexible tubing, the acoustic output of the bridge when terminated by this variable load could be measured.

In order to determine the sound pressures generated at the eardrum during the impedance measurements, the driver input and the bridge adjustments were replicated, a null was obtained by appropriately varying the external variable impedance, and the sound pressure of the acoustic output of the bridge was measured by means of the probe microphone. This sound pressure was assumed to equal that generated at the eardrum under the corresponding conditions during impedance measurements. This process was repeated for all inputs and bridge settings employed during impedance measurements. Variations in the acoustic output of the bridge, at any given frequency, due to changing settings of the bridge were generally small. Up to 150 cps these variations were below ±.2 db; for the remaining frequencies employed variations did not exceed ±2 db, except at 200 cps where variations as large as ±7 db were observed.

Procedure

Two female Ss (JR and LL) and one male S (FP), all in their twenties, were employed in the present investigation. (These Ss are identical to the ones employed for the loudness matching experiments described in Part I of this report.) None suffered from any previously known hearing disorder.

Measurements of volume between speculum and eardrum were conducted prior to the impedance measurements, according to the methods described above. Results were as follows: S JR: .47 cc, .50 cc, .50 cc (mean: .49 cc); S LL: .51 cc, .505 cc, .52 cc (mean: .51 cc); S FP: .72 cc, .72 cc (mean: .72 cc).

In order to maximize the comparability of impedance measures obtained at different stimulating sound intensities, the following procedure for collecting these measures was adopted. For any given frequency employed, the bridge was left in place on the ear during a complete series of measurements extending from the weakest sound intensity for which a null could just be detected to the maximum level which the S could tolerate. The electrical input to the driver was raised in steps of 10 db between each impedance determination; when the maximum level was approached, 5 db increases were used in most cases.

The following frequencies were employed: 20, 32, 50, 80, 125, 200, 320, 500, 800, and 1250 cps; (consecutive values of this series are spaced approximately 1/5 decade apart). One experimental session comprised one series of impedance determinations for each of these frequencies. The S was allowed sufficient rest between series of determinations so that after-effects of the stimulation reportedly had subsided. Subjects JR and FP completed four sessions each, and S LL completed two sessions.

## Results

Figures 5 and 6 show typical measures of equivalent volume and resistance at a given frequency as a function of the intensity of the stimulating tone

Insert Figs. 5 - 6 about here

for each of four series of determinations for Ss JR and FP, respectively. It will be noted that the measurements of the different series exhibit a displacement relative to each other, in such a way that a series with low values of equivalent volume (i.e., with high values of reactance) contains high values of resistance, and vice versa. This kind of relationship between equivalent volume and resistance was found in the majority of cases. We shall have occasion later to look into the possible causes of this particular kind of variability of the data.

Choosing initially to disregard this variability, average impedance values were computed for each intensity level at each frequency. In so doing, measures of equivalent volume were averaged and then converted to corresponding reactance. Also, small differences in sound pressure level at the eardrum (due to differences in the settings of the bridge) were disregarded, and the average resistance or reactance was plotted against the average of these levels. Figures 7 - 9 display for each S the average acoustic resistance and reactance as a function of the intensity of the stimulating tone, with the frequency of this tone as parameter. Logarithmic ordinates were employed for better separation.

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Insert Figs. 7 - 9 about here

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Inspection of Figs. 7 - 9 reveals that the impedance measures show a rather stable level at the lower sound pressure levels. These "initial" impedance values are the concern of the present part of this report. From Figs. 7 - 9 these initial levels were estimated visually. Table 1 contains

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Insert Table 1 about here

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these estimated values, and Fig. 10 shows these initial impedance levels as a function of frequency for all three Ss.

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Insert Fig. 10 about here

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In order to estimate the transmission characteristic of each middle ear investigated an attempt will be made--for each S--to adjust the parameters of the electrical analog of the middle ear developed by Zwislocki (1962) in such a way that the model exhibits the same impedance/frequency relationship as found for the given ear. If this can be accomplished with a reasonable degree of success, it may be assumed that the transmission characteristic of the model is a close approximation to that of the corresponding middle ear. Before proceeding to this task, however, it will be in order to discuss the mechanical assumptions underlying Zwislocki's electrical analog.

## Mechanical Equivalent of Zwislocki's Middle-Ear Analogy

### Introduction

Based on anatomical data and on measurements of the acoustic impedance at the eardrum, Zwislocki (1962) has developed an electrical network with properties analogous to the acoustico-mechanical properties of the middle ear (see Fig. 11). (For an exposition of the theory of mechanical and acoustical

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Insert Fig. 11 about here

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analogies, see Beranek [1954].) This is not the place for a detailed account of the anatomy of the middle ear, nor of the considerations underlying Zwislocki's model. For this information, the reader is referred to standard textbooks, and to Zwislocki's papers (1957, 1962). It may be of interest, however, to present a mechanical equivalent of Zwislocki's model. This mechanical equivalent will serve two purposes: 1) for many, a purely mechanical model may be easier to understand than an electrical one (especially, perhaps, as regards the effect of varying various elements); 2) by explicitly stating the mechanical assumptions underlying the middle-ear model, the reader will be able better to check these against anatomical and other kinds of information.

While acoustical circuits are most conveniently treated in terms of impedance, mechanical circuits are more easily handled in terms of mobility, (that is, the inverse of impedance). The diagram of Fig. 11, which is stated in terms of impedance, therefore, is transformed into the equivalent mobility diagram which appears in Fig. 12. (This transformation may be carried out conveniently according to the "dot" method described by Beranek

Insert Fig. 12 about here

[1954].) In this diagram the first vertical branch represents the mobility of the middle-ear cavities; the first horizontal section represents the mobility of the eardrum; the second vertical branch represents the rotational mobility of the malleo-incudal complex; the mobility of the incudo-stapedial joint is represented by the second horizontal section; and the mobility of the stapedial complex (including that of the oval and the round window, and that of the cochlea) is represented by the last vertical branch. In the following, each of these main sections will be considered in turn.

Middle-ear cavities

The anatomical correlates of the first part of the mobility analogy of the middle ear are the following. The tympanic cavity is located behind the eardrum, and connects through a narrow passage (the epitympanum) with a smaller cavity, the antrum, which in turn connects with the pneumatic cells. According to Zwislocki's model, the mechanical (or acoustical) equivalent of this arrangement, as seen from the eardrum, is a piston acting on a volume of air enclosed in a space with semi-rigid walls; this space connects via a tube of intermediate diameter (Beranek, 1954) with another volume of air. Figure 13 illustrates this mechanical equivalent. Indices correspond to those of Figs. 11

Insert Fig. 13 about here

and 12. (A volume of air comprises a mechanical (or acoustical) compliance, represented by an inductance in a mobility analogy; the soft tissue covering

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the walls of the tympanic cavity acts as a mechanical responsiveness, represented by a resistance in the analogy; and a tube of intermediate diameter behaves mechanically (or acoustically) as a parallel combination of a mechanical responsiveness and a mass, the latter being represented in the analogy by a capacitance (Beranek, 1954)).

Eardrum

When attempting to construct a mechanical equivalent of that part of Zwislocki's model that represents the eardrum, it should be borne in mind that when levers are employed in the equivalent, many such mechanical equivalents may lead to the same (reduced) electrical analogy. The mechanical equivalent to be described in the following represents, in the opinion of the present author, a reasonable choice among the many possible equivalents.

The rudimentary anatomical and mechanical information concerning the eardrum and its coupling to the malleus is summarized by Zwislocki: "...at low and medium frequencies the major central portion of the eardrum moves nearly as a rigid body and with the same amplitude as the part of malleus attached to it. The eardrum appears to rotate around its upper edge--a mode of motion facilitated by a flexible fold near its lower edge. Nevertheless, not the entire membrane moves with the same amplitude. Toward the edges, the motion decreases to zero. Also, due to their flexibility, parts of the eardrum can move even after a complete fixation of the ossicles. At high frequencies, the mode of motion changes and different sections vibrate in different phases. All this means that, although the coupling between the eardrum and the malleus is close, it is not perfect, and some of the acoustic energy activating the eardrum is not transmitted to the ossicles" (1962, p. 1515). This information, together with the information available from

Zwislocki's model, led to the mechanical conception illustrated in Fig. 14.

Insert Fig. 14 about here

Here the simple lever OA represents a section $d_1$ of the eardrum close to the malleus. The floating lever AB represents areas $d_2$ of the eardrum further removed from the malleus. The flexible fold near the lower edge of the eardrum is represented by an infinite mobility at B, and the mobility of the mass of section $d_2$ of the eardrum is represented by $M_{d_2}$. (The mass of section $d_1$ may be treated together with the mass of malleus; and since the mass of $d_1$ is very small compared to the mass of malleus, it may effectively be ignored.) The two levers are joined by a frictionless hinge at A. Both levers couple via a compliance and a resistance to the malleus. The mobility of malleus, loaded by the remainder of the middle ear, is denoted by z*. The force f, representing the sound pressure at the eardrum, is regarded as attacking the junction of the two sections of the eardrum. Finally, the middle-ear cavities, represented by the mobility $z_t$, are regarded as coupling to the junction of the two sections of the eardrum.

Denoting the parallel combination of the mobilities $C_{d_1}$ and $r_{d_1}$ by $m_{d_1}$, and that of $C_{d_2}$ and $r_{d_2}$ by $m_{d_2}$, the total mobility u/f of the system depicted in Fig. 14 at point A can be shown to equal:

$$(1) \quad u/f = \frac{z^*(k_5 m_{d_1} + k_6 z^*) + (z^* + m_{d_1})(k_7 m_{d_2} + k_8 M_{d_2} + k_9 z^*)}{k_1 m_{d_1} + k_2 m_{d_2} + k_3 M_{d_2} + k_4 z^*},$$

where

$$(2) \quad k_1 = \frac{a+b}{a} \frac{d}{c} \frac{d}{c+d}$$

$$(3) \quad k_2 = \frac{1}{k_8} = \frac{a}{a+b} \frac{c+d}{c}$$

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(4) $$k_3 = \frac{1}{k_7} = \frac{a}{a + b} \; \frac{c}{c + d}$$

(5) $$k_4 = \frac{ac - bd}{ac} \left(\frac{a}{a + b} - \frac{d}{c + d}\right)$$

(6) $$k_5 = \left(\frac{a + b}{a}\right)^2 \frac{d}{c}$$

(7) $$-k_6 = k_9 = \frac{a + b}{a} \; \frac{ac - bd}{ac},$$

a, b, c, and d denoting the lengths of the segments of the levers of Fig. 14.

In general, the expression (1) for the mobility of the mechanical system cannot be represented by the first horizontal section of the mobility diagram of Fig. 12. If it is assumed, however, that

(8) $$\frac{a}{b} = \frac{d}{c},$$

the expression for the mobility of the mechanical system is reduced to:

(9) $$u/f = \frac{1}{k_1 k_3} \; \frac{m_{d_1}(m_{d_2} + \frac{k_3}{k_1} M_{d_2}) + z^* \, (m_{d_1} + m_{d_2} + \frac{k_3}{k_1} M_{d_2})}{m_{d_1} + m_{d_2} + \frac{k_3}{k_1} \; M_{d_2}}.$$

This expression is equivalent to:

(10) $$u/f = \frac{1}{k_1 k_3}\{[m_{d_1} \; || \; (m_{d_2} + \frac{k_3}{k_1} \; M_{d_2})] + z^*\},$$

or

(11) $$u/f = \left(\frac{a + b}{a}\right)^2 \{[m_{d_1} \; || \; (m_{d_2} + \left(\frac{b}{a + b}\right)^2 M_{d_2})] + z^*\}.$$

These latter expressions will be seen to describe a mobility which, apart from the constants involved, is equivalent to the mobility depicted in the first horizontal section of the diagram of Fig. 12.

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We have thus arrived at the conclusion that, when the two lever ratios involved as seen from point A are assumed to be equal, the mechanical diagram of Fig. 14 is an equivalent of the corresponding part of Zwislocki's model of the middle ear. This particular assumption does not appear less reasonable than the remaining assumptions involved in this part of Zwislocki's model.

Malleo-incudal complex and incudo-stapedial joint

The second vertical and the second horizontal branch of Zwislocki's model (Fig. 12) represent the malleus, the incus, and the incudo-stapedial joint. The joint between malleus and incus is assumed to be rigid, so that the combination of these two ossicles acts as one body. This body is suspended by ligaments, supplying resistance and compliance, and is able to rotate about some axis. The long process of incus and the top of stapes are connected in the incudo-stapedial joint that is conceived of as a hinge with a certain resistance and compliance. Finally, the tensor tympani muscle attaches to a point of the malleus, supplying a certain amount of resistance and compliance.

Figure 15 indicates the layout of the various elements described above,

Insert Fig. 15 about here

and Fig. 16 gives a mechanical equivalent in which rotary motions have been

Insert Fig. 16 about here

transformed to translational motions, and in which the mobility of the tensor tympani ($z_{tt}$) and the rotational mobility of malleus-incus ($z_r$) have been combined into a total mobility $z_o$ with the components $M_o$, $r_c$, and $C_o$. In both figures, elements with index s refer to the incudo-stapedial joint, and

$z_c$ denotes the mobility of the top of stapes. The electrical analogy of the mechanical system of Fig. 16 is identical to the second vertical and the second horizontal branch of Zwislocki's model.

Stapedial load

The pertinent mechanico-anatomical information concerning the mobility of the stapes is the following (Zwislocki, 1962). The footplate of stapes is suspended in the oval window by the annular ligaments. These are supposed to be quite compliant at the anterior end of the footplate, and quite stiff at the opposite end. Each section of these ligaments acts as a combination of a resistance and a compliance. Immediately behind the footplate, and before the entrance to the cochlea proper, a column of perilymph is located which acts as a mass. The cochlea itself acts as a resistance, and the terminating round window acts as a combination of a resistance and a compliance.

Figure 17 gives a mechanical equivalent of the system just described.

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Insert Fig. 17 about here

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$M_s$ and $M_p$ denote the mass of the stapes and the mass of the column of perilymph, respectively. $r_c$ indicates the resistance of the cochlea, and elements with indices 'ow' and 'or' represent the component mobilities of the oval and the round window, respectively.

Figure 18a gives the electrical analogy of the mechanical system of

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Insert Fig. 18a about here

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Fig. 17, and Fig. 18b gives a reduced electrical analogy. It will appear

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Insert Fig. 18b about here

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that only by disregarding the mobility of the round window, i.e., by assuming that the mobility of the round window is large compared to the mobility of the annular ligaments of the oval window, is it possible to reduce the electrical analogy to the same form as that of the terminating branch of Zwislocki's model. Such an assumption does not appear unreasonable.

It should be mentioned that the contribution of the stapedius muscle to the mobility of the stapes is not explicitly incorporated in Zwislocki's model. This mobility, however, may be conceived of as acting in parallel with the mobility of the annular ligaments, and thus does not affect the validity of the form of the electrical analogy.

## Analog Approximation

### Input impedance

A digital electronic computer (Digital PDP-4) was programmed to calculate the reactance and the resistance at selected frequencies of Zwislocki's electrical analog of the middle ear shown in Fig. 11. The programming was so arranged that 1) the reactance and the resistance were calculated at the same frequencies as those employed in the measurement of the acoustic impedance at the eardrum; 2) these calculated values were stored in the memory of the computer; 3) after a complete set of values were computed, these values could be read out in the form of corresponding voltages at a given rate; 4) resistance values were read out in the form of proportionate voltages, while reactance could be read out either as a proportionate voltage, or as a voltage proportionate to the logarithm of the reactance. By feeding the read-out voltages to a graphic level recorder (Bruel & Kjaer 2305), fitted with a linear potentiometer, a graphic record of linear reactance, of logarithmic reactance, or of resistance as a function of frequency was obtained. In addition, the attenuation of the network (expressed as the ratio of the input voltage to the voltage appearing across $R_c$, in db) was calculated for each frequency; these values likewise were available for graphical recording. Further, additional programs provided a greater number of frequencies, as well as a typewritten print-out of the calculated values for any specified frequency.

The set of parameter values of the electrical analog given by Zwislocki (1962) was used as a starting point. Each parameter was systematically varied, and plots were made of the corresponding reactance and resistance values. These plots then served as a guide for adjusting the parameters to make the impedance of the analog match the measured acoustic impedance for each S as closely as possible. The degree of agreement between calculated and target values was evaluated by superimposing the obtained graphs of reactance values and resistance values, respectively, on a corresponding graph prepared from the target values. Thus, degree of agreement was assessed independently for reactance and for resistance; as we shall see shortly, this may be said to constitute a limitation of the technique employed. The linear or the logarithmic graphical representation of reactance was employed depending on which section of the reactance graph was concentrated on at a given moment (that is, depending on whether large or small reactance values were at the center of attention).

Even with a fairly high-speed computer, this matching process is a slow one. The total time consumed in calculating and recording reactance and resistance values for a given set of parameters is about five minutes. With 18 different parameters and, in this case, a limited insight on the part of the experimenter into the mechanics of the model, the set of parameter values finally selected as providing the best approximation very likely could be improved upon to quite some extent.

In Table 2, columns 4, 7, and 10 list the final selection of parameter

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Insert Table 2 about here

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values for each of the three Ss. For comparison, column 2 gives Zwislocki's values. In Table 3, the computed values of reactance and resistance for these sets of parameter values are given, together with the target values.

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Insert Table 3 about here

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In attempting visually to assess the degree of agreement between calculated and observed values, two kinds of graphs may be employed. One kind is the one employed during the matching process, i.e., a graph of reactance vs. frequency and a graph of resistance vs. frequency, each graph containing calculated as well as observed values. As mentioned before, this presentation suffers from the limitation that degree of agreement is assessed separately for the two impedance components. The other kind of graphical presentation consists of a plot of resistance vs. reactance, with frequency as parameter. In this latter kind of graph all the available information is displayed in a single graph, and the compound degree of agreement between calculated and observed values may be assessed.

Figures 19 - 21 display calculated and observed impedance components for each S. Observed values are indicated by filled circles, calculated

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Insert Figs. 19 - 21 about here

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values by open circles. Points representing observed and calculated values, respectively, for the same frequency are connected by a broken line, and the frequency in question is given as the parameter.

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In evaluating the calculated impedance components relative to the observed ones, two main questions must be considered. One question is: Can the approximation in question be regarded as satisfactory, and if not, what are the possible causes for the discrepancy? The second question is: Regarding the approximation as satisfactory, to what extent is the set of parameter values unique, that is, could an equally satisfactory approximation be obtained by another set of parameter values?

Concerning the first of these questions we may note two things: 1) The slope of the line connecting points representing observed values is steeper than the line for calculated values for all Ss up to approximately 500 cps. 2) Absolute values, and, in the case of S JR, logarithmic (i.e., relative) values, show a greater discrepancy at the lowest frequencies than at the remaining frequencies. The reason for the latter kind of discrepancy may very well be that changes in acoustic impedance had already taken place for the lowest sound pressure levels at which measurements were possible at the very lowest frequencies, as indicated by the fact that no clear leveling-off of acoustic impedance with decreasing sound pressure level is indicated in Figs. 7 - 9. Therefore, no further explanation of this fact will be attempted. The difference in slope mentioned above may in principle be attributed to any one or more of the following causes: a) poor adjustment of parameters; b) deficiency of the model; c) deficiencies in the measurement of acoustic impedance. The fact that the same kind of deviation between calculated and observed values is observed for all three Ss renders the first possible cause less likely than the remaining two. And since the deviations in question occur in a frequency range for which there is no reason to believe that the acoustic bridge should not function properly, the most likely cause of the observed deviations seems to be a deficiency in the model of the middle ear employed.

This is not a very serious matter, however, since the deviations encountered very likely will suggest to someone with the proper competence what change in the analog should be made.

Accepting, of necessity, our approximations as satisfactory (at least, for the time being), we must consider the second main question: To what extent is each set of parameter values a unique solution? A systematic approach to the answer to this question would consist in changing one parameter value by an amount sufficient to give a significantly poorer approximation, and then attempt to restore the original approximation by appropriately changing the values of the remaining parameters. This process would then be repeated for each of the 18 parameters. However, because of the amount of time required to carry through such a process, this approach is not practically feasible (at present, at least).

A partial insight into the uniqueness of a given solution may be gained by investigating the changes in the two impedance components as a function of frequency for changes in the value of each parameter in isolation. In case isolated changes of the values of each of two parameters produce practically identical changes in the impedance components, the initial set of parameter values is non-unique at least to that extent. In case changes of the value of each parameter in isolation produce clearly distinguishable changes in the impedance components, a higher degree of uniqueness is indicated, but the possibility still remains that the simultaneous change of the values of two or more parameters might produce changes of impedance components practically identical to those caused by changes in the value of a given parameter.

As mentioned earlier, an exploration of the effect of changes in the value of each parameter has already been performed to serve as a guide to the adjustment of parameter values. This exploration was performed with Zwislocki's set of parameter values as a starting point. Since the sets of parameter values adopted for Ss LL and FP are reasonably close to Zwislocki's set of values, the results of the following partial analysis of uniqueness may be applied to these two Ss. In the case of S JR, however, some of the parameter values depart so much from Zwislocki's values that the results of the following analysis cannot be regarded as applicable to this S.

On the basis of their effect on the two impedance components within the frequency range from 20 cps to 1000 cps, the parameters of Zwislocki's middle-ear model may roughly be divided into three classes: 1) those with practically no effect on the impedance components (for a range of variation from 25 per cent to 400 per cent of the original value); 2) those which affect mainly the resistance; and 3) those which affect the resistance as well as the reactance. To the first group belong the following parameters: $L_{d_2}$, $L_c$, $C_t$, $C_{d_2}$, $R_a$, $R_m$, $R_{d_1}$, $R_{d_2}$. Of the "effective" parameters, two inductances ($L_a$ and $L_o$), one capacitance ($C_p$), and three resistances ($R_o$, $R_s$, and $R_c$) belong to the second group, while the third group contains only capacitances ($C_{d_1}$, $C_o$, $C_s$, and $C_c$).

Within the group of parameters that mainly affect the resistance, three different types of variation of resistance are encountered. One is produced by the two inductances $L_a$ and $L_o$ and consists in an increase in resistance with increasing inductance from approximately 300 cps and upwards. Although the increase in resistance peaks at different frequencies for the two inductances, the resulting changes in resistance are hardly discriminable within the frequency range considered. Another kind of variation is produced by $R_o$ and $R_c$, and consists in a change in the general level of the resistance values, at least up to approximately 500 cps. $R_s$ exhibits the same kind of effect for smaller variations; for larger values of $R_s$ the resistance at lower frequencies is more affected. Finally, $C_p$ produces changes in resistance clearly discriminable from the effect of any other parameter in effectively translating the resistance values along the frequency axis. (In addition, $C_p$ affects the reactance from 100 cps and upwards to some extent.)

The concomitant variations in resistance and reactance caused by the parameters belonging to the third group separate into three distinguishable kinds, for all of which changes in reactance are approximately inversely proportional to frequency: 1) level of resistance decreases, and (negative) reactance decreases with an increase of parameter value ($C_{d_1}$); 2) level of resistance increases, and (negative) reactance decreases with an increase of parameter value ($C_o$, $C_c$); 3) resistance increases at a higher rate the lower the frequency, and (negative) reactance decreases with an increase of parameter value ($C_s$).

This analysis thus indicates that for Ss LL and FP, some trade-off is indeed possible between parameters within each of three groups, viz., $L_a$ and $L_o$; $R_o$, $R_c$, and $R_s$; and $C_o$ and $C_c$. In addition, the values of the "ineffective" parameters are highly indeterminate. Two kinds of additional information will be effective in reducing this lack of uniqueness. One kind of information has already been utilized in Zwislocki's selection of parameter values, namely, anatomical considerations. The usefulness of this kind of information, however, is limited by the fact that such information cannot be obtained for the particular individual under consideration, but must be restricted to general statements concerning the population as a whole. The other kind of additional information would be measurements of acoustic impedance at the eardrum for frequencies outside the range now available.

(It may be noted in passing that, since the effect of $L_c$ is negligible, the two last branches of the analog network are completely interchangeable with respect to their effect on the input impedance of the network. With respect to the transfer characteristic of the network, however, no such interchangeability obtains. Thus, in this case the already available anatomical information is essential for assigning the parameter values involved to the proper branches.)

Transfer characteristic

We may now proceed to examine the transfer characteristic of the analog network for each of the three sets of parameter values. This transfer characteristic may be expressed as the input voltage necessary to maintain a constant voltage across the resistor $R_c$, as a function of frequency. In the ear, this corresponds to a plot of the sound pressure level at the ear-drum required to maintain a constant sound pressure across the cochlea, likewise as a function of frequency. Since sound pressure across the cochlea, velocity of the stapes footplate, and acoustic energy dissipated in the cochlea are all proportional due to the purely resistive impedance of the cochlea (Zwislocki 1962), the above-mentioned plot may be conceived of as representing the input required to keep any of these three quantities constant.

Columns 4, 7, and 10 of Table 4 give the voltage attenuations of the

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Insert Table 4 about here

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analog network for our standard series of frequencies for each set of parameter values. These attenuations are shown graphically in Fig. 22. In order to

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Insert Fig. 22 about here

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ascertain the "degree of uniqueness" of these transfer characteristics, the following procedure was undertaken. For each set of parameter values, the range of variation of each parameter was determined for which no significant deterioration occurred of the match between observed and calculated impedances, and the corresponding change in attenuation of the network was computed. The criteria for a significant deterioration of impedance match were made very liberal. In the case of S JR, a change in resistance of ±200 ohms, or a change in reactance of ±1000 ohms or ±50 per cent, were required. In the case of Ss LL and FP, the criteria were ±100 ohms change in resistance, or ±750 ohms or ±50 per cent change in reactance. For each set of parameter values, columns 3, 6, and 9 of Table 2 list the minimum parameter values, and columns 5, 8, and 11 the maximum parameter values meeting these criteria. No attempt was made to determine the corresponding limits for the simultaneous variation of two or more parameters. The corresponding minimum and maximum attenuations for each standard frequency are listed in Table 4, with 320 cps being used as a common point of reference (differences in level of attenuation being of no interest in the present context). A graphical presentation of these values will be given later (Fig. 27).

The effect of the various parameters on the attenuation can briefly be described as follows. In the case of Ss LL and FP, changes in attenuation of 5 db or more are caused by the variations listed in Table 2 of all of the inductances, and by $C_t$, $R_{d_2}$, and $R_s$. All these changes in attenuation take place above 1000 cps. The attenuation at lower frequencies is affected mainly by $C_o$, $C_s$, and $C_c$, but the listed changes in the values of these parameters always cause changes in attenuation of less than 5 db. In the case of S JR, the attenuation was less affected by the listed variations in parameter values. In no case did the change in attenuation exceed 5 db.

The attenuation above 1000 cps was affected mainly by only two inductances, viz., $L_o$ and $L_c$, and by $R_{d_2}$, $R_o$, and $R_s$. At the lower frequencies, the same parameters as mentioned above were effective, i.e., $C_o$, $C_s$, and $C_c$.

## Comparision of Analog Data and Experimental Results

### Limiting equal-loudness contours

One possible conception of the mechanism responsible for the shape of the equal-loudness contours for a given listener is that the 'loudness' of a given tone is determined by the following factors: 1) internal noise which, according to Zwislocki's theory of loudness outlined in Part I of this report, will affect mainly loudnesses associated with tones of low intensities; 2) the conducting properties of the middle ear, which may be regarded as constant for low and medium sound intensities; 3) the effect on the conducting properties of the middle ear at higher and high sound intensities of a) the middle-ear muscles and b) changes in the axis of rotation of the ossicles; 4) the 'loudness-detecting' mechanism at the level of the sensory cells (or higher).

According to this conception, all equal-loudness contours would be parallel to each other at sound intensities sufficiently high to render the inherent noise negligible, were if not for the operation of the middle-ear muscles, and the possible changes of axis of rotation of the ossicles. This, in turn, means that all matching functions would approach a linear asymptote with slope 1. Since the sound pressure levels are known at which changes in acoustic impedance at the eardrum (and thus, presumably, the action of the middle-ear muscles) begin to occur (for frequencies below approximately 1000 cps), we may estimate for each frequency combination the position of this asymptote. From these estimated asymptotes we can derive the shape of the hypothetical equal-loudness contour that would obtain if the effect of the middle-ear muscles and of the possible changes in axis of rotation of the ossicles did not occur. Thus, this hypothetical equal-loudness contour, which will be called a "limiting contour," should reflect the 'static' sound conducting properties of the middle ear (assuming the 'loudness-detecting' mechanism at the sensory level to remain constant).

In order to estimate the position of the above-mentioned asymptotes, the average loudness matches given in Tables 2 - 4 of Part I of this report are plotted relative to the matches for 320 cps. (Since these matches represent symmetric and transitive sets, the choice of reference frequency is of no consequence.) These plots are shown in Figs. 23 - 25. The positions of the

Insert Figs. 23 - 25 about here

estimated asymptotes, arbitrarily referred to 60 db SPL at 320 cps, appear in Table 5, columns 2, 5, and 8. The resulting limiting contours, being a plot

Insert Table 5 about here

of these position values as a function of frequency, are shown in Fig. 26.

Insert Fig. 26 about here

Relation between limiting contours and attenuation of analog network

As mentioned earlier, the plot of voltage attenuation of the analog network as a function of frequency (Fig. 22) may be regarded as corresponding to a plot of the sound pressure levels required at the eardrum to maintain a constant velocity of the stapes footplate and, thus, a constant volume velocity of the cochlear fluid. In other words, this plot provides a means of converting a given sound pressure level at the eardrum at a given frequency into a relative value of the corresponding volume velocity of the cochlear fluid,-- assuming, of course, that the model represented by the analog network is applicable. Thus, by subtracting the number of decibels representing the voltage attenuation of the network from the db-level of the limiting equal-loudness contour at each frequency, we obtain a plot o nypothetical relative values of volume velocity of cochlear fluid under the limiting condition of equal-loudness. These values appear in Table 5 and are plotted in Fig. 27 together with the maximum range of variation derived from the

Insert Fig. 27 about here

minimum and maximum attenuation values given in Table 4.

According to Zwislocki (1965), a variable more relevant than the volume velocity of the cochlear fluid is the maximum displacement amplitude of the cochlear partition. In order to convert the volume velocity of the cochlear fluid to maximum displacement amplitude of the cochlear partition, the following steps are performed: 1) Volume velocity of cochlear fluid is directly proportional to velocity of stapes footplate. 2) Velocity of stapes footplate (in db) is converted to displacement of stapes footplate (in relative db) by subtracting 20 db/decade from velocity values. 3) Displacement of stapes footplate (in db) is converted to maximum amplitude of volume displacement of cochlear partition (in relative db) by adding 12 db/decade to displacement values (Zwislocki, 1965). 4) Maximum amplitude of volume displacement of cochlear partition (in db) is converted to maximum displacement amplitude of cochlear partition (in relative db) by adding 6 db/decade to volume displacement values in the frequency range from 100 cps and upwards (Zwislocki, 1965). I ombination, these four steps amount to subtracting 2 db/decade above 100 cps from the volume velocity values of Fig. 27. Because of the irregular appearance of the plots of Fig. 27, this correction of values has not actually been performed. Roughly, the plots of Fig. 27 may be taken to represent the relative values of maximum displacement of the cochlear partition for the condition of limiting equal-loudness.

One possible interpretation of Fig. 27 is that the maximum displacement of the cochlear partition is constant above approximately 200 cps for equally-loud tones of sufficient intensity. The increase in displacement necessary to maintain equal-loudness at the lower frequencies may be explained under reference to the diminishing innervation density of the cochlear partition near the helicotrema. The rather large variations exhibited at the high frequencies in Fig. 27, which clearly exceed the range of variation accountable for by isolated variation of individual parameters, may be disregarded under reference to the fact that the choice of parameter values is based on measurements of acoustic impedance at frequencies below that frequency range in which these large variations occur. Finally, the fact that the curves for all three Ss show a somewhat correlated variation with frequency for the medium frequencies may be attributed to the fact that the obtained impedance match between model and real-ear was less than satisfactory in this frequency range, indicating that an appropriate revision of the analog network might lead to more clear-cut results in this frequency range. What remains after this three-fold discounting of the data is the observation that between approximately 200 cps and 1250 cps, the maximum displacement of the cochlear partition shows no obvious and systematic variation with frequency. This observation lends some support to the hypothesis that the "equal-loudness-detecting" mechanism, at least for medium and high sound intensities, is based on the detection of equal maximum displacement amplitudes of the cochlear partition.

Variability of acoustic impedance at eardrum

As mentioned earlier, and as illustrated in Figs. 5 and 6, the measures of acoustic impedance at the eardrum exhibit systematic deviations from one series of determinations to the next. We shall now consider two possible explanations of this phenomenon, both of which may be tested by means of the analog network.

The first possibility for explaining the obtained level differences in the measures of equivalent volume and of resistance is to assume that varying pressure differences across the eardrum exist at different times. Such pressure differences have been shown to affect the impedance at the eardrum (Thomsen, 1958; Terkildsen & Thomsen, 1959). This explanation is supported by the following observations. One S (LL) swallowed quite frequently during the impedance determinations. It was noted that if a null of the bridge had been attained just prior to the S's swallowing, this event would completely destroy the null. Further, the level differences in equivalent volume and resistance measures were on the whole considerably smaller for this S (LL) than for the two other Ss who swallowed only very infrequently. (This comparison, however, is rendered a little questionable by the fact that only two series of determinations are available for S LL, compared to four series for the other two Ss.)

Previous investigations of the relation between pressure difference across the eardrum and the impedance at the eardrum by Thomsen (1958) and Terkildsen & Thomsen (1959) unfortunately contain no information regarding the normal range of sporadic pressure differences across the eardrum. Thus, it is not possible to test the assumption advanced here against these authors' data. In any case, however, a reasonable precaution in future experimentation of this nature would be to make the S swallow (by sipping liquid through a flexible tube) just prior to each impedance determination; thereby, presumably, a pressure difference close to zero across the eardrum would obtain at each determination.

Accepting for the moment that pressure differences across the eardrum are responsible for the observed differences in acoustic impedance at the eardrum, the question arises as to what specific mechanism is involved in this process. Two general avenues of explanation offer themselves. One would assume that a given static pressure difference across the eardrum would cause a displacement of one or more components so that some of the compliances (and, possibly, resistances) involved in the middle-ear system were altered. This approach is unsatisfactory because such changes in compliance would occur only for rather large displacements, i.e., for displacements of a magnitude sufficient to exceed the range of applicability of Hooke's law. Thus, the continuity of change in impedance with changes in pressure across the eardrum as observed by the above-mentioned investigators would not be accounted for. In addition, when tested on the analog network as described in the following, it did not appear possible to produce changes of input impedance of the network of the same kind as those observed at the eardrum by manipulating the appropriate compliances (and resistances) of the network.

The other possible mechanism by which pressure differences across the eardrum might cause changes in the impedance at the eardrum assumes that such a static pressure difference displaces the eardrum which, in turn, displaces the malleo-incudal complex in such a way as to alter the axis of rotation of this complex. This, again, would mean that the lever-ratio of this complex would vary with varying dc-pressures across the eardrum.

This latter hypothesis may be tested by means of the analog networks described earlier. A change in the lever-ratio of the malleo-incudal complex corresponds in the model to a change in the input/output ratio of the transformer representing this lever. In the transformer-less circuit actually employed, a change in lever-ratio is represented by a change in the impedance of each component following the components representing that lever. Specifically, these impedances will vary with the square of the lever-ratio.

By varying the values of those parameters associated with the incudo-stapedial joint and the cochlea (that is, those located after the malleo-incudal complex) in such a way that all inductances and all resistances, involved are multiplied by a constant, and all capacitances involved are multiplied by the reciprocal of this constant, the effect of a varying transformer ratio on the input impedance may be computed.

The following analysis will be restricted to the data of Ss JR and FP, for each of which four series of determinations of acoustic impedance are available. Figs. 28 and 29 show for each S the average initial impedance

Insert Figs. 28 - 29 about here

values for each series of determinations, represented as individual points. The full lines represent, for each frequency involved, the change in impedance of the corresponding analog network when the relevant impedances of the network are multiplied by a constant assuming values from .67 to 1.5. Arrows on these lines indicate the direction of the change in impedance for increasing values of this multiplier.

When the axis of rotation of the malleo-incudal complex is changed, not only does the lever-ratio of this complex change, but the effective rotational mass of the complex changes as well. This latter change, however, is not necessarily related to the former change in any simple way because the change in rotational mass will depend on the geometrical distribution of masses within the complex. To get an idea of the effect of this change in rotational mass, however, we will assume it to be proportional to the changes in the impedances that follow, that is, proportional to the square root of the lever-ratio. The changes in input impedance, when changes in rotational mass of the malleo-incudal complex are taken into account as explained, are represented in Figs. 28 and 29 by broken lines. An evaluation of these results will be given later.

As mentioned in the beginning of this section, another possibility exists for explaining the observed differences in acoustic impedance at the eardrum. This other possibility consists in assuming that the volume of air enclosed between the eardrum and the acoustic bridge cannot be maintained absolutely constant from one series of determinations to the next, despite the precautions described earlier. By means of the analog networks the effect of variations of this volume of air on the acoustic impedance can be calculated in the following way.

In an electrical analogy, a volume of air in front of the eardrum is represented by a capacitor connected in parallel with the network representing the middle ear. We therefore want to construct a network with a capacitor representing the average volume of air enclosed between eardrum and bridge connected across the input terminals, and with the same input impedance as the original analog network. By varying the value of the capacitor across the input, the effect on the input impedance of corresponding changes of the volume of air may be computed. This task may be accomplished as follows. From the previous calculations the input impedance of the original network is known in terms of a resistance and a reactance for a given frequency. For this frequency, then, the input impedance of the network is indentical to that of a series combination of a resistance and a reactance of these values. We now construct a network consisting of a capacitor in parallel with a series combination of a resistance and a reactance, so that the capacitor has a value corresponding to the average volume of air enclosed for the given S, and in which the values of the resistance and the reactance are so chosen that the input impedance of this network is identical to the input impedance of the original network, at the given frequency. By changing the value of the parallel capacitor of this latter network by a predetermined amount, the effect on the input impedance of a corresponding change in the volume of air can be computed.

Figures 30 and 31 depict the result of these computations for Ss JR and

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Insert Figs. 30 - 31 about here

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FP, for a variation of ±10 per cent of the average of the measured volumes of air enclosed between eardrum and acoustic bridge. Lines connect the computed impedance values, with arrows indicating direction of change of impedance for -10 per cent, 0 per cent, and +10 per cent variation.

In comparing the predicted variations in input impedance based on the two kinds of mechanism suggested (Figs. 28 - 31), first of all the similarity of predictions is noted. A closer evaluation of the relative merits of the suggested mechanisms may be based on 1) the extent to which the predicted relative range of variation corresponds to the range observed; and 2) the extent to which the direction of predicted change corresponds to the observed direction. On the first count, the 'volume mechanism' gives poorer results for S JR than the other mechanism, while both mechanisms give comparable results for S FP. On the second count, the 'volume mechanism' seems slightly superior to the 'lever mechanism' for both Ss. In conclusion, we may say that on the basis of the present data it is not possible to choose one suggested mechanism for the other. It may be said, however, that if the 'lever mechanism' is to be assumed, results are somewhat better if a concurrent change in moment of inertia of the malleo-incudal complex is assumed. Also, the fact that pressure differences across the eardrum are known to produce changes in accoustic impedance at the eardrum would indicate that the 'lever mechanism' should not be completely ruled out. Possibly both mechanisms should be conceived of as operating simultaneously.

The changes in network attenuation associated with the changes in lever ratio employed ($\pm 1:\sqrt{1.5} = \pm 1:1.22$) were found to be quite small, being in the order of 1-3 db in the frequency range from 20 cps to 1250 cps. Corresponding changes in attenuation for variations in volume of air were not computed.

## Discussion and Comments

### Anatomical interpretation of each set of parameter values

In attempting to give an anatomical interpretation of each of the three sets of parameter values for the analog network arrived at earlier, we may limit ourselves to consider those parameters for which the permissible range of variation, as given in Table 2, excludes the 'normal' value given by Zwislocki (column 2 of Table 2). (The following interpretations, of course, are subject to the limitation imposed by the fact that the validity of the parameter values, as indeed the validity of the analog network itself, have not been clearly established.)

For Ss LL and FP, the only two parameters exhibiting the above condition are $C_o$ and $C_c$. The lower capacitive value found for $C_o$ would indicate that the compliance of the suspension of the malleo-incudal complex for both of these Ss were smaller than the 'normal' compliance assumed by Zwislocki. Contrarily, the higher capacitive values found for $C_c$ would indicate a higher compliance than 'normal' of the annular ligaments of the oval window.

Since compliances, as well as resistances, of the various flexible elements of the middle ear may well be assumed to be subject to rather large individual variation, these deviating compliance values do not seem disturbing.

More radical departures from the 'normal' pattern are found in the case of S JR. In the area of the eardrum, a very small value is found for the compliance $C_{d_1}$ that represents the coupling between the malleus and that section of the eardrum closest to the malleus. A possible interpretation of this finding might be that this particular eardrum is thicker, or otherwise different in structure, than a 'normal' eardrum; (the fact that the value of $C_{d_2}$, corresponding to the compliance of the remainder of the eardrum, may assume values down to zero without significantly altering the input impedance of the network, keeps this possibility open). It is conceivable that a direct otological examination of the eardrum in question might supply relevant information concerning this interpretation.

Of the five parameters associated with the tympanic cavities (i.e., $L_a$, $C_p$, $C_t$, $R_a$, and $R_m$), two ($C_p$ and $R_m$) show ranges of variation that exclude the 'normal' values, and a third ($R_a$) deviates strongly in absolute value. The considerably smaller value of $C_p$ found for S JR might mean, either that the volumes of the antrum and/or of the pneumatic cells are considerably smaller than normal, or that the passage from antrum to pneumatic cells is obstructed. This latter notion may gain support from the fact that the two resistances involved, $R_a$ and $R_m$, both take on quite high values, indicating the possibility of the presence of an abnormal amount of mucous secretions on the walls of this part of the middle ear.

As far as the malleo-incudal complex of S JR is concerned, a lower value than 'normal' is found for the compliance of the supporting ligaments, as was the case for the other two Ss. Further, a large increase of the moment of inertia (i.e., rotational mass) is found. This latter fact may be attributed to a larger than 'normal' mass of the malleo-incudal complex, and/or to the axis of rotation of this complex being displaced from a line passing through the center of gravity of this complex. Of these two possible causes, the latter may be considered the more likely. (The moment of inertia of a circular disk around an axis parallel to the axis of symmetry triples when this axis is displaced from passing through the center of gravity to passing through a point on the periphery of the disk.)

The values for S JR of the parameters associated with the remaining parts of the middle ear, i.e., the incudo-stapedial joint and the cochlear complex, are very close to the 'normal' values.

Absolute thresholds and temporal summation

Zwislocki (1965) derives a theoretical absolute threshold curve utilizing a number of assumptions. All of these except one were employed in the present study in deriving the relationship between maximum displacement amplitude of the cochlear partition and frequency under the limiting condition of equal-loudness. The remaining assumption employed by Zwislocki in deriving the absolute threshold curve is that due to temporal summation, the maximum displacement amplitude of the cochlear partition at threshold decreases by 10 db/decade for frequencies above 100 cps. Utilizing this additional assumption, the absolute thresholds for the three Ss, as given in Tables 2 - 4 in Part I of this report, were converted to relative maximum displacement corrected for the effect of temporal summation (omitting, as before, a correction of -2 db/decade). These values are plotted in Fig. 32. In spite of some

---

Insert Fig. 32 about here

---

rather large variations, the plotted curves may be taken as an indication that absolute threshold above approximately 200 cps is in fact reached at a given maximum displacement amplitude corrected for temporal summation.

Inspection of the matching functions for Ss JR and FP (Figs. 23 and 25) reveals that these functions seem to reach their asymptotic level at a point practically independent of frequency for frequencies above 100 cps. For S JR this point corresponds to about 70 db SPL at 320 cps, and for S FP to about 50 db SPL at 320 cps. Both of these points are well below the level of onset of impedance changes. This observation, together with the above-mentioned assumption, leads to formulating the following hypothesis: Temporal summation decreases with increasing displacement amplitude of the cochlear partition, and becomes ineffective when a given maximum displacement amplitude is reached, this amplitude being independent of frequency at least for frequencies above 100 cps. This variation in the effect of temporal summation may either substitute, or it may complement, the mechanism utilizing the concept of 'internal noise' in the theory of loudness due to Zwislocki described in Part I of this report.

Resistance of analog network at low frequencies

The curves given by Zwislocki (1962, 1965) for the resistive component of the input impedance of his analog network indicate that this component is roughly constant from 1500 cps and down to at least 100 cps. The circumstance that measurements of the acoustic impedance at the eardrum show the resistive component of this impedance to increase somewhat with decreasing frequency leads Zwislocki to comment: "Empirical observations indicate that the slightly increased resistance at low frequencies is probably due to an artifact in measurements [of acoustic impedance]" (1965, p. 42).

Calculations of the resistive component of the input impedance of the analog network, using Zwislocki's set of parameter values, however, show a definite increase of this component with decreasing frequency. For our standard series of frequencies below 1500 cps (i.e., 1250, 800, 500, 320, 200, 125, 80, 50, 32, and 20 cps), the following values of the resistance was found: 303, 318, 302, 309, 341, 402, 485, 575, 637, and 672 ohms. Thus, the artifact responsible for the above-mentioned divergence may be associated with the technique employed by Zwislocki for the measurement of the electrical impedance of his analog network, rather than with the measurements of acoustic impedance at the eardrum.

Control of volume of air in acoustic impedance measurements

The calculated changes in acoustic impedance at the eardrum as a function of changes in the volume of air enclosed between the eardrum and the acoustic bridge depicted in Figs. 30 and 31 clearly illustrate the importance of an accurate determination of this volume, as well as the importance of maintaining this volume constant, for obtaining accurate (relative or absolute) measures of acoustic impedance. In the case of S FP, the more 'normal' of the two Ss considered, variations of reactance with varying enclosed volume of air increases with decreasing frequency; at 500 cps the effect is slight, while at 50 cps the relative changes in reactance about equals the relative changes in enclosed volume. Relative changes in resistance for this S are practically independent of frequency, amounting to about 1.5 times the relative changes in volume. For S JR, relative changes of both reactance and resistance with varying enclosed volume of air are practically independent of frequency. Reactance changes in about the same proportion as does the enclosed volume, while resistance changes at about twice the rate of this volume.

## Acknowledgements

The measurements of acoustic impedance were performed with an acoustic bridge provided on loan by the Grason-Stadler Co. The program for the computation of impedance and attenuation of the analog network was written by Sally Ginet, and the program for computing the effect of changing volumes of air was written by David Vander Yacht. All these services are gratefully acknowledged.

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Table 1

| f | JR | | LL | | FP | |
|---|---|---|---|---|---|---|
| | X | R | X | R | X | R |
| cps | ohms | ohms | ohms | ohms | ohms | ohms |
| 20 | -12000 | 2700 | -6300 | 1090 | -6200 | 1050 |
| 32 | -11000 | 2300 | -4800 | 880 | -4300 | 880 |
| 50 | -9100 | 1600 | -3200 | 780 | -3500 | 780 |
| 80 | -6800 | 1400 | -2550 | 555 | -3050 | 640 |
| 125 | -4600 | 1000 | -1720 | 450 | -1540 | 395 |
| 200 | -3350 | 820 | -1190 | 330 | -1150 | 360 |
| 320 | -2300 | 710 | -850 | 252 | -850 | 340 |
| 500 | -1350 | 510 | -425 | 242 | -575 | 338 |
| 800 | -415 | 680 | -215 | 250 | -370 | 365 |
| 1250 | - | - | - | - | -145 | 290 |

Initial levels of acoustic impedance at the eardrum (for low sound pressure levels) as a function of frequency, as estimated from Figs. 7 - 9.

Table 2

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zw. | | JR | | | LL | | | FP | |
| | | min. | | max. | min. | | max. | min. | | max. |
| $L_a$ | 14 | 0 | 14 | 400 | 10 | 30 | 45 | 0 | 20 | 45 |
| $L_{d2}$ | 15 | 0 | 5 | 100 | 0 | 15 | 45 | 0 | 15 | 35 |
| $L_o$ | 40 | 75 | 140 | 190 | 0 | 25 | 75 | 25 | 90 | 150 |
| $L_c$ | 20 | 0 | 20 | 100 | 0 | 40 | 100 | 0 | 40 | 100 |
| $C_p$ | 5.1 | .40 | .60 | .95 | 2.8 | 3.8 | 6.0 | 3.0 | 4.0 | 5.5 |
| $C_t$ | .35 | .25 | .45 | .70 | 0 | .35 | 1.2 | 0 | .35 | 2.0 |
| $C_{d1}$ | .23 | .035 | .08 | .14 | .20 | .28 | .40 | .23 | .28 | .35 |
| $C_{d2}$ | .40 | 0 | .40 | 100 | 0 | .40 | 100 | 0 | .40 | 100 |
| $C_o$ | 1.4 | .30 | .40 | .60 | .40 | .70 | 1.3 | .50 | .70 | 1.1 |
| $C_s$ | .25 | 0 | .25 | .50 | 0 | .25 | ∞ | 0 | .25 | ∞ |
| $C_c$ | .60 | .21 | .40 | 1.2 | .70 | 2.4 | ∞ | 1.0 | 2.4 | 9.0 |
| $R_a$ | 10 | 0 | 700 | 3500 | 0 | 10 | 100 | 0 | 110 | 125 |
| $R_m$ | 390 | 1000 | 2000 | 5500 | 100 | 850 | 2200 | 300 | 700 | 1800 |
| $R_{d1}$ | 40 | 0 | 40 | 3500 | 0 | 40 | 400 | 0 | 40 | 350 |
| $R_{d2}$ | 220 | 0 | 220 | ∞ | 0 | 220 | ∞ | 0 | 220 | ∞ |
| $R_o$ | 70 | 0 | 70 | 350 | 0 | 140 | 375 | 0 | 140 | 350 |
| $R_s$ | 3000 | 500 | 3000 | 6000 | 100 | 2000 | ∞ | 400 | 2000 | ∞ |
| $R_c$ | 600 | 300 | 600 | 1000 | 450 | 750 | 1050 | 600 | 900 | 1200 |

Final selection of parameter values of the analog network for Ss JR, LL, and FP (columns 4, 7 and 11). Zwislocki's (1962) parameter values are given for comparison in column 2. The remaining columns list the minimum and maximum parameter values (when the value of the parameter in question is varied in isolation) giving an acceptable match between calculated and observed impedances, according to the criteria described in the text. Inductances are given in millihenries, capacitances in microfarads, and resistances in ohms. The values of $R_a$ and $R_m$ in column 2 are not explicitly stated by Zwislocki (1962), but were estimated from his Fig. 3.

Table 3

| f cps | JR X Ohms | | JR R Ohms | | LL X Ohms | | LL R Ohms | | FP X Ohms | | FP R Ohms | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Actual | Analog | Actual | Analog | Actual | Analog | Actual | Analog | Actual | Analog | Actual | Analog |
| 20 | -12000 | -24774 | 2700 | 2283 | -6300 | -9864 | 1090 | 1054 | -6200 | -9784 | 1050 | 1009 |
| 32 | -11000 | -15869 | 2300 | 2100 | -4800 | -6373 | 880 | 908 | -4300 | -6285 | 880 | 906 |
| 50 | -9100 | -10567 | 1600 | 1796 | -3200 | -4249 | 780 | 721 | -3500 | -4177 | 780 | 760 |
| 80 | -6800 | -6952 | 1400 | 1385 | -2550 | -2760 | 555 | 541 | -3050 | -2720 | 640 | 600 |
| 125 | -4600 | -4633 | 1000 | 1040 | -1720 | -1810 | 450 | 429 | -1540 | -1791 | 395 | 488 |
| 200 | -3350 | -2963 | 820 | 803 | -1190 | -1147 | 330 | 363 | -1150 | -1138 | 360 | 419 |
| 320 | -2300 | -1838 | 710 | 675 | -850 | -715 | 252 | 327 | -850 | -710 | 340 | 388 |
| 500 | -1350 | -1091 | 510 | 625 | -425 | -440 | 242 | 308 | -575 | -449 | 338 | 390 |
| 800 | -415 | -460 | 680 | 679 | -215 | -221 | 250 | 289 | -370 | -324 | 365 | 385 |
| 1250 | - | +131 | - | 1302 | - | +94 | - | 375 | -145 | -123 | 290 | 247 |
| 2000 | - | -1690 | - | 826 | - | -432 | - | 488 | - | -89 | - | 821 |
| 3200 | - | -718 | - | 172 | - | -195 | - | 300 | - | -239 | - | 358 |
| 5000 | - | -358 | - | 168 | - | -126 | - | 280 | - | -153 | - | 301 |

Observed acoustic impedances, and impedances computed on the basis of the parameter values of Table 2, for each S.

Table 4

| f | Zw | JR | | | LL | | | FP | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | min | | max | min | | max | min | | max |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 20 | 31 | 38 | 39 | 40 | 24.5 | 27 | 31 | 23 | 25 | 30 |
| 32 | 27 | 33.5 | 35 | 36.5 | 21 | 23 | 25 | 20 | 21.5 | 24 |
| 50 | 23.5 | 30 | 31.5 | 33 | 17.5 | 19.5 | 21.5 | 16.5 | 18 | 19.5 |
| 80 | 19.5 | 26.5 | 28 | 29.5 | 14 | 16 | 18 | 13 | 14.5 | 16 |
| 125 | 16 | 23 | 24 | 25 | 11 | 12.5 | 14 | 10 | 11 | 12 |
| 200 | 11.5 | 19 | 19.5 | 20 | 8 | 9 | 10 | 7.5 | 8 | 8.5 |
| 320 | 7.5 | 15 | 15 | 15 | 6 | 6 | 6 | 4.5 | 4.5 | 4.5 |
| 500 | 4 | 9.5 | 10.5 | 11.5 | 2 | 3 | 4 | 2 | 2.5 | 3 |
| 800 | 1 | 2.5 | 5 | 7.5 | 0 | 1 | 2.5 | .5 | 1.5 | 3 |
| 1250 | 1 | 1 | 5.5 | 8.5 | .5 | 5 | 12 | .5 | 2 | 10 |
| 2000 | 10 | 6 | 11.5 | 14.5 | 5 | 14.5 | 19 | 8 | 19 | 25 |
| 3200 | 11.5 | 11.5 | 17 | 21 | 5 | 9.5 | 18 | 9 | 14.5 | 20.5 |
| 5000 | 12.5 | 16 | 21 | 24.5 | 6 | 11 | 19.5 | 10 | 16.5 | 23 |

Voltage attenuations in db (rounded to nearest multiple of .5 db) as a function of frequency for analog network for each set of parameter values (columns 4, 7, and 10). Attenuations for Zwislocki's set of parameter values are given for comparison (column 2). Attenuations corresponding to minimum and maximum values of individual parameters, as given in Table 2, appear in the remaining columns, and are normalized with respect to the attenuation at 320 cps.

Table 5

| | JR | | | LL | | | FP | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| f | Limiting contour | Network att. | Vol. vel. for lim. contour | Limiting contour | Network att. | Vol. vel. for lim. contour | Limiting contour | Network att. | Vol. vel. for lim. contour |
| cps | db | db | db | db | db | db | db | db | db |
| 20 | - | 39 | - | - | 27 | - | - | 25 | - |
| 32 | 97 | 35 | 62 | - | 23 | - | - | 21.5 | - |
| 50 | 88 | 31.5 | 56.5 | 90 | 19.5 | 70.5 | 83 | 18 | 65 |
| 80 | 83 | 28 | 55 | 81 | 16 | 65 | 79 | 14.5 | 64.5 |
| 125 | 73.5 | 24 | 49.5 | 71.5 | 12.5 | 59 | 72.5 | 11 | 61.5 |
| 200 | 68 | 19.5 | 48.5 | 65 | 9 | 56 | 64.5 | 8 | 56.5 |
| 320 | 60 | 15 | 45 | 60 | 6 | 54 | 60 | 4.5 | 55.5 |
| 500 | 58.5 | 10.5 | 48 | 63.5 | 3 | 60.5 | 61.5 | 2.5 | 59 |
| 800 | 57 | 5 | 52 | 57.5 | 1 | 56.5 | 63 | 1.5 | 61.5 |
| 1250 | 51 | 5.5 | 45.5 | 65.5 | 5 | 60.5 | 62.5 | 2 | 60.5 |
| 2000 | 59.5 | 11.5 | 48 | 66.5 | 14.5 | 52 | 68.5 | 19 | 49.5 |
| 3200 | 66.5 | 17 | 49.5 | 79 | 9.5 | 69.5 | 79 | 14.5 | 64.5 |
| 5000 | 53.5 | 21 | 32.5 | 81 | 11 | 70 | 60 | 16.5 | 43.5 |

1) Positions of linear asymptotes with slope 1 for each set of matching functions appearing in Figs. 23 - 25 (for sound pressure levels causing no change in acoustic impedance at the eardrum) arbitrarily referred to 60 db SPL at 320 cps; each set of these values defines a corresponding 'limiting equal-loudness contour' (columns 2, 5, and 8). 2) Voltage attenuations in db as a function of frequency for analog network for each set of parameter values (columns 3, 6, and 9; replicated from Table 4, columns 4, 7, and 10). And 3) hypothetical relative values in db for each S of the volume velocity of the cochlear fluid as a function of frequency under the limiting condition of equal-loudness, derived as the difference between the db-value of the limiting contour and the network attenuation at each frequency.

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## Figure Captions

Fig. 1. Experimental set-up for the measurement of acoustic impedance at the eardrum. A driver unit, suspended by strings from the ceiling, is connected to the Y-tube of the bridge by means of a rubber tube. The bridge is exerting its own weight on the ear of the S who is resting on a cot.

Fig. 2. Set-up for the measurement of volume enclosed between eardrum and acoustic bridge. With the S positioned on a cot, the speculum is inserted in his meatus, and one end of a bar, suspended at its other end, is placed in contact with the free end of the speculum. The length of this bar is adjusted so as to exert a downward force on the speculum equal to the weight of the acoustic bridge. The electrode of the speculum insert connects via a clip-lead to the bar, from the other end of which another wire leads to the ohmmeter set-up described in the text.

Fig. 3. Speculum fitted with plastic collar, and insert for speculum moulded from resin glue. The insert is fitted with a piece of 1 mm dia. steel tubing, and with a piece of wire serving as an electrode.

Fig. 4. Arrangement for determining the sound pressure level generated at the eardrum during measurements of acoustic impedance. The acoustic bridge is terminated by a variable acoustic impedance consisting of a syringe containing various amounts of cotton. A probe microphone inserted in front of the tip of the bridge measures the acoustic output of the bridge when a null has been obtained by means of the variable impedance for given settings of the bridge.

Fig. 5. Acoustic impedance at the eardrum as a function of the sound pressure level of the stimulating tone as determined in four series of measurements. Parameter is chronological order of series. Data for S JR at 500 cps.

Fig. 6. As Fig. 5, data for S FP at 200 cps.

Fig. 7. Average acoustic impedance at the eardrum as a function of the sound pressure level of the stimulating tone, with frequency of stimulating tone as parameter. Logarithmic ordinates are used for better separation. A broken line between two points indicates that, for one or both of these determinations, only a broad null could be obtained; this situation was usually encountered at the lowest sound pressure levels. Data for S JR.

Fig. 8. As Fig. 7, data for S LL.

Fig. 9. As Fig. 7, data for S FP.

Fig. 10. Initial levels of acoustic impedance at the eardrum (for low sound pressure levels) as a function of the frequency of the stimulating tone for each S. Logarithmic ordinates.

Fig. 11. Zwislocki's (1962) impedance analogy of the middle ear. Subscripts a, p, m, and t refer to the middle-ear cavities; $d_1$ and $d_2$ to the eardrum; and o, s, and c to the malleo-incudal complex, the incudo-stapedial joint, and the cochlear complex, respectively.

Fig. 12. Mobility version of Zwislocki's analogy of the middle ear. Subscripts as for Fig. 11.

Fig. 13. Mechanico-acoustical equivalent of the middle-ear cavities, according to Zwislocki's analogy.

Fig. 14. Mechanical equivalent of the eardrum, according to Zwislocki's analogy. See text (p. 14) for description.

Fig. 15. Schematic representation of the elements involved in the malleo-incudal complex and the incudo-stapedial joint. $z_r$ and $z_s$ denote the rotational mobilities of malleus-incus and of the incudo-stapedial joint, respectively, and $z_{tt}$ and $z_c$ denote the mobilities of the tensor tympani and of the top of stapes, respectively.

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Fig. 16. Mechanical equivalent of the system depicted in Fig. 15. Rotational movements have been converted to translational movements, and the mobilities of tensor tympani and of malleus-incus have been combined to a single mobility with the components $M_o$, $r_o$, and $C_o$.

Fig. 17. Mechanical equivalent of stapedial load. $C'_{ow}$, $r'_{ow}$, and $C''_{ow}$, $r''_{ow}$ represent the component mobilities of the anterior and the posterior end, respectively, of the annular ligaments of the oval window. $C_{rw}$ and $r_{rw}$ denote the component mobilities of the round window, $M_s$ and $M_p$ denote the masses of stapes and the column of perilymph, respectively, and $r_c$ denotes the (resistive) mobility of cochlea.

Fig. 18. (a) Complete electrical analogy of the mechanical system of Fig. 17, with corresponding subscripts. (b) Reduced electrical analogy of the mechanical system of Fig. 17. Compliances and resistances of anterior and posterior ends of annular ligaments have been combined, and the masses of stapes and the column of perilymph have been combined to a single mass, $M_c$.

Fig. 19. Resistance vs. reactance with frequency as parameter for observed and for calculated impedances. Points representing observed and calculated impedances, respectively, for a given frequency are joined by a broken line. Logarithmic coordinates. Data for S JR.

Fig. 20. As Fig. 19, data for S LL.

Fig. 21. As Fig. 19, data for S FP.

Fig. 22. Voltage attenuation (i.e., ratio of input voltage to voltage across $R_c$) of analog network as a function of frequency, for each set of parameter values.

Fig. 23. Average loudness matches plotted relative to the matches for 320 cps. (Points within a circle indicate 'threshold matches') From this

graph, the position of a linear asymptote with slope 1 is estimated for each matching function utilizing only matches at sound pressure levels causing no change of acoustic impedance at the eardrum. Data for S JR, from Table 2 in Part I of this report.

Fig. 24. As Fig. 23, data for S LL, from Table 3 in Part I of this report.

Fig. 25. As Fig. 23, data for S FP, from Table 4 in Part I of this report.

Fig. 26. Limiting equal-loudness contours for each S, i.e., any equal-loudness contour that supposedly would be obtained at higher and high sound intensities if changes in transfer characteristic of the middle ear did not occur. Based on estimates of linear asymptote with slope 1 for the matching functions for each S as given in Figs. 23 - 25.

Fig. 27. Hypothetical relative volume velocity in db of cochlear fluid for each S as a function of frequency under the limiting condition of equal-loudness. By subtracting 2 db/decade from the plotted values, ~~the plotted~~ curves may be taken to represent relative values (in db) of the maximum displacement amplitude of the cochlear partition under the same condition (for frequencies above 100 cps). Vertical lines connect points representing the maximum and minimum values corresponding to isolated variation of individual parameter values according to Table 2. Plotted points for S FP have been displaced by 10 db for better separation.

Fig. 28. Average initial acoustic impedance for each series of determinations plotted as resistance vs. reactance, with frequency as parameter (individual points). Dots connected by full lines represent the input impedance of the analog network when the relative lever-ratio of the malleo-incudal complex assumes values of $\sqrt{.67}$, 1, and $\sqrt{1.5}$, with arrows indicating the direction of impedance change for increasing values of this lever-ratio. Dots connected

by broken lines represent the input impedance of the analog network when changes in lever-ratio of the malleo-incudal complex are assumed to be accompanied by changes in the rotational mass of this complex. Logarithmic coordinates. Data for S JR.

Fig. 29. As Fig. 28, data for S FP.

Fig. 30. Average initial acoustic impedance for each series of determinations plotted as resistance vs. reactance, with frequency as parameter (individual points). Dots connected by lines represent the input impedance of the analog network when the capacitance representing the volume of air enclosed between eardrum and acoustic bridge is changed by amounts of -10 per cent, 0 per cent, and + 10 per cent relative to its average measured value. Arrows on these lines indicate direction of impedance change for increasing volumes of air. Logarithmic coordinates. Data for S JR.

Fig. 31. As Fig. 30, data for S FP.

Fig. 32. Hypothetical relative volume velocity in db plus 10 db/decade at absolute threshold as a function of frequency, for each of three Ss. Above 100 cps, these values may be taken to represent relative values (in db) of maximum displacement amplitude of cochlear partition at absolute threshold. (Correction of -2 db/decade omitted, see text.)

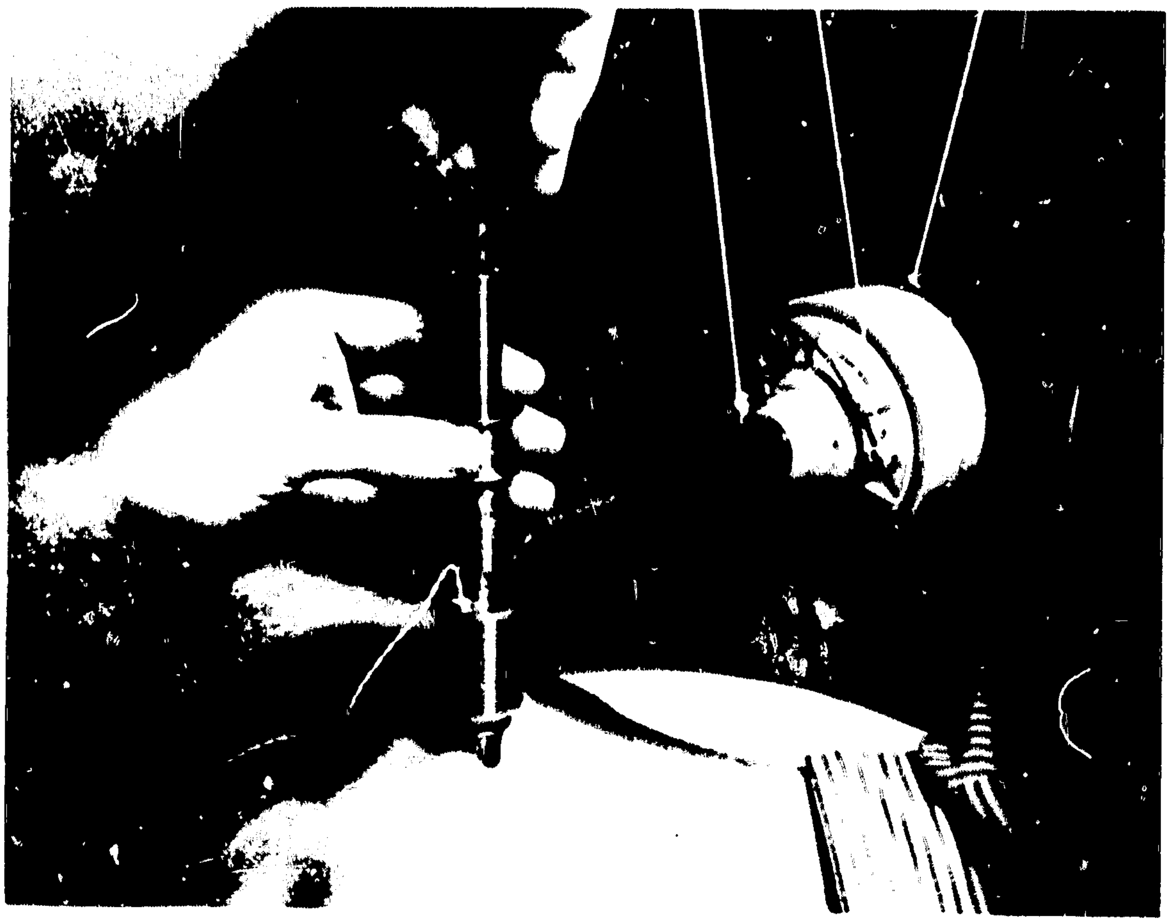


Figure 1

Figure 2

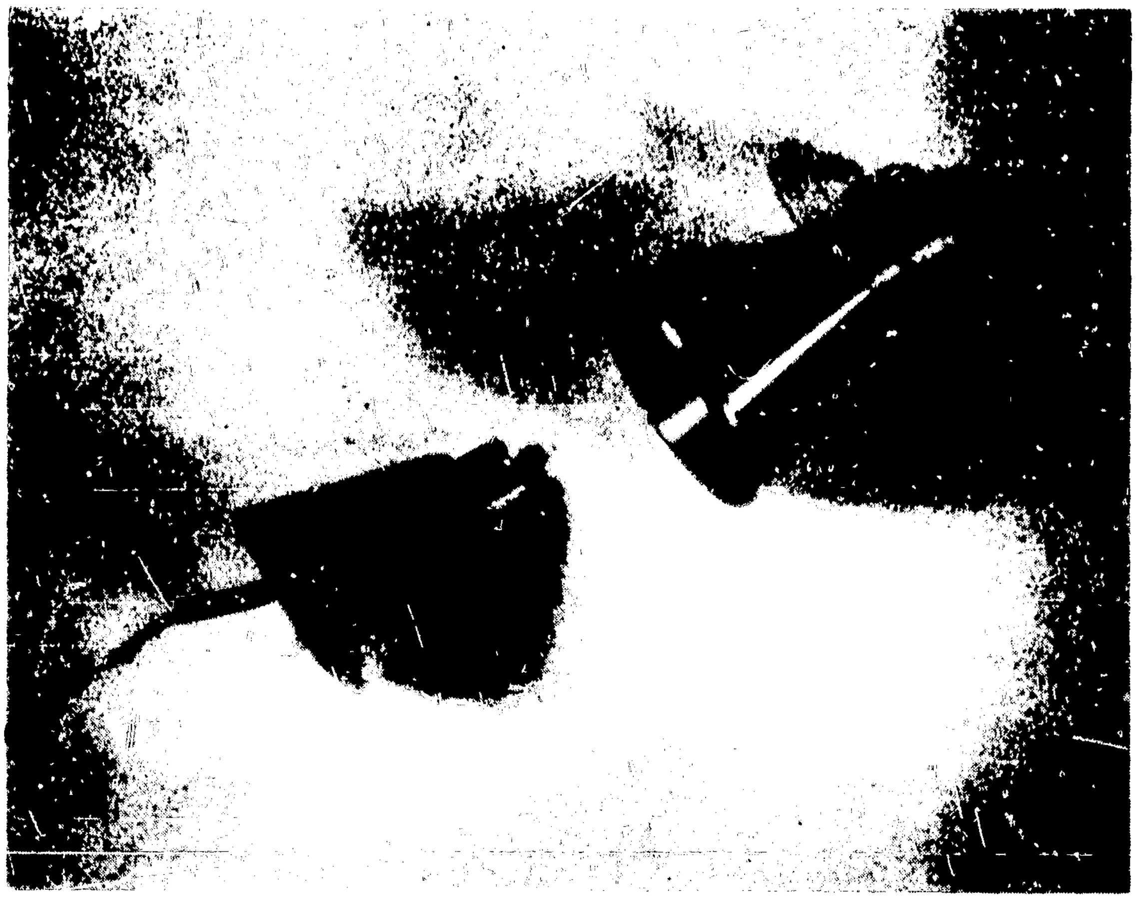


Figure 3

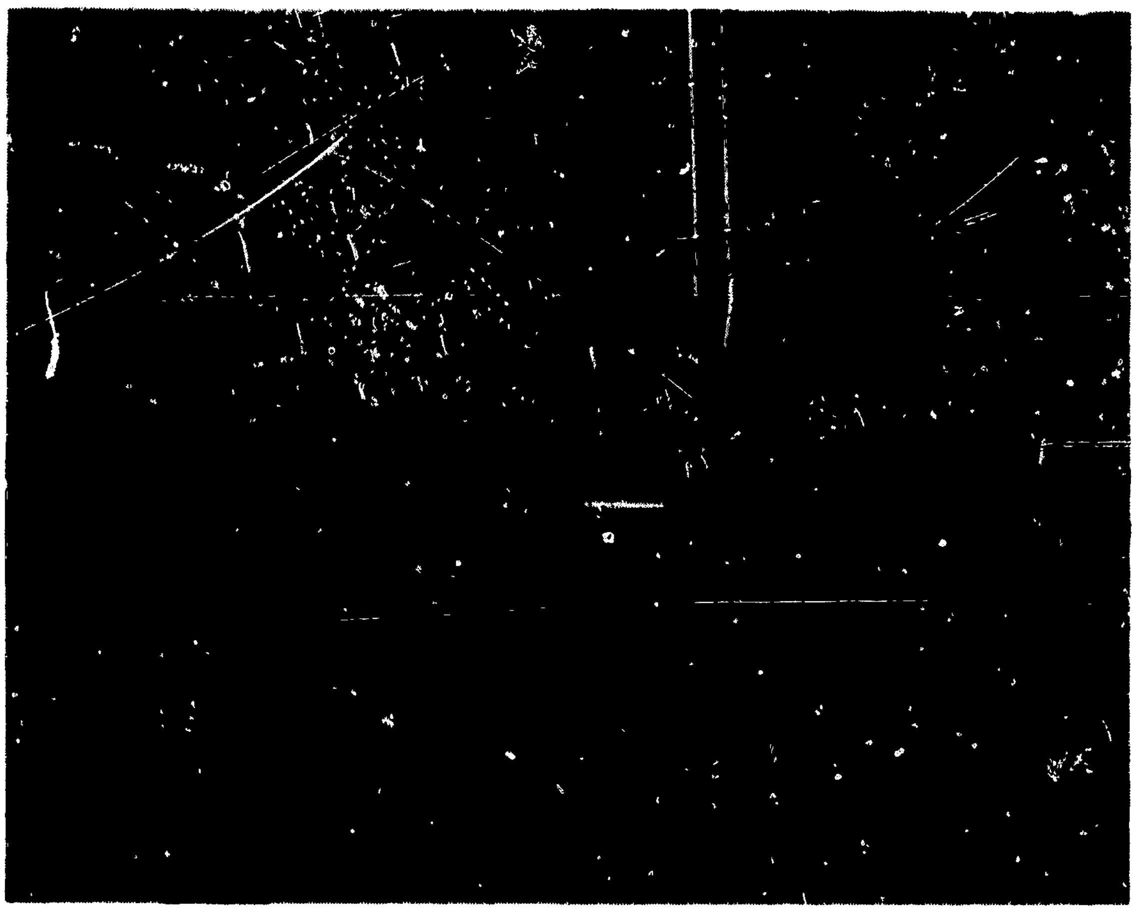
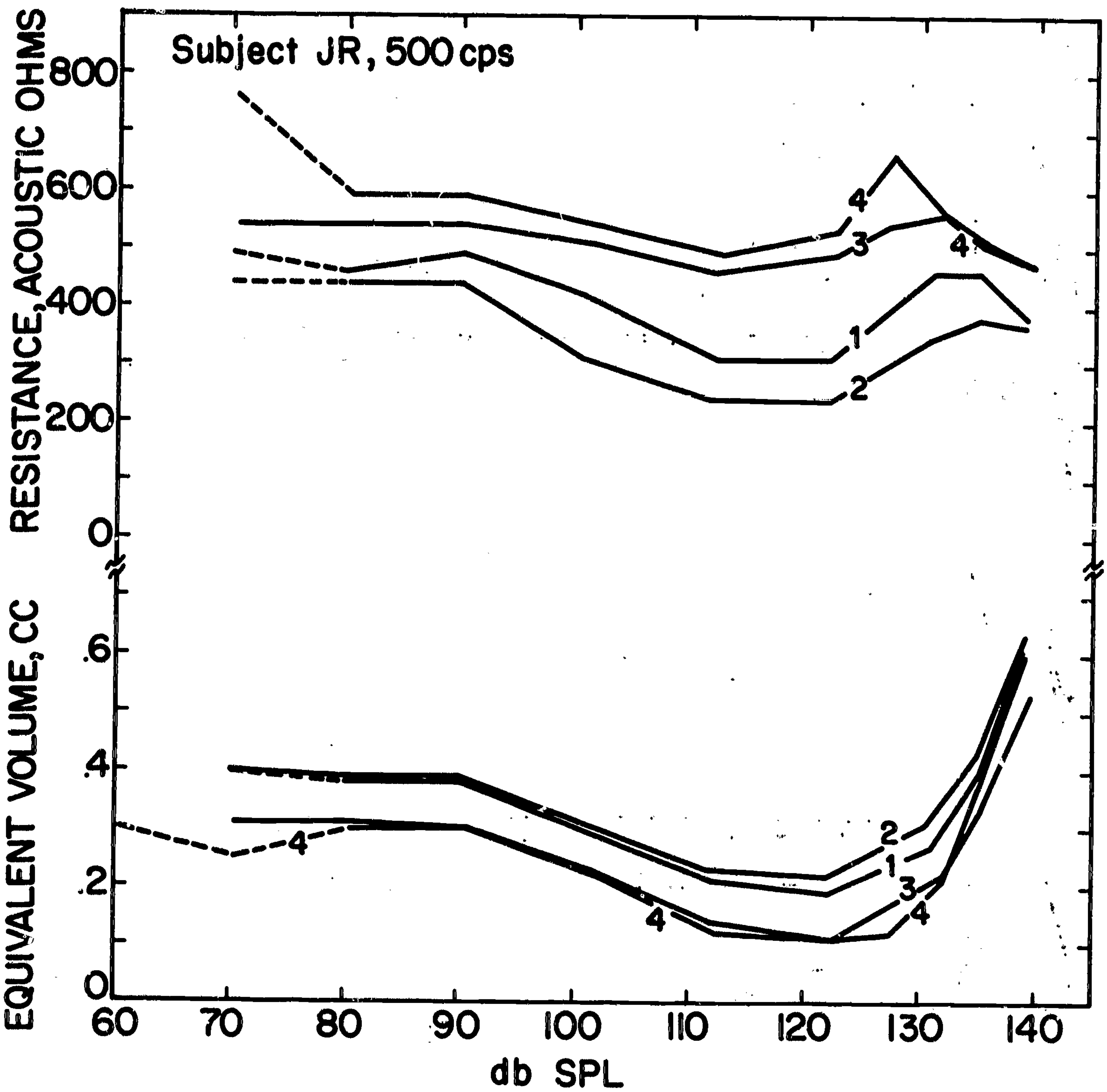
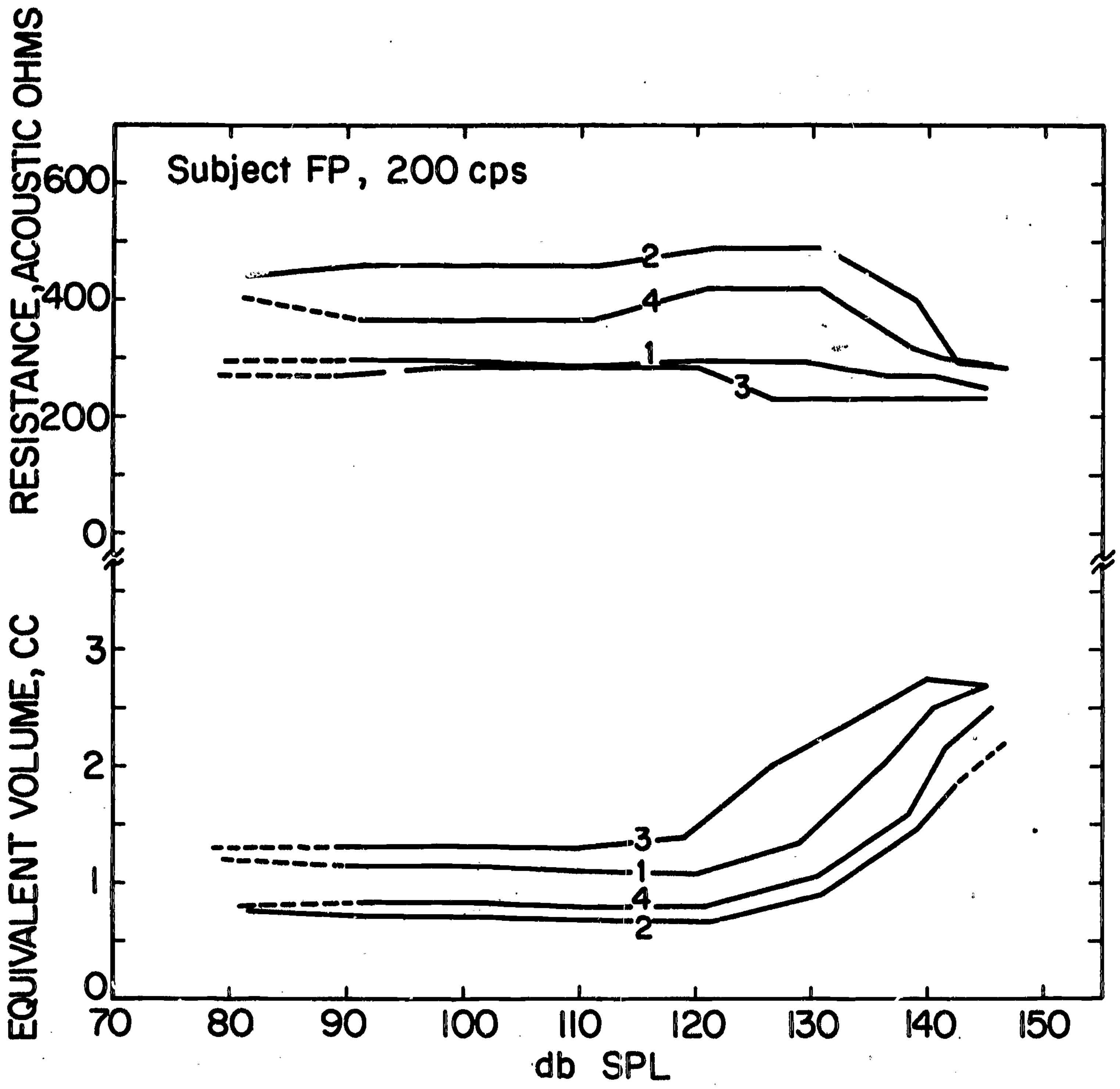


Figure 4



Subject JR, 500 cps
RESISTANCE, ACOUSTIC OHMS
800
600
400
200
0
EQUIVALENT VOLUME, CC
.6
.4
.2
0
60
70
80
90
100
110
120
130
140
db SPL
1
2
3
4


Fig. 5



Subject FP, 200 cps
RESISTANCE, ACOUSTIC OHMS
600
400
200
0
2
4
1
3
EQUIVALENT VOLUME, CC
3
2
1
0
3
1
4
2
70
80
90
100
110
120
130
140
150
db SPL


Fig. 6

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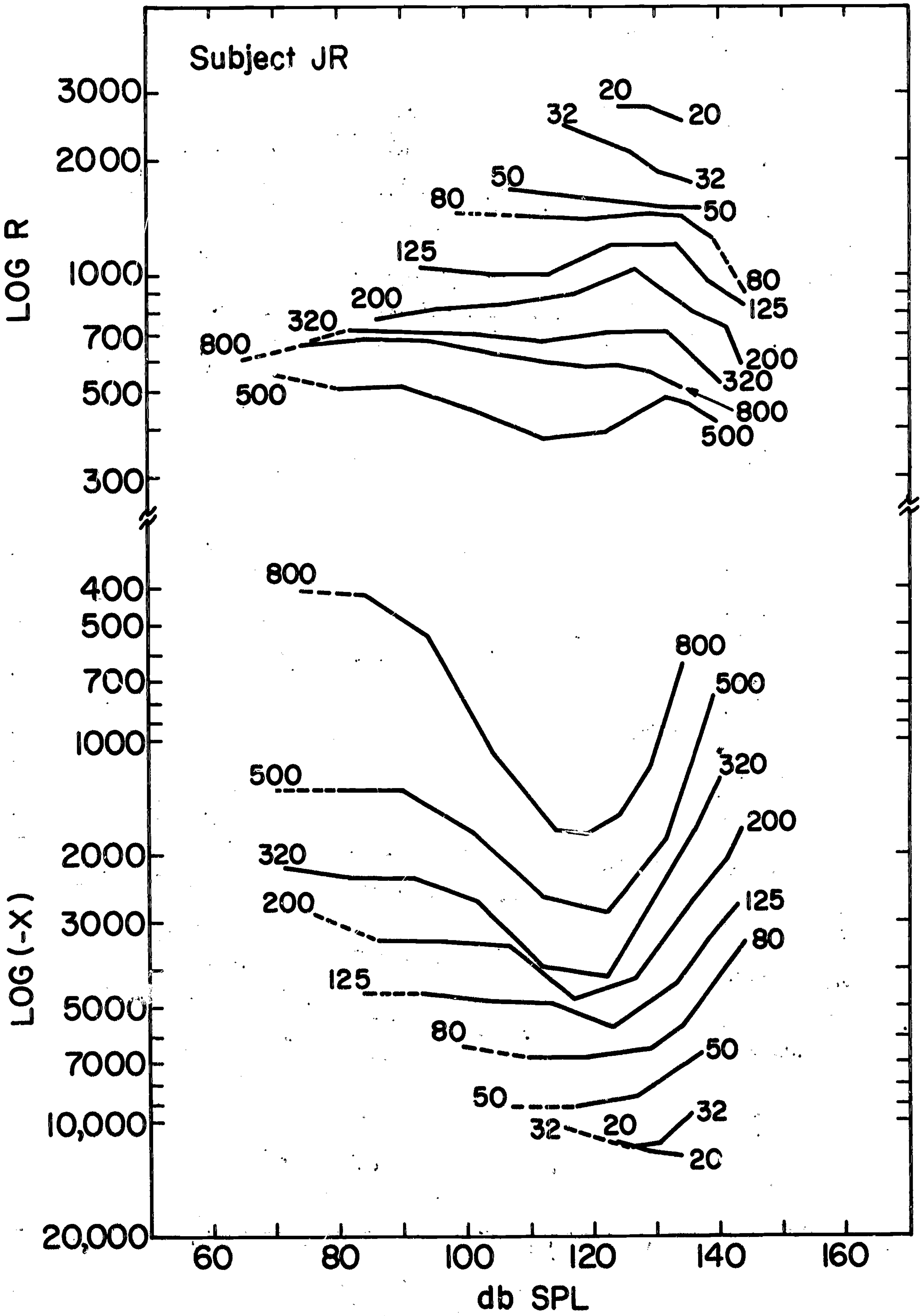
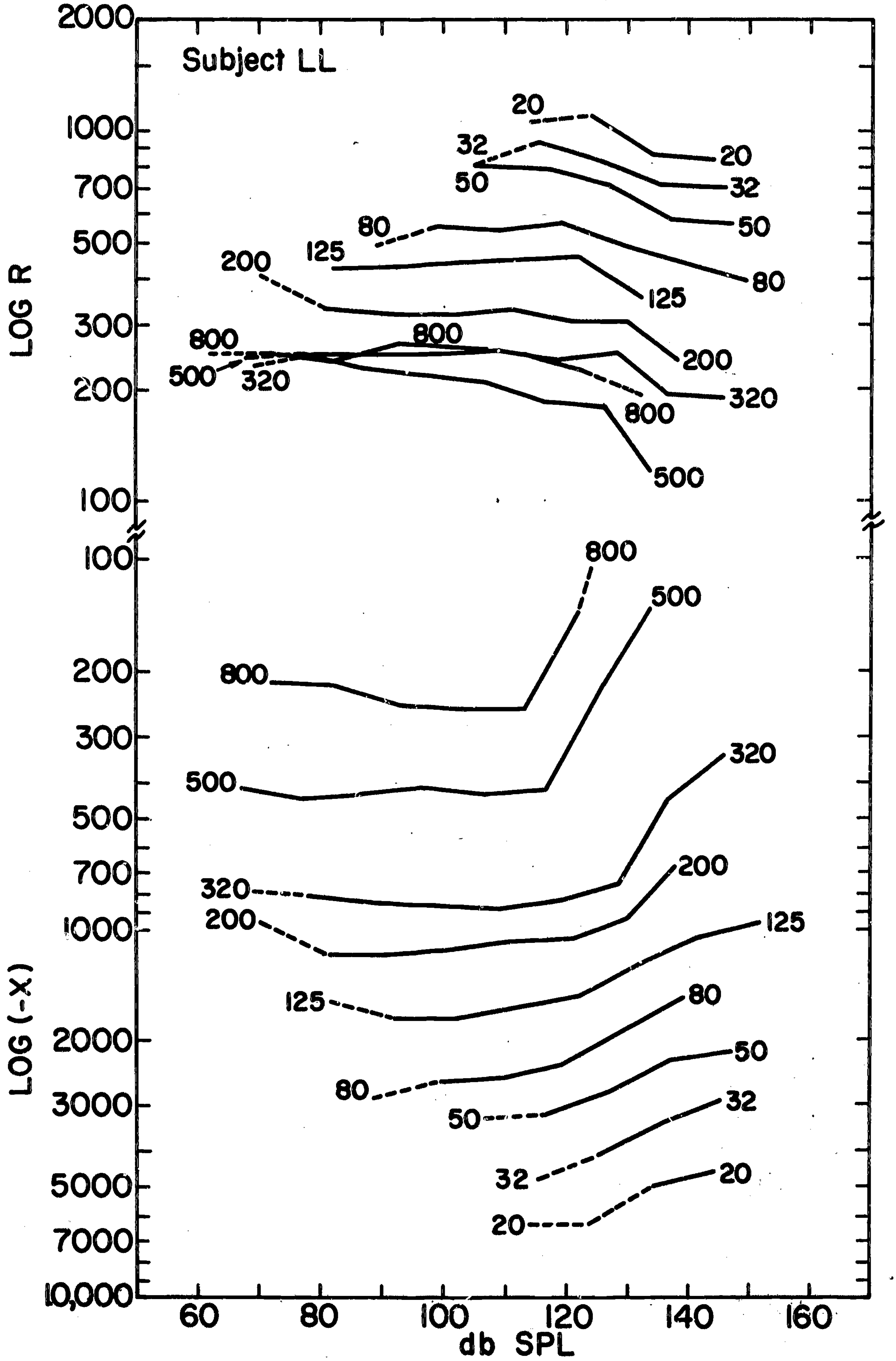


Subject JR
LOG R
LOG (-X)
db SPL
3000
2000
1000
700
500
300
400
500
700
1000
2000
3000
5000
7000
10,000
20,000
60
80
100
120
140
160
20
32
50
80
125
200
320
800
500


Fig. 7



Subject LL
LOG R
LOG (-X)
db SPL
2000
1000
700
500
300
200
100
100
200
300
500
700
1000
2000
3000
5000
7000
10,000
60
80
100
120
140
160
20
32
50
80
125
200
320
500
800


Fig. 8

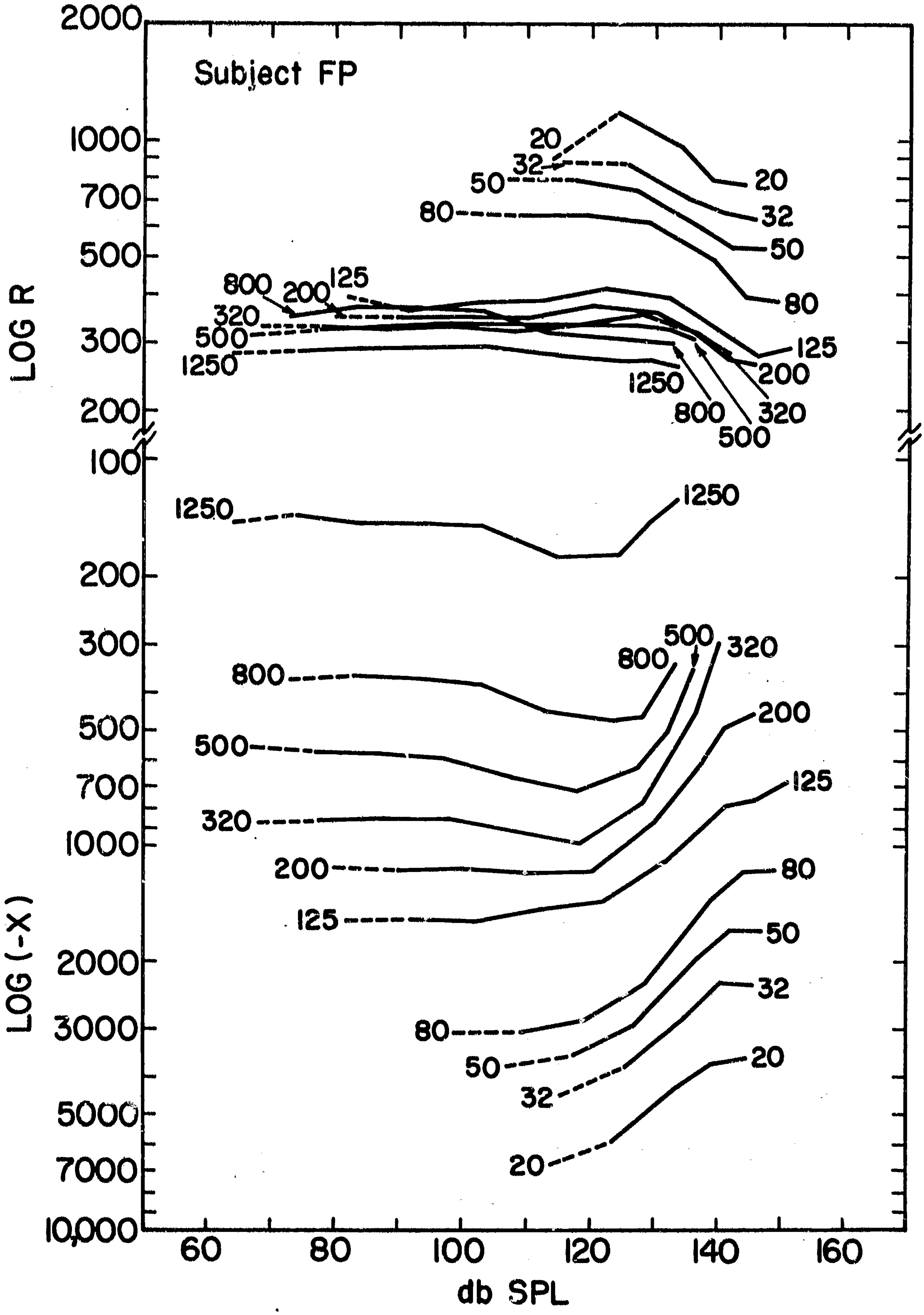

Subject FP
LOG R
LOG (-X)
db SPL
2000
1000
700
500
300
200
100
200
300
500
700
1000
2000
3000
5000
7000
10,000
60
80
100
120
140
160
20
32
50
80
125
200
320
500
800
1250

Fig. 9

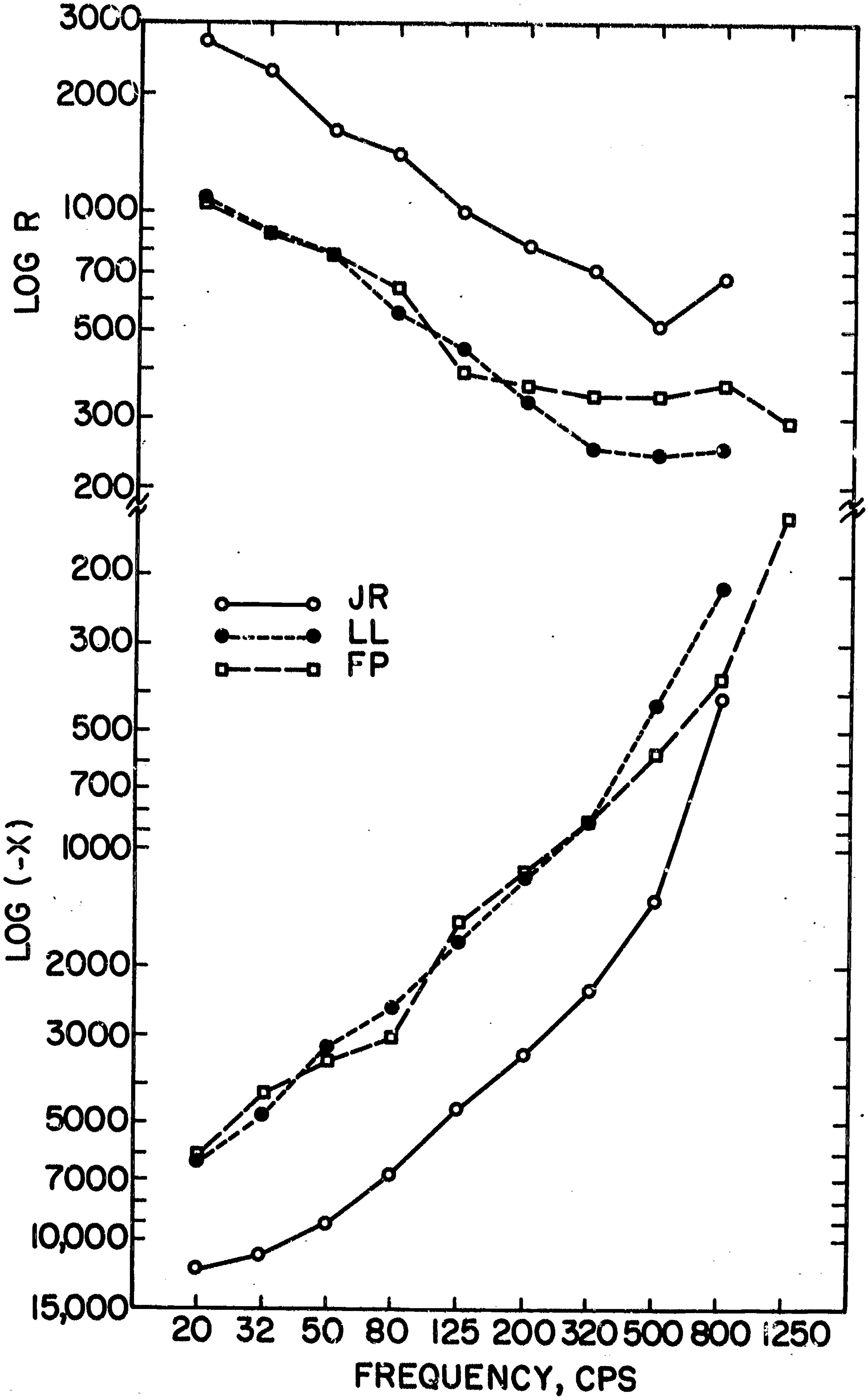

3000
2000
1000
700
500
300
200
LOG R
200
300
500
700
1000
2000
3000
5000
7000
10,000
15,000
LOG (-X)
JR
LL
FP
20 32 50 80 125 200 320 500 800 1250
FREQUENCY, CPS

Fig. 10

ERIC

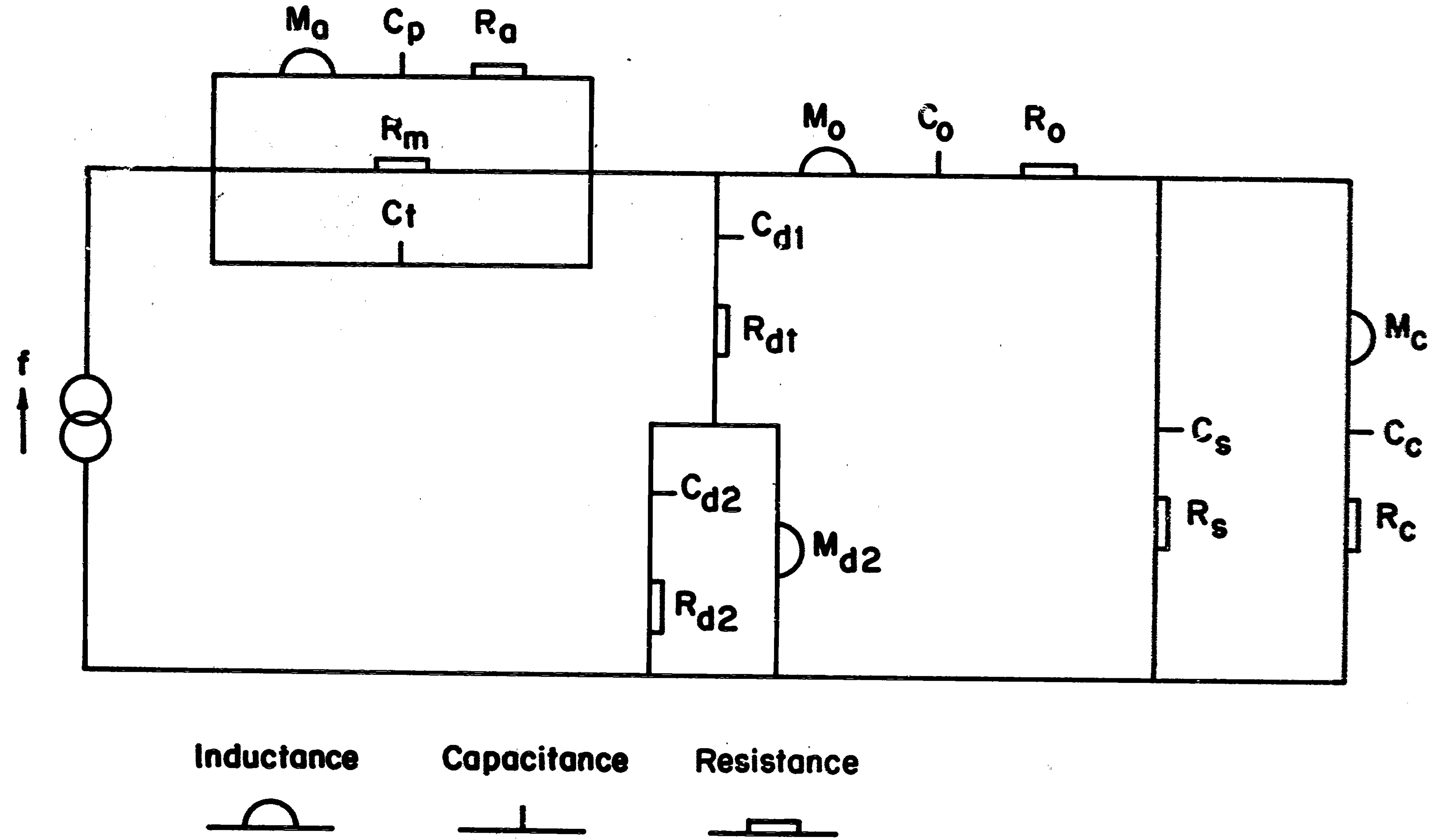

Ma
Cp
Ra
Rm
Ct
Mo
Co
Ro
Cd1
Rdt
f
Cd2
Md2
Rd2
Cs
Rs
Mc
Cc
Rc
Inductance
Capacitance
Resistance

Fig. 11

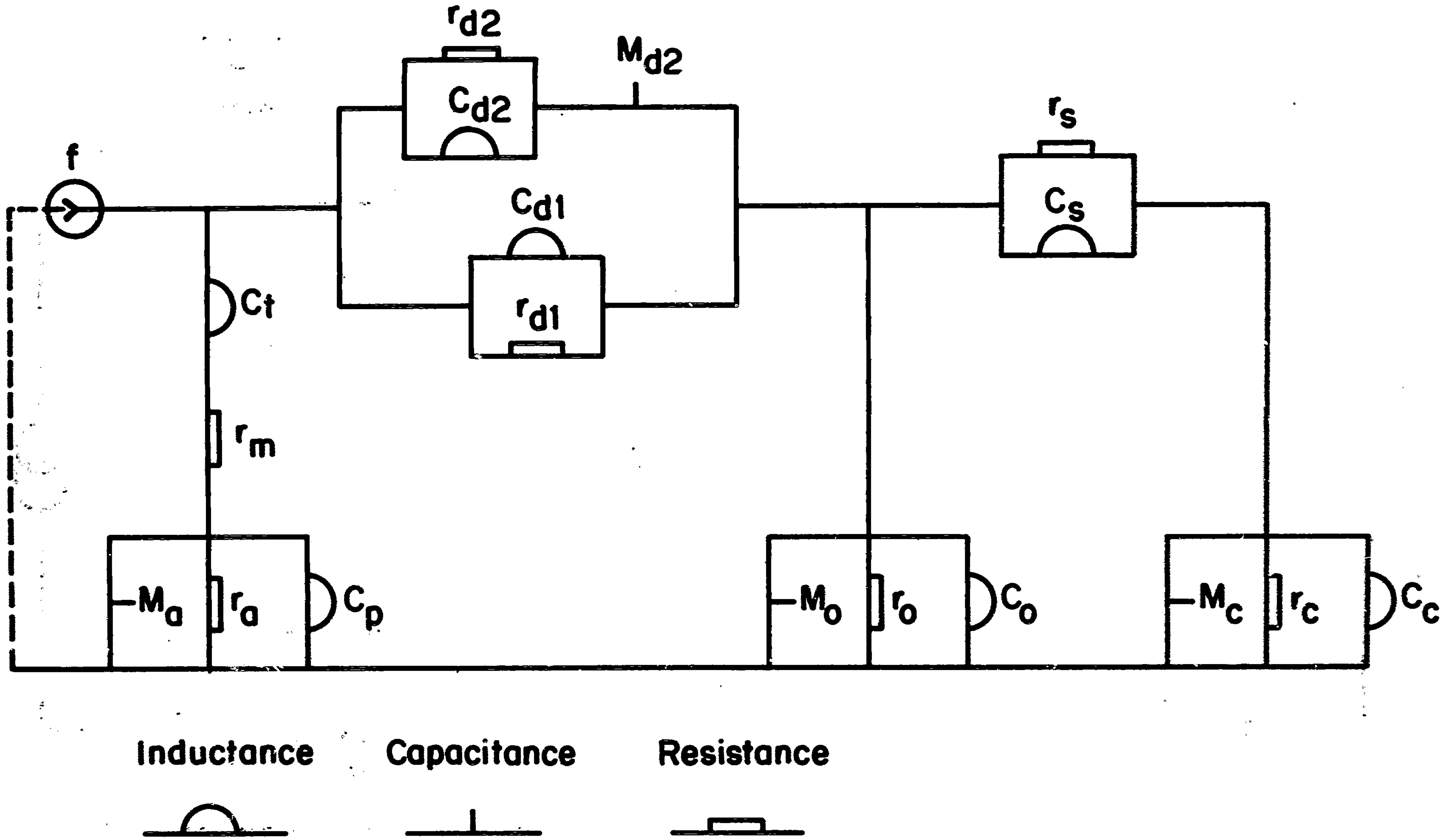

f
$r_{d2}$
$C_{d2}$
$M_{d2}$
$C_{d1}$
$r_{d1}$
$C_t$
$r_m$
$r_s$
$C_s$
$M_a$
$r_a$
$C_p$
$M_o$
$r_o$
$C_o$
$M_c$
$r_c$
$C_c$
Inductance
Capacitance
Resistance

Fig. 12

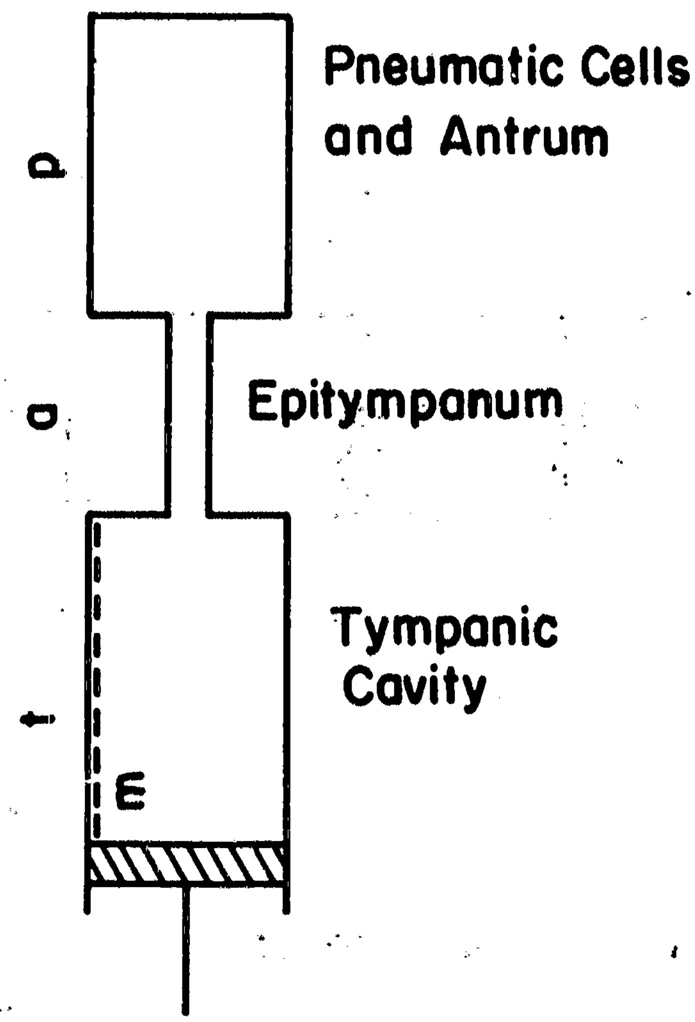



Fig. 13

ERIC

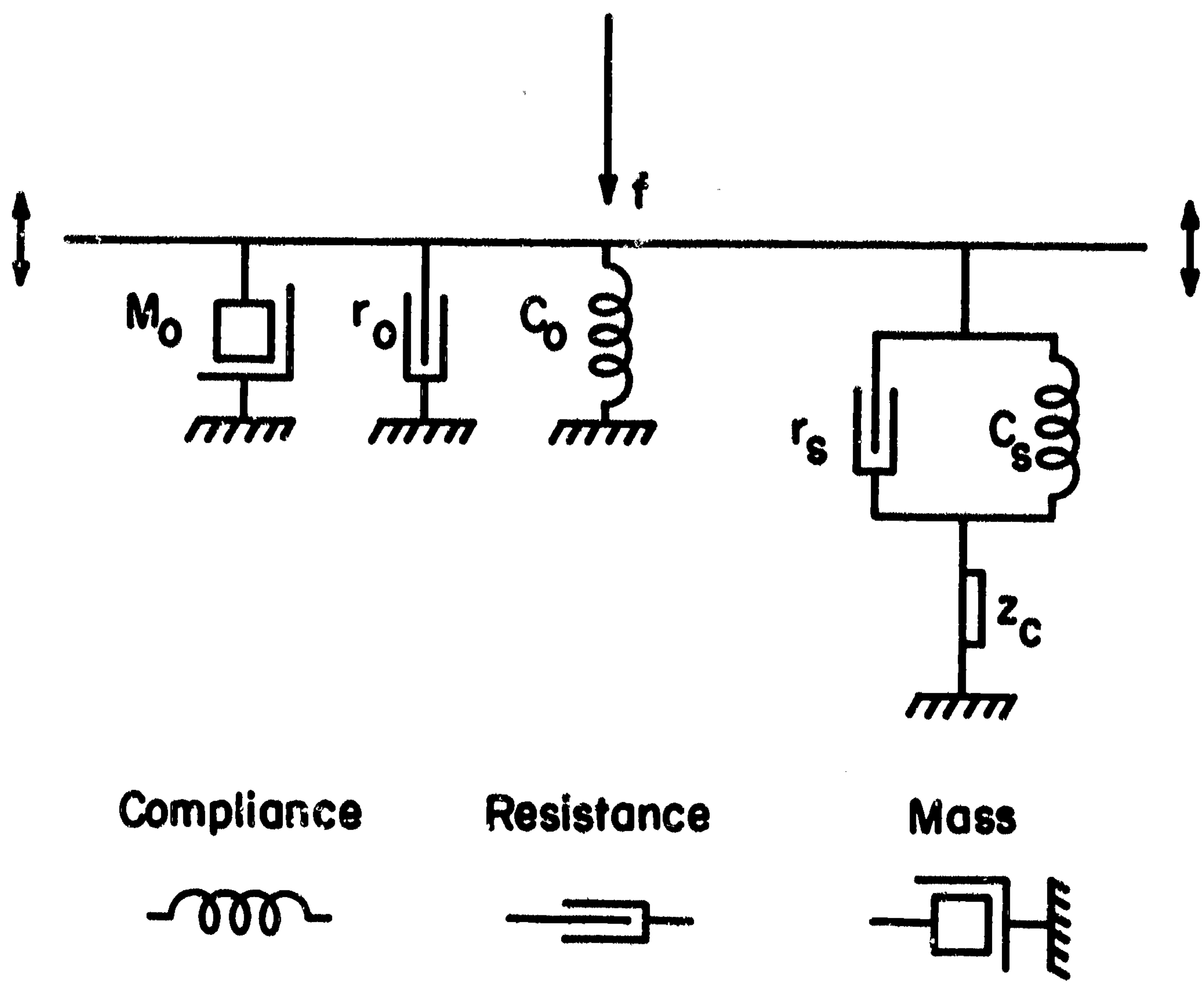



Fig. 14

ERIC

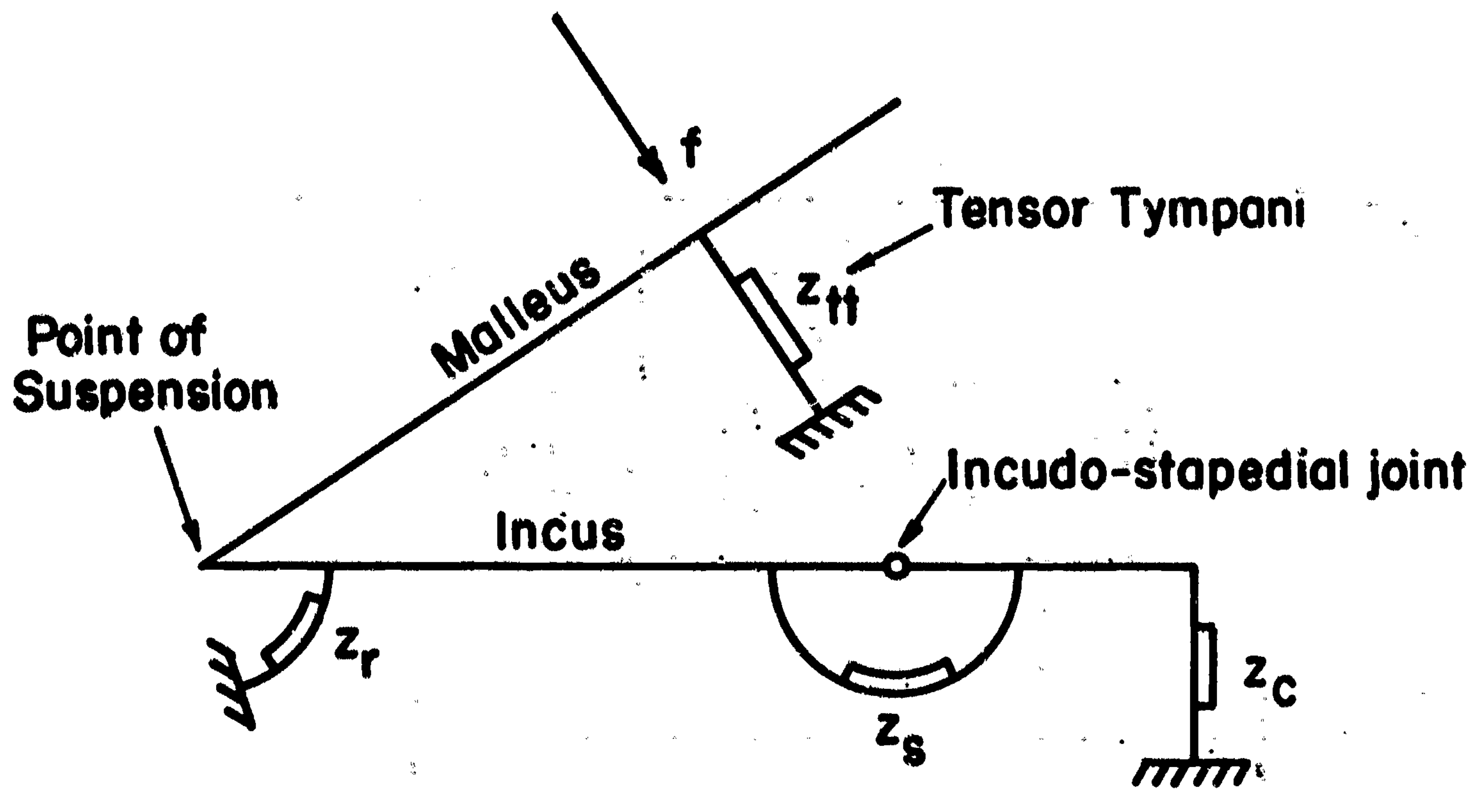

f
Tensor Tympani
Malleus
$z_{tt}$
Point of
Suspension
Incudo-stapedial joint
Incus
$z_r$
$z_c$
$z_s$

Fig. 15

ERIC

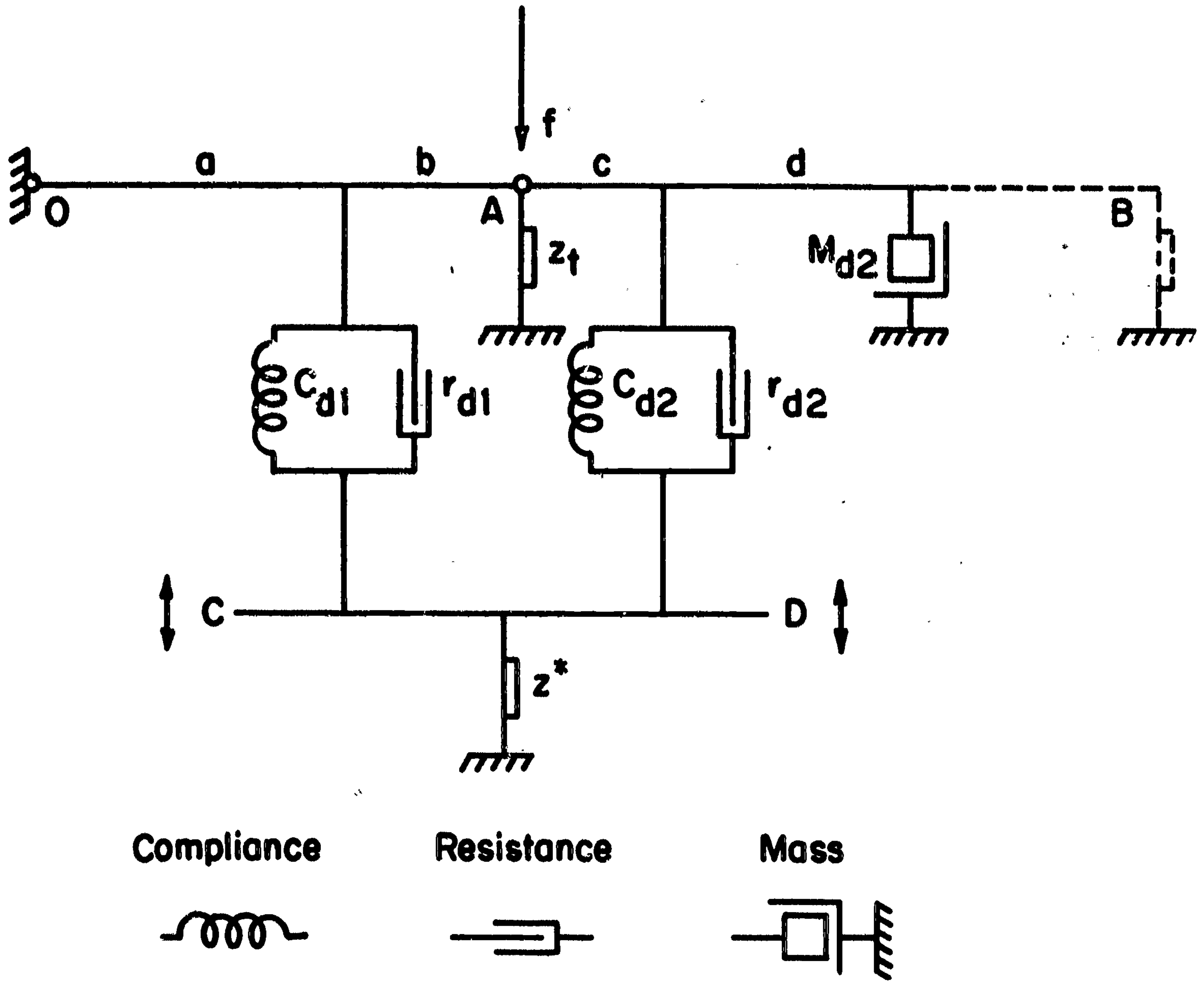

f
a
b
c
d
O
A
B
$z_t$
$M_{d2}$
$C_{d1}$
$r_{d1}$
$C_{d2}$
$r_{d2}$
C
D
$z^*$
Compliance
Resistance
Mass

Fig. 16

ERIC

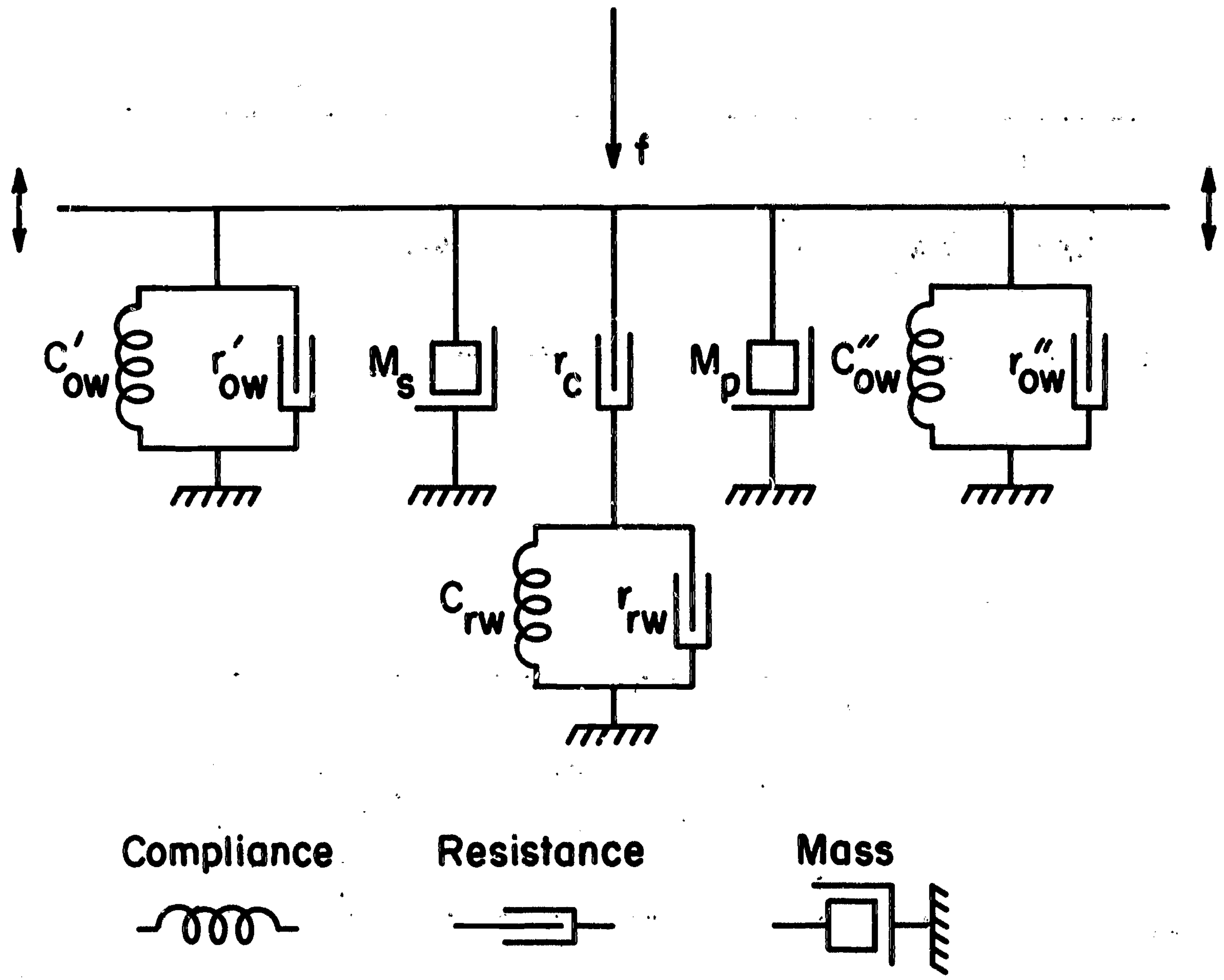



Fig. 17

ERIC

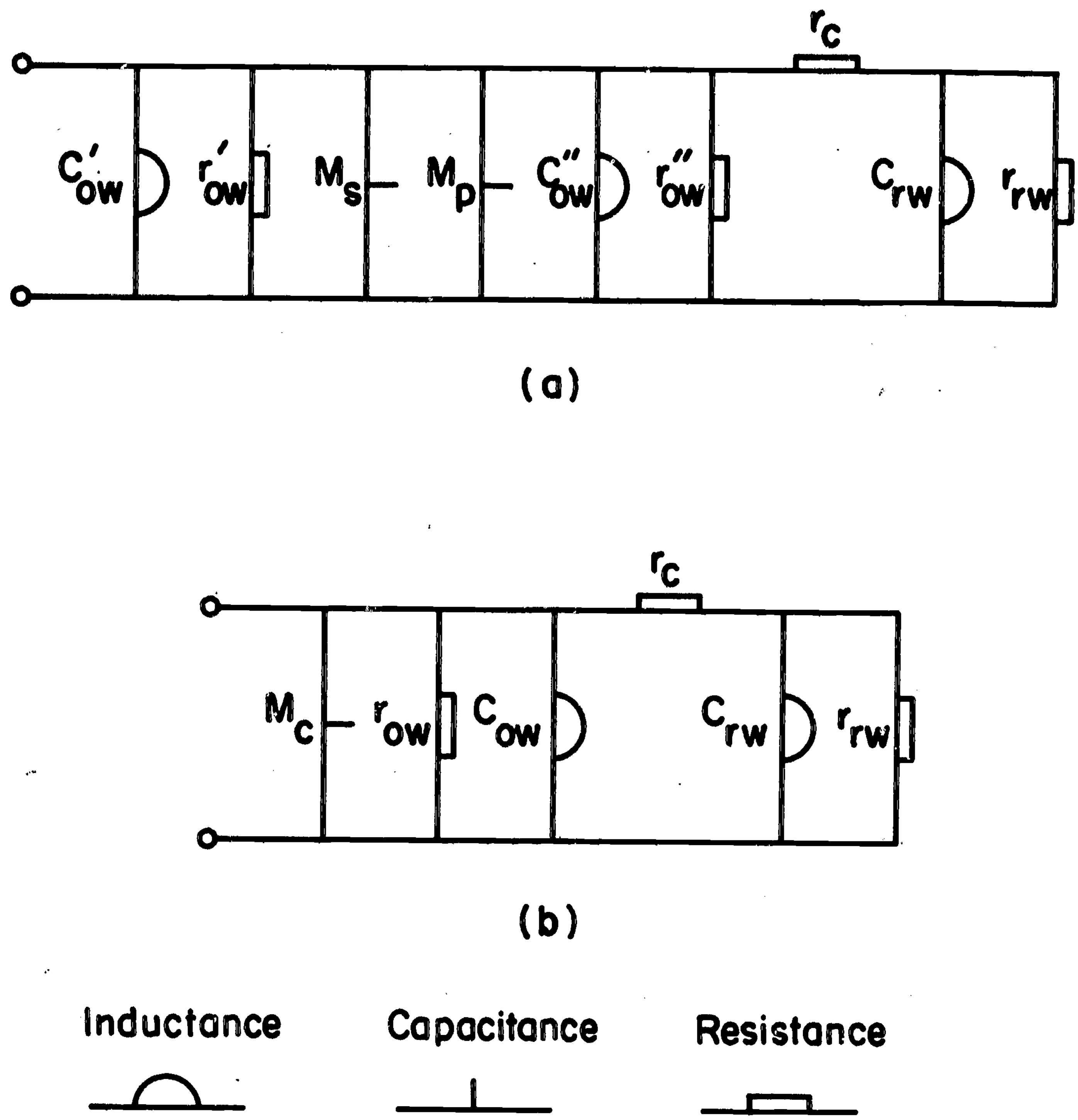

r_c
C'_ow
r'_ow
M_s
M_p
C''_ow
r''_ow
C_rw
r_rw
(a)
r_c
M_c
r_ow
C_ow
C_rw
r_rw
(b)
Inductance
Capacitance
Resistance

Fig. 18

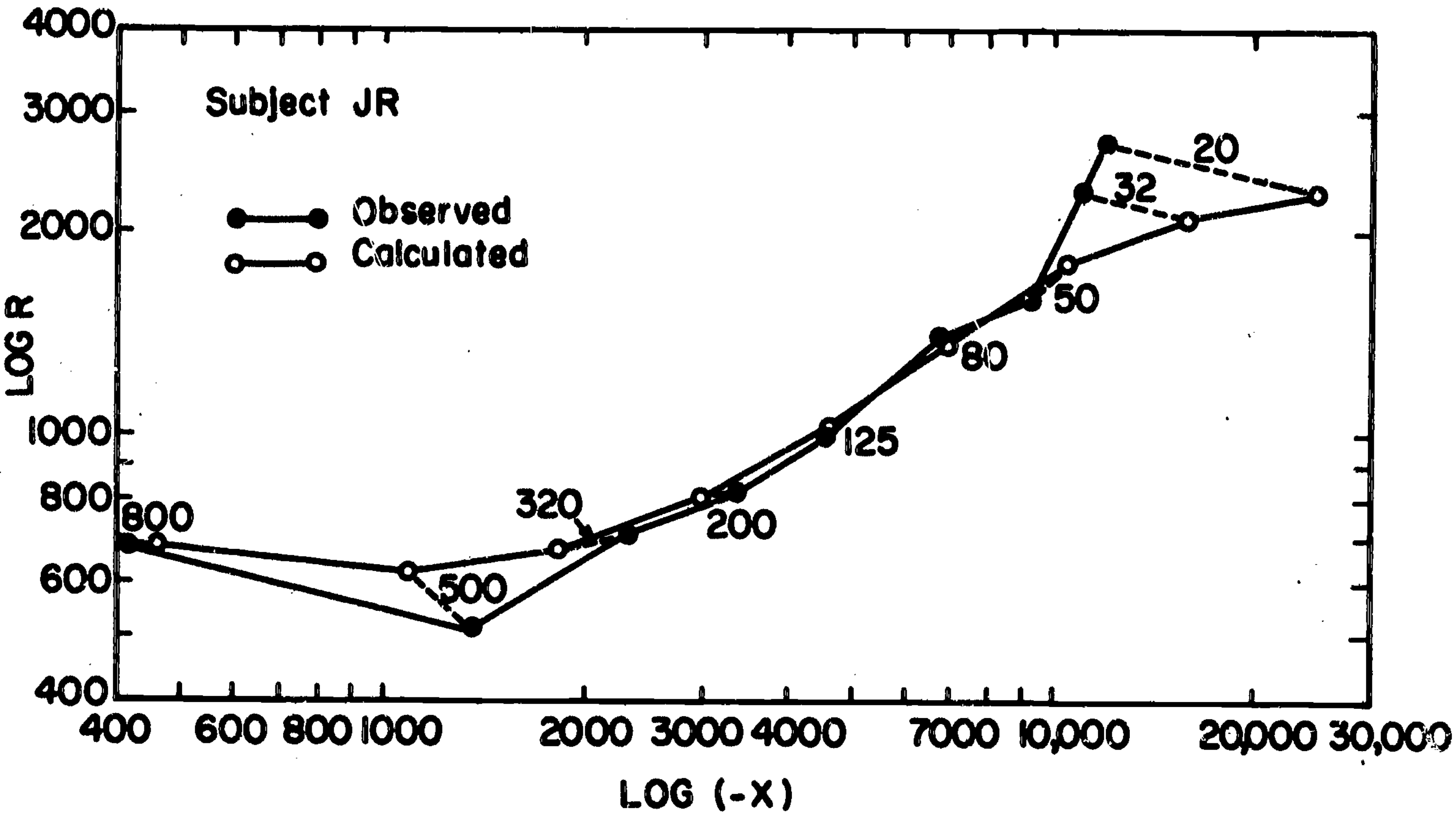
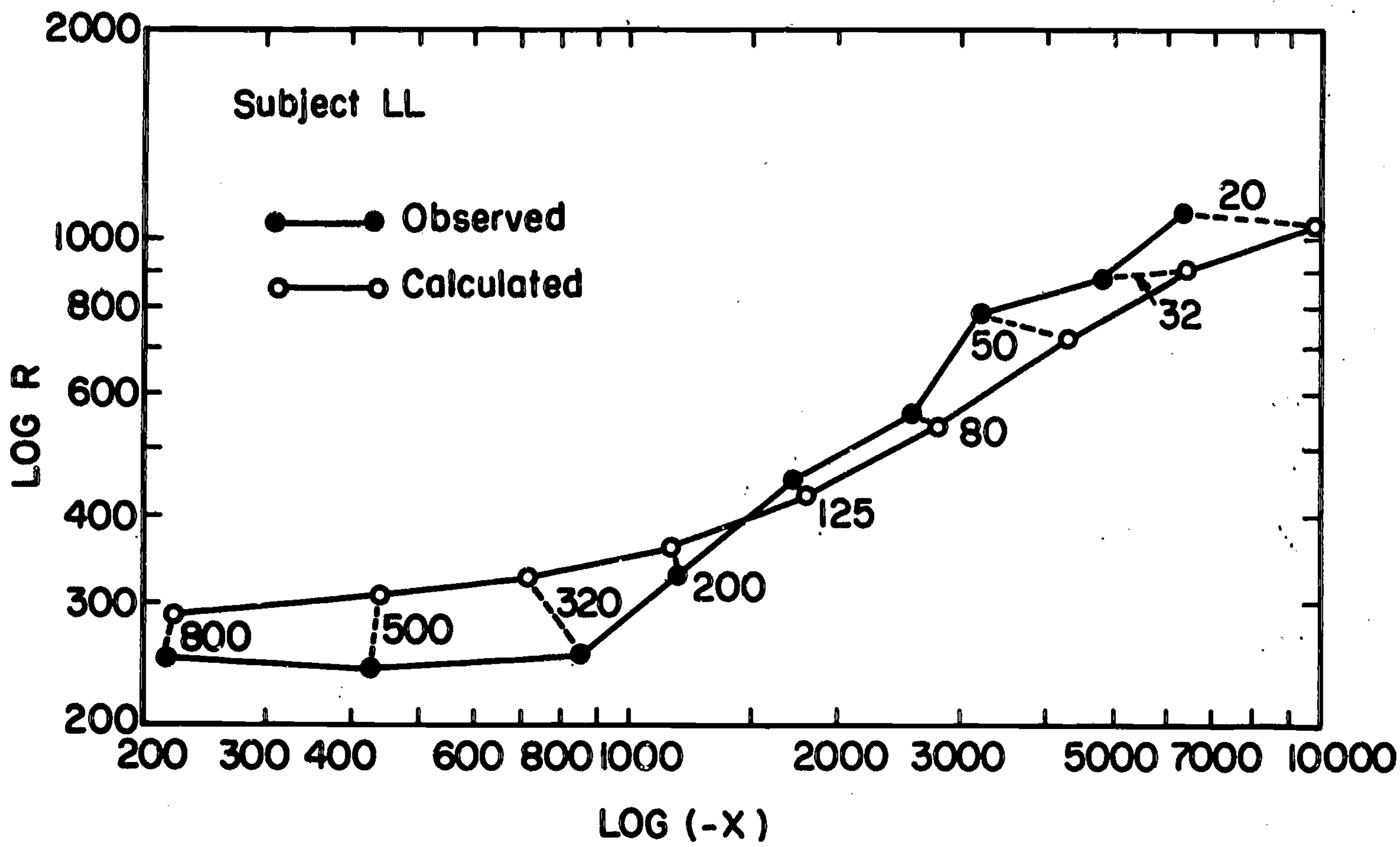

Subject JR
Observed
Calculated
LOG R
4000
3000
2000
1000
800
600
400
400
600
800
1000
2000
3000
4000
7000
10,000
20,000
30,000
LOG (-X)
20
32
50
80
125
200
320
500
800

Fig. 19

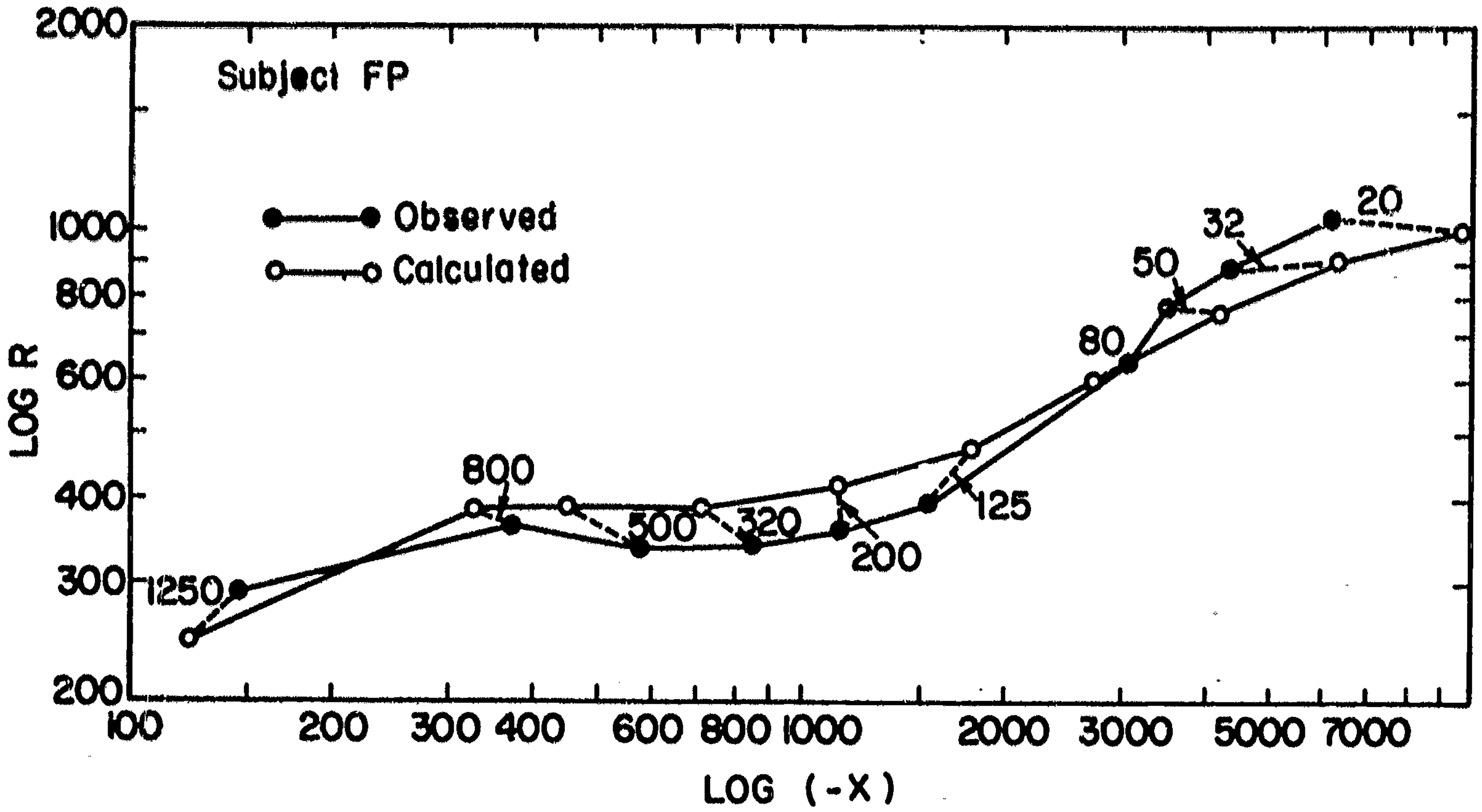
ERIC



Subject LL
Observed
Calculated
LOG R
LOG (-X)
2000
1000
800
600
400
300
200
200 300 400 600 800 1000 2000 3000 5000 7000 10000
800
500
320
200
125
80
50
32
20


Fig. 20

ERIC



Subject FP
Observed
Calculated
LOG R
2000
1000
800
600
400
300
200
100
200
300
400
600
800
1000
2000
3000
5000
7000
LOG (-X)
1250
800
500
320
200
125
80
50
32
20


Fig. 21

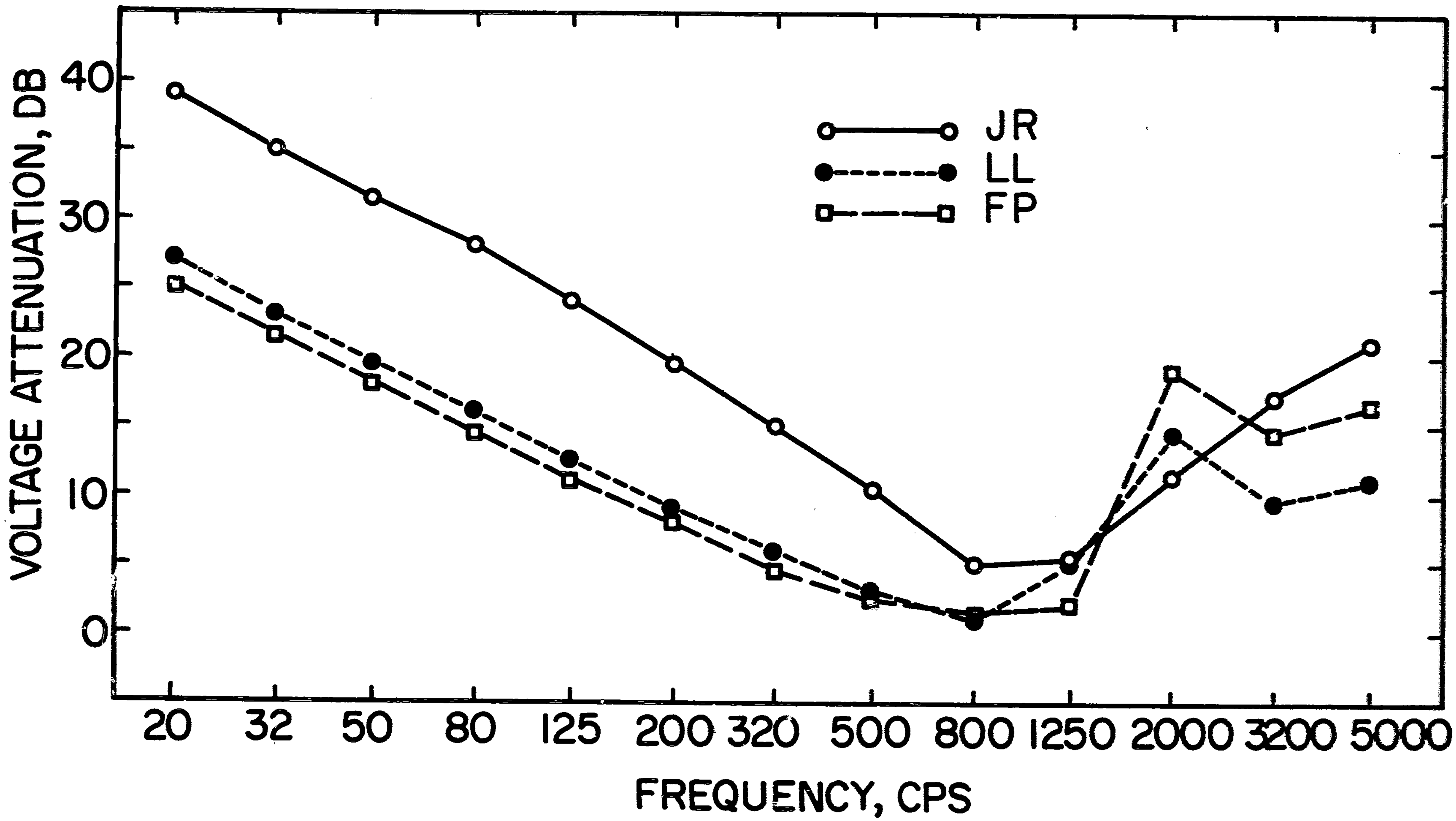
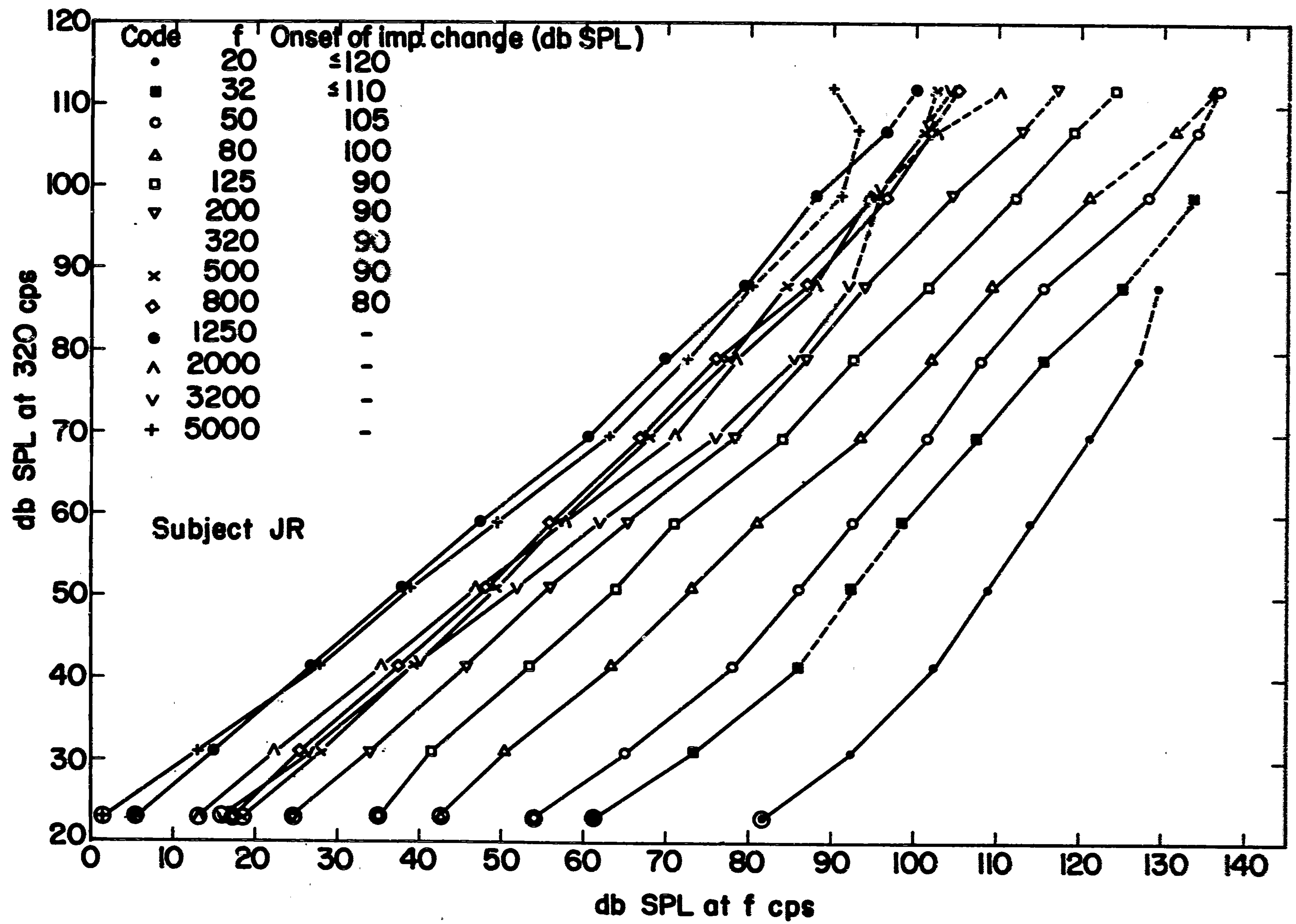
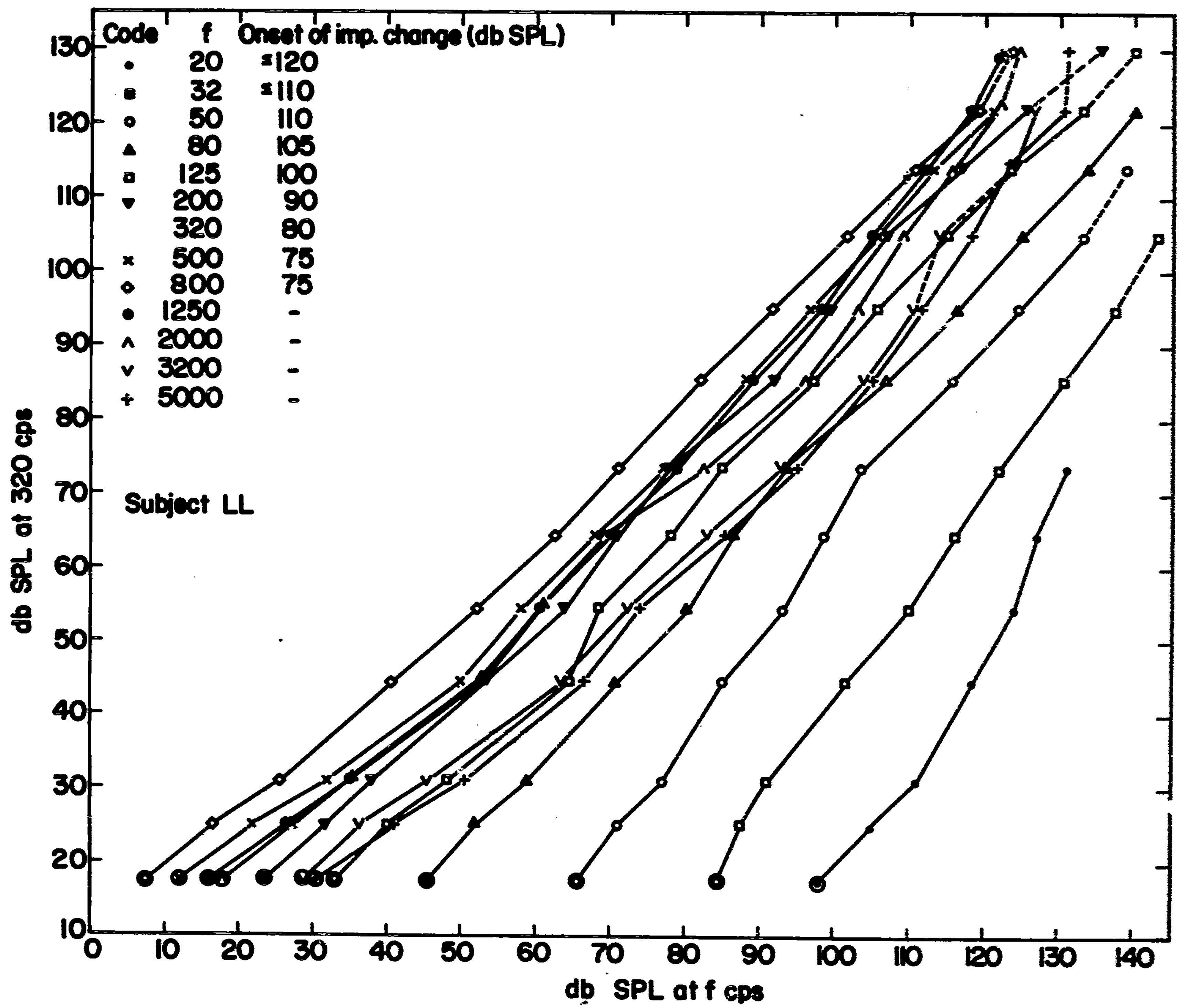

JR
LL
FP
VOLTAGE ATTENUATION, DB
40
30
20
10
0
20
32
50
80
125
200
320
500
800
1250
2000
3200
5000
FREQUENCY, CPS

Fig. 22



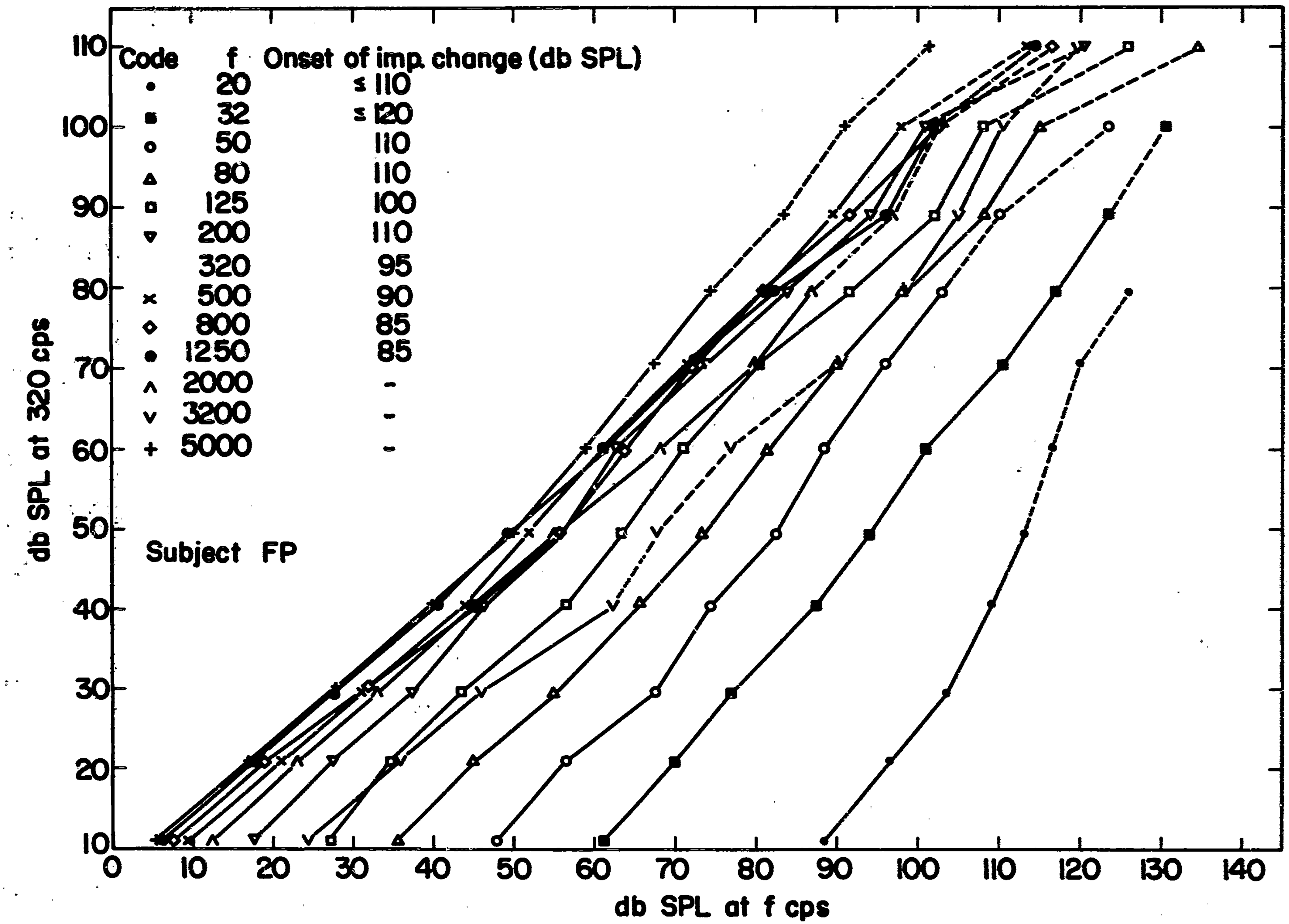
Code f Onset of imp. change (db SPL)
20 ≤120
32 ≤110
50 105
80 100
125 90
200 90
320 90
500 90
800 80
1250 -
2000 -
3200 -
5000 -
Subject JR
db SPL at 320 cps
db SPL at f cps


Fig. 23



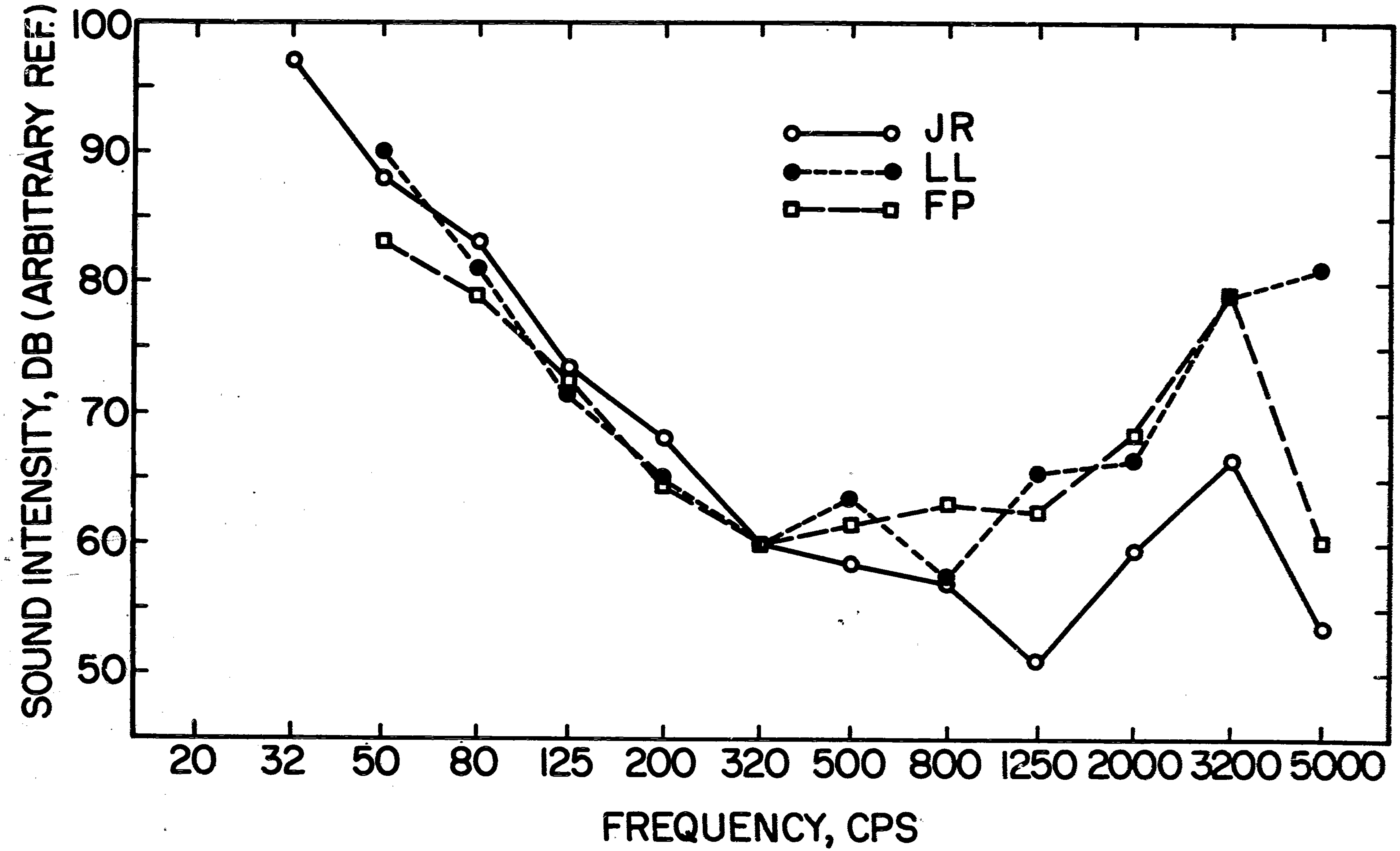
Code f Onset of imp. change (db SPL)
• 20 ≤120
■ 32 ≤110
○ 50 110
▲ 80 105
□ 125 100
▼ 200 90
320 80
× 500 75
◇ 800 75
● 1250 -
^ 2000 -
v 3200 -
+ 5000 -
Subject LL
db SPL at 320 cps
db SPL at f cps


Fig. 24



Code f Onset of imp. change (db SPL)
• 20 ≤ 110
■ 32 ≤ 120
○ 50 110
△ 80 110
□ 125 100
▽ 200 110
320 95
× 500 90
◇ 800 85
● 1250 85
∧ 2000 -
∨ 3200 -
+ 5000 -
Subject FP
db SPL at 320 cps
db SPL at f cps
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140


Fig. 25



JR
LL
FP
100
90
80
70
60
50
SOUND INTENSITY, DB (ARBITRARY REF.)
20
32
50
80
125
200
320
500
800
1250
2000
3200
5000
FREQUENCY, CPS


Fig. 26

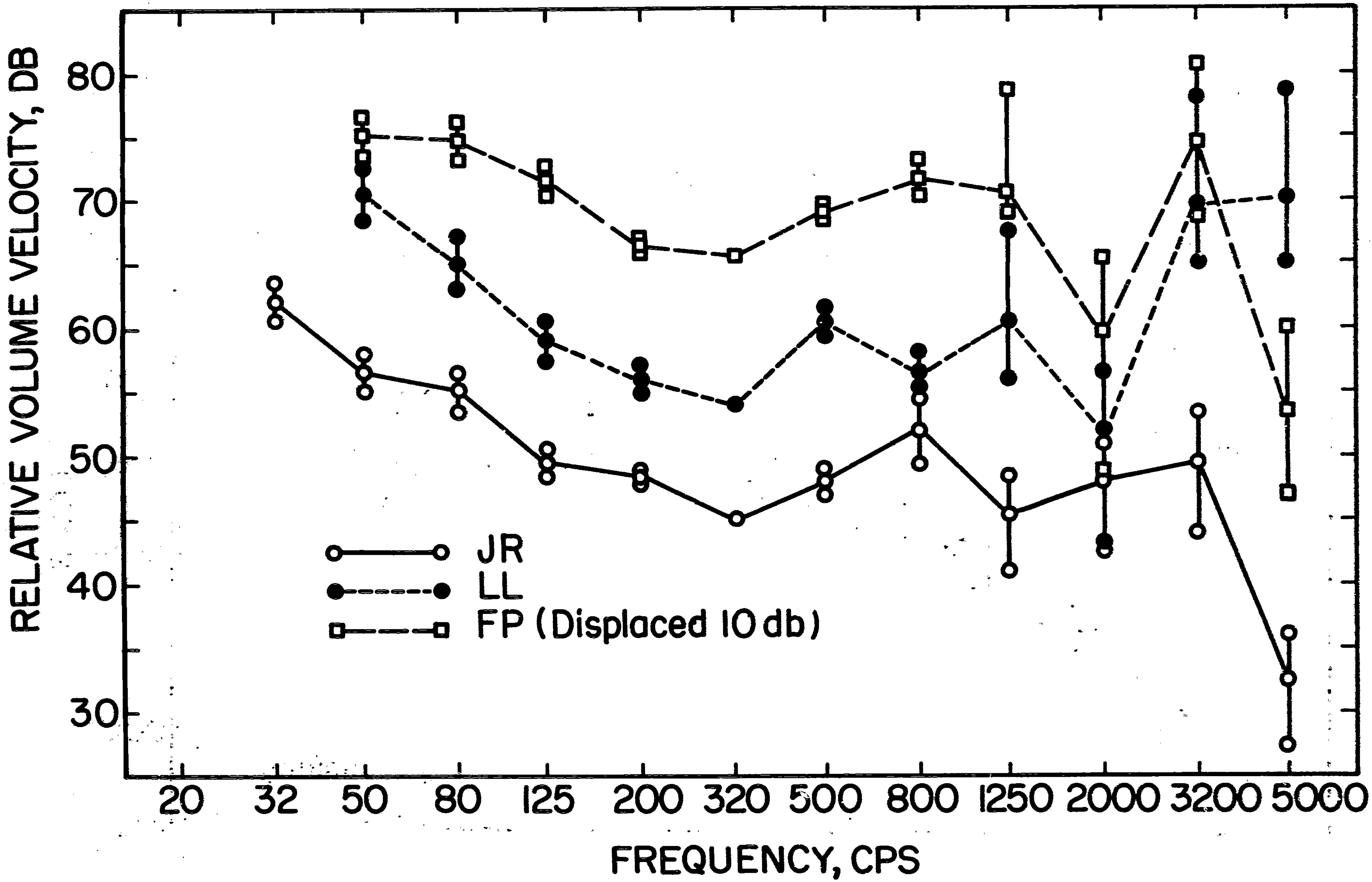

RELATIVE VOLUME VELOCITY, DB
80
70
60
50
40
30
20
32
50
80
125
200
320
500
800
1250
2000
3200
5000
FREQUENCY, CPS
JR
LL
FP (Displaced 10 db)

Fig. 27

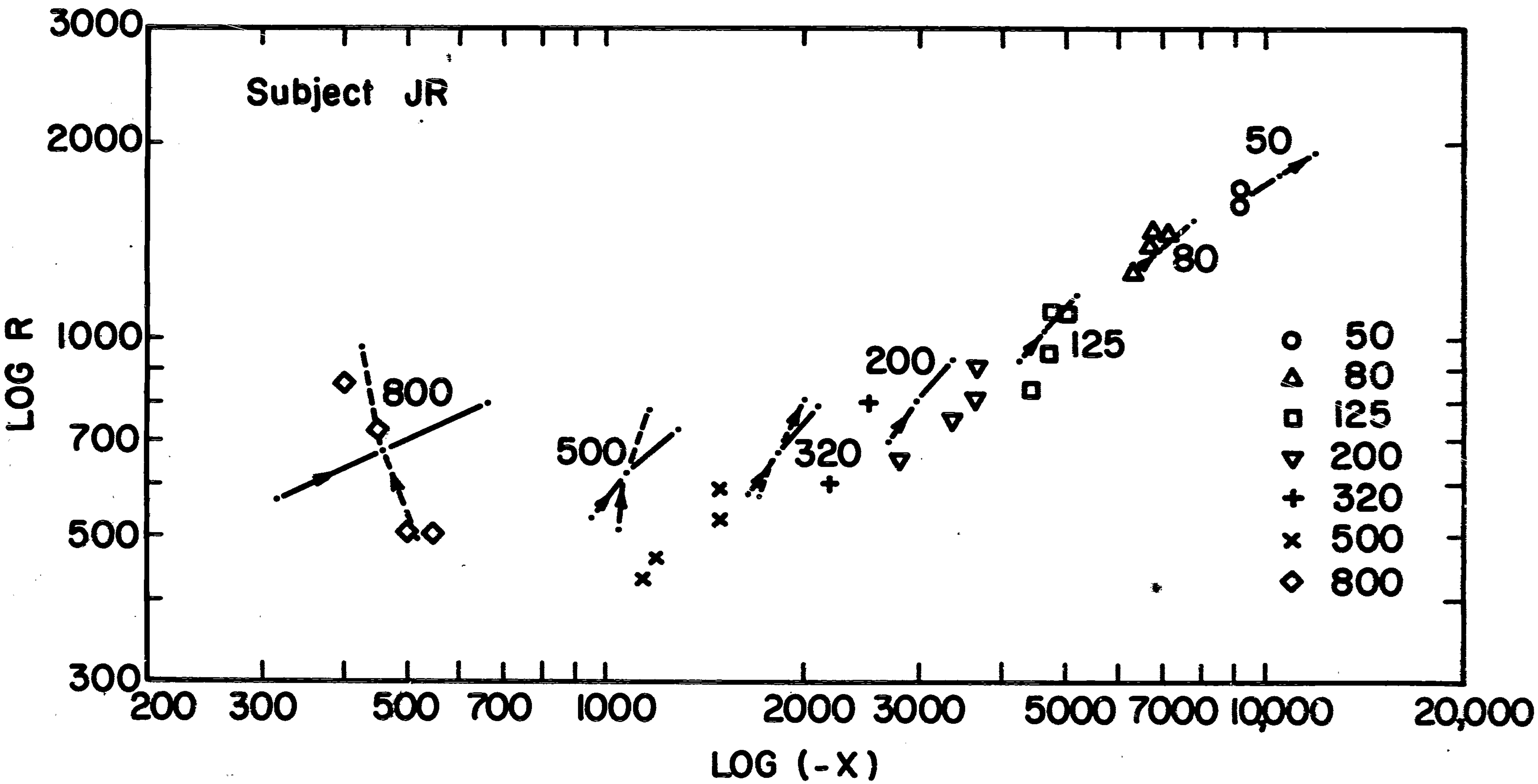

Subject JR
LOG R
3000
2000
1000
700
500
300
200
300
500
700
1000
2000
3000
5000
7000
10,000
20,000
LOG (-X)
800
500
320
200
125
80
50
○ 50
△ 80
□ 125
▽ 200
+ 320
× 500
◇ 800

Fig. 28

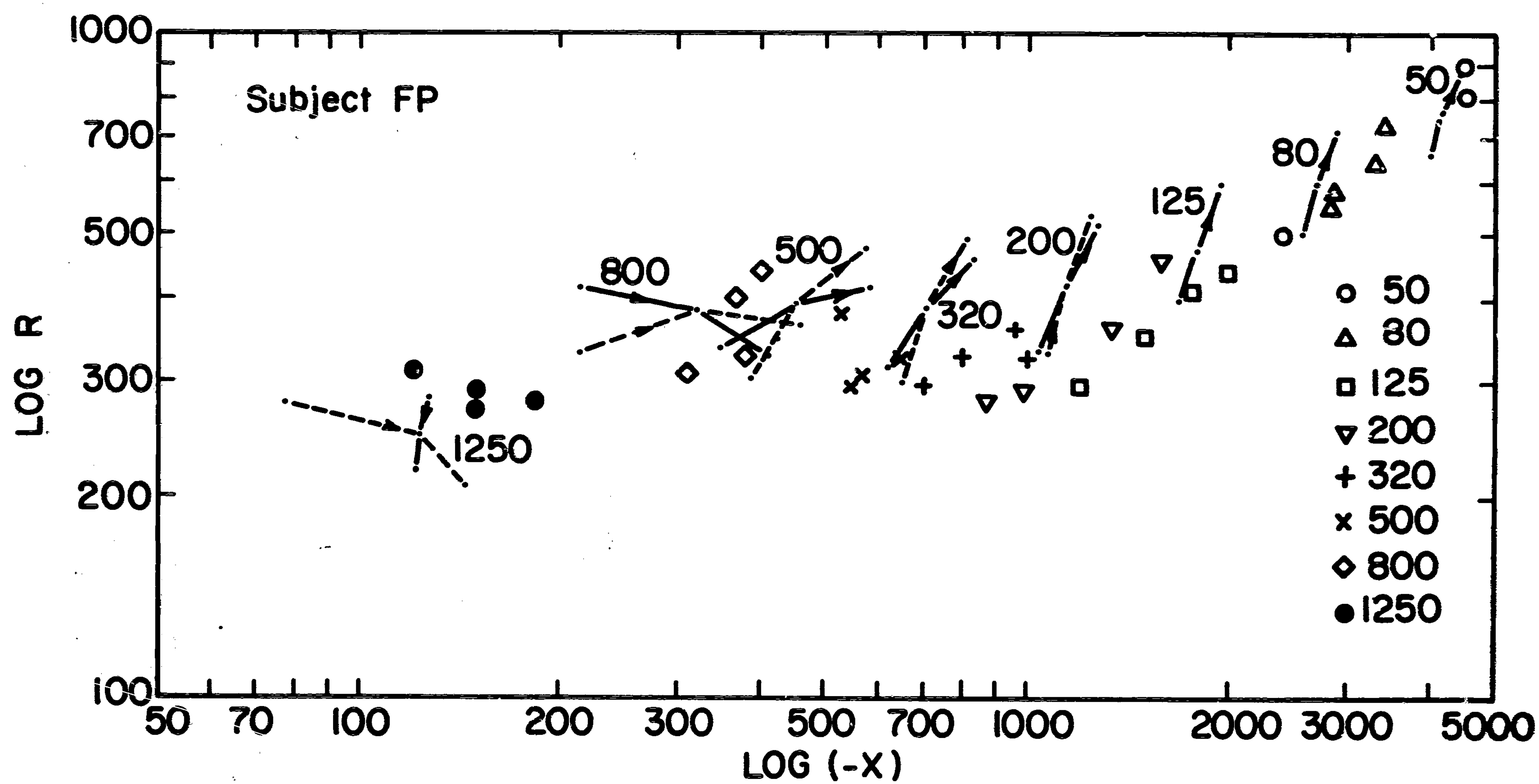

Subject FP
LOG R
LOG (-X)
1000
700
500
300
200
100
50
70
100
200
300
500
700
1000
2000
3000
5000
800
500
320
200
125
80
50%
1250
o 50
△ 80
□ 125
▽ 200
+ 320
× 500
◇ 800
● 1250

Fig. 29

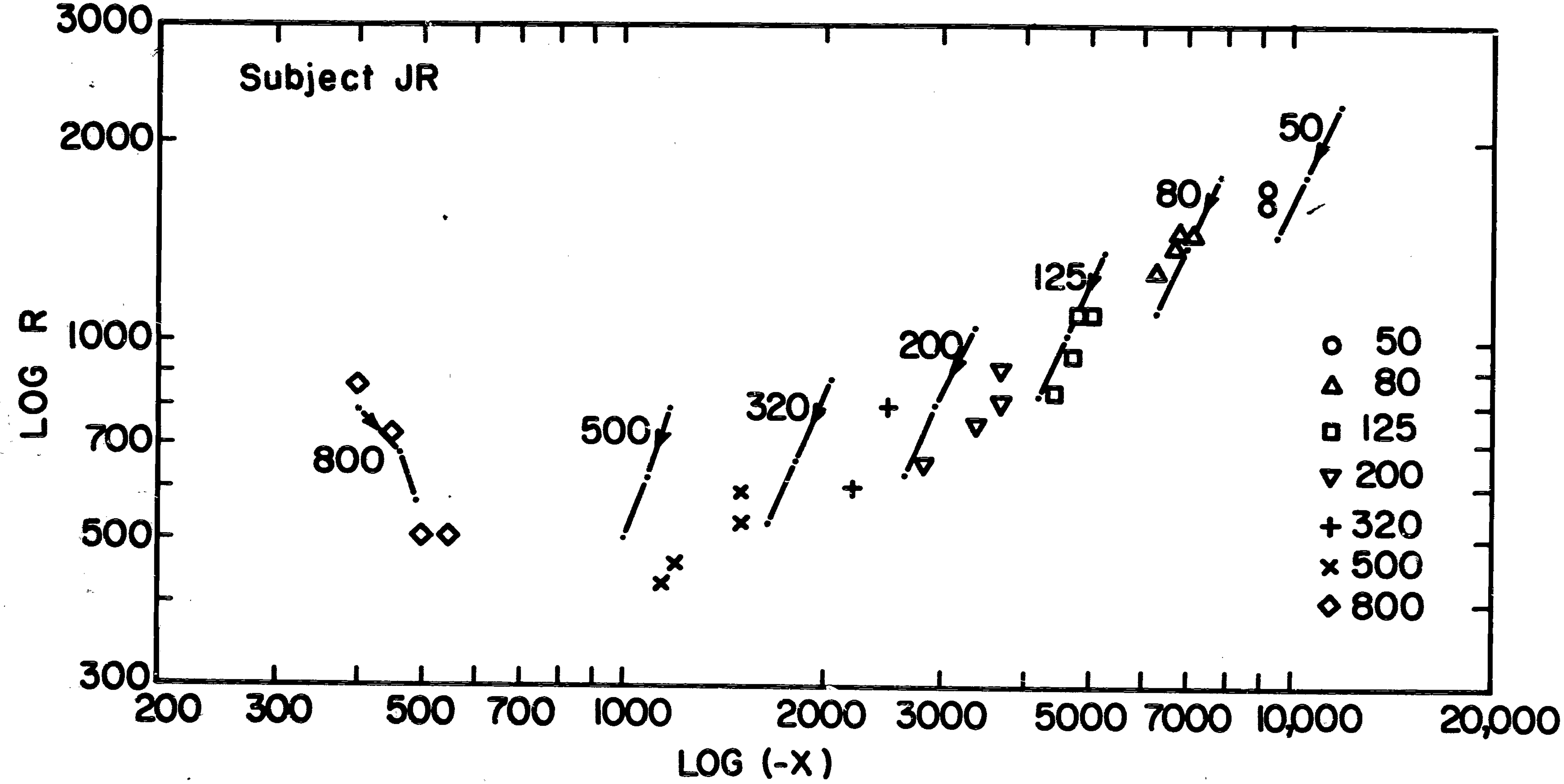
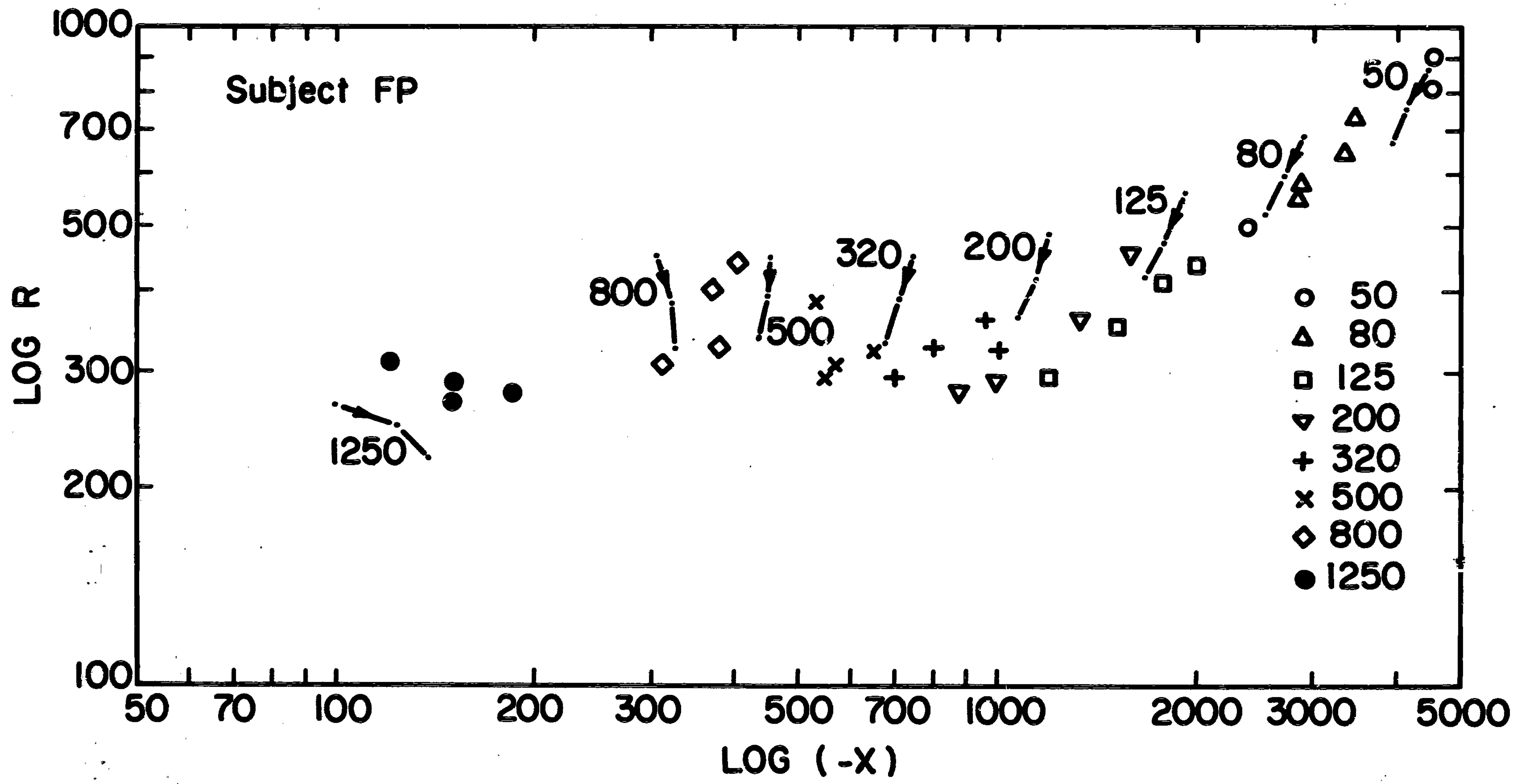

Subject JR
LOG R
3000
2000
1000
700
500
300
200
300
500
700
1000
2000
3000
5000
7000
10,000
20,000
LOG (-X)
50
80
125
200
320
500
800
∞
○ 50
△ 80
□ 125
▽ 200
+ 320
× 500
◇ 800

Fig. 30


Subject FP
LOG R
1000
700
500
300
200
100
LOG (-X)
50
70
100
200
300
500
700
1000
2000
3000
5000
50
80
125
200
320
500
800
1250
Fig. 31

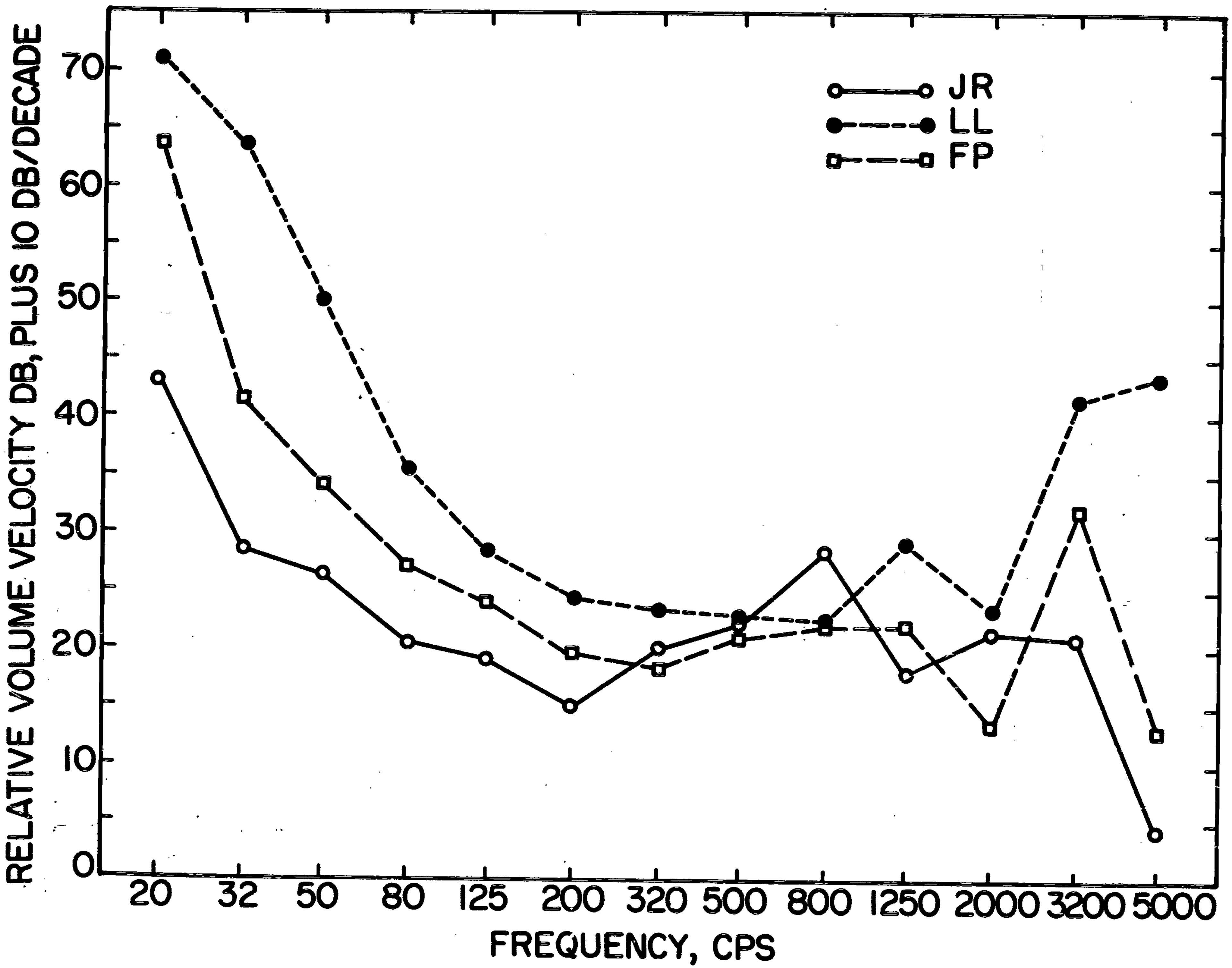

JR
LL
FP
70
60
50
40
30
20
10
0
RELATIVE VOLUME VELOCITY DB, PLUS 10 DB/DECADE
20
32
50
80
125
200
320
500
800
1250
2000
3200
5000
FREQUENCY, CPS

Fig. 32

# Repetition and Animacy in Active and Passive Sentence Construction

Joan Prentice, L. S. Barritt, & M. I. Semmel

# Repetition and Animacy in Active and Passive Sentence Construction[1]

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Indiana University

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Center for Research on Language and Language Behavior

## Abstract

A series of four cartoon-type slides were presented to 54 Ss for serial recall. The passive construction was used more often to describe events in which the object had been the actor in the preceding slide than when the actor had been the preceding object. Stimulus repetition was identified as a variable effecting an increase in verbal response strength. If a word at high response strength tends to be emitted early, there is a corresponding change in the probabilities of using alternative grammatical frames. Actor-object animacy was tentatively identified as a semantic attribute related to differences in the occurrence of the passive transformation.

The grammatical form which an utterance takes has been related to the learning and recall of information (Miller, 1962; Mehler, 1963; Gough 1965). Miller has gone so far as to suggest that investigation of sentence structure is research into the operation of the human mind, a term which has long been absent from the vocabulary of the psychologist.

The preceding studies raise questions about the nature of the stimulus conditions which determine the structure of sentences. For example, active and passive sentences convey the same denotative meaning but a different connotative meaning (Johnson, in press). Are the conditions specifiable which alter the probability that an utterance will be active or passive? The present investigation seeks to clarify the relationship between stimulus conditions and sentence production.

It has been found that sentences that have initial nouns at high response strength are learned more quickly than sentences that have terminal nouns at high response strength (Prentice, in press). Inference from these findings suggests that sentences in natural language will tend to start with a noun which is at high response strength. If the initial noun used is the receiver of some action, then the sentence form used to complete the utterance is likely to be in the passive form, e.g., "The boy was hit by the car." If the boy is the significant unit (i.e., at high response strength), then the sentence is passive. Conversely, if the car were the more important item, the above action would be described in the active sentence form.

The present study begins with a learning task in which the S is required to recall the happenings in a sequence of cartoon pictures. In Table 1 are displayed two sequences for illustration.

---

Insert Table 1 about here

---

Note that in each sequence there is an item common to each pair of pictures. The girl in the first two pictures, the ball in the next two, etc. In other words, there is a chaining of these separate happenings by the inclusion of one common item in each pair of pictures. If a subject were asked to recall the above sequences, a likely strategy would involve the use of the common item in each pair to aid in recall. In other words, the common item would tend to have higher response strength and therefore is predicted to occur first in recall and to influence the sentence form used.

In the "Active Probable" Sequence (Sequence A), the chaining involves the object in one picture becoming the actor in the succeeding picture. Therefore, it is predicted that for picture 2, Sequence A, the response will be "The girl kicked the ball," while in Sequence P it will be "The girl was kicked by the boy."

Another factor which can be related to sentence form is the animacy of the actor and/or object. Clark (1965) found that, when Ss were asked to complete active and passive sentence frames, the receiver of the action was more likely to be animate in passive frames (object of action used as sentence subject) than in active frames (object of action used as sentence object). In both active and passive frames, however, animacy resides most often with the intiator of the action. Similarly, Johnson (in press) found that Ss rated passive actors more animate than passive objects, although these ratings were more neutral in passive sentences than the corresponding positions in active sentences. In both studies, the Ss were required to deal with prescribed frames.

The present study seeks to clarify the relationship between stimulus conditions and the production of active and passive sentences. It is hypothesized that the manipulation of the response strength of nouns by the chaining procedure described above will influence the production of active and passive sentences.

## Method

### Materials

Two sets of four-colored cartoon slides were prepared: boy kicking girl, girl kicking ball, ball hitting pot, pot hitting boy (Set 1); and girl kicking boy, boy kicking pot, pot hitting ball, ball hitting girl (Set 2). Note that Set 2 is merely Set 1 with actor and object reversed.

In the sequence designed to elicit passives (Sequence P) the actor of one picture was the object in the succeeding picture. Conversely, in the sequence designed to elicit actives (Sequence A) the object of one picture was the actor in the next picture. (See Table 1).

### Procedure

Sets 1 and 2 were presented alternately to each S. Within each set the order of picture presentation was fixed by experimental condition (Sequence A or P), i.e., order is an independent variable. The first picture in each set was varied, however. Every picture was used once as the starting picture in a sequence. The order of use of the first picture was randomly determined. Three different orderings of starting points were derived (starting-point orders 1, 2, and 3). Table 2 displays the arrangement of Sequence A or P conditions by starting point orders.

Insert Table 2 about here

Ss were assigned randomly in blocks of six to starting point order (1, 2, or 3) and sequence conditions (A or P) in order of their appearance in the laboratory. Slides were shown at a 5-sec. rate on a Kodak Carousel projector. The projector was stopped at the end of each series of four slides, and each S was required to recall the slides in order. Responses were recorded by hand. Each sequence of four pictures was presented and recalled twice in succession. Thus, there were eight recall opportunities for a set of pictures when first presented. The second presentation of the same set (with a different starting point) gave eight more opportunities for response. With four pictures in a set (and hence four starting points) there were 32 recall opportunities for each set. Sets 1 and 2 were presented alternately, so with 32 response opportunities for each set, there were a total of 64 recall opportunities distributed equally across eight slides.

Subjects

The 54 Ss were University of California (Berkeley) undergraduates who were native speakers of English. They were paid for participating in the experiment.

## Results and Discussion

The dependent variable in this study was the number of passive sentences contributed by each S. The summary statistic for group comparison was computed by dividing the total number of passives produced by the number of Ss in that condition, A or P. The average number of passive constructions per S in Sequences A and P was .74 and 4.81, respectively. In the former condition only eight Ss emitted passives, while in the latter 16 gave this construction.

It was hypothesized earlier that the name of an item that appeared in both of two pictures would tend to be greater in response strength, to occur first in recall, and therefore, to influence the sentence form used in describing the pictures during recall.

Confirmation of this repetition hypothesis is dependent on an analysis of pairs of consecutively correct recalls. The Ss who received Sequence P gave reliably more passives as second correct responses than did Sequence A Ss (Mann-Whitney U test, $z = 3.22$, $p < .01$). Half the sequence P Ss, but only one Sequence A S, used the passive construction in a second consecutively-correct response. The respective means were 3.04 and .15 passives. Sequence P Ss made more errors than did Sequence A Ss, so the larger number of passives cannot be attributed to a greater opportunity for Sequence P Ss to meet scoring standards.

The passive construction was used more frequently in recall when the object was repeated than when the actor was repeated. The stimulus materials were different only in order of presentation. Repetition of an item (actor or object) in a sequence of events is thus identified as a variable which changes the probability that a passive sentence will be generated. It can be inferred that stimulus repetition increases the strength of the verbal response to that stimulus, and that a verbal response at high strength tends to be emitted early in a communication. Whether changes in verbal response strength, and concomitant probabilistic changes in selection of grammatical form, obtain at the time of observation (input and storage), or during recall (retrieval), is not answered in this study.

Table 3 lists the frequencies with which the various combinations of animate and inanimate actors and objects elicited the passive construction. The event most frequently eliciting the passive involved an animate object (boy or girl)

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Insert Table 3 about here

---

and an inanimate actor (pot or ball). An animate actor rarely occurred at the end of a sentence. Since only two slides were used in each of the possible animate-inanimate combinations, generalization of the results to the populations of events represented by the slides is premature. Nonetheless, the large discrepancies in the number of passives used to describe different events, which were alternatively described by the active construction, indicate that the use of a transform may vary along semantic and/or psychological dimensions.

## References

Clark, H. H. Some structural properties of simple active and passive sentences. J. verb. Learn. verb. Behav., 1965, 4, 365-370.

Gough, P. B. Grammatical transformations and speed of understanding. J. verb. Learn. verb. Behav., 1965, 4, 107-111.

Johnson, M. G. Syntactic position and rated meaning. J. verb. Learn. verb. Behav., in press.

Mehler, J. Some effects of grammatical transformation on the recall of English sentences. J. verb. Learn. verb. Behav., 1963, 2, 346-351.

Miller, G. A. Some psychological studies of grammar. Amer. Psychol., 1962, 17, 748-762.

Prentice, Joan L. Response strength of single words as an influence in sentence behavior. J. verb. Learn. verb. Behav., in press.

## Footnote

1. This study was prepared in part under the auspices of the Center for Research on Language and Language Behavior (pursuant to USOE contract OE 5-14-036) and in part during the senior author's USPHS postdoctoral fellowship Grant No. 1-F2-MH-22, 845-01, at the Institute of Human Learning, University of California, Berkeley.

Table 1

Set 1 of Cartoon Pictures Used as Stimuli
to Elicit Active and Passive Sentences

| Picture | Active Probable Sequence<br>Sequence A | Passive Probable Sequence<br>Sequence P |
|---|---|---|
| 1 | Boy kicking girl | Girl kicking ball |
| 2 | Girl kicking ball | Boy kicking girl |
| 3 | Ball hitting pot | Pot hitting boy |
| 4 | Pot hitting boy | Ball hitting pot |

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Table 2

Subject Assignment to Sequence Conditions A and P

by Three Starting Point Orders

| Starting Point Orders | Sequence: Active | Sequence: Passive | Totals |
|---|---|---|---|
| 1 | Set 1 / Set 2 Presented alternately N=9 | Set 1 / Set 2 Presented alternately N=9 | N=18 |
| 2 | Set 1 / Set 2 Presented alternately N=9 | Set 1 / Set 2 Presented alternately N=9 | N=18 |
| 3 | Set 1 / Set 2 Presented alternately N=9 | Set 1 / Set 2 Presented alternately N=9 | N=18 |
| Totals | N=27 | N=27 | N=27 |

Table 3

Distribution of Passive Sentences Among Animate And Inanimate Actors and Objects in Serial Recall of Visual Stimuli

| Object (traditional "subject") | Actor | Frequency Correct Passives | Per cent Correct Passives | Frequency Total Passives | Per cent Total Passives |
|---|---|---|---|---|---|
| Animate | Animate | 1 | .8 | 1 | .7 |
| Animate | Inanimate | 109 | 83.8 | 125 | 83.3 |
| Inanimate | Animate | 0 | 0 | 0 | 0 |
| Inanimate | Inanimate | 20 | 15.4 | 24 | 16.0 |

# A Comparison of the Psycholinguistic Functioning of "Educationally-Deprived" and "Educationally-Advantaged Children

L. S. Barritt, M. I. Semmel, & P. Weener

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# A Comparison of the Psycholinguistic Functioning of "Educationally-Deprived" and "Educationally-Advantaged" Children

Loren S. Barritt, Melvyn I. Semmel, and Paul D. Weener
Center for Research on Language and Language Behavior

Abstract

A comparison was made of the scores on the Illinois Test of Psycholinguistic Ability obtained by three groups of kindergarten and first-grade children. Two of these groups were chosen from a "disadvantaged" environment while the third group came from an "advantaged" setting. Analysis of profile similarities reveals the greatest concordance between groups on subtests requiring sequential habits. The largest discrepancies are on the "analogues," "vocabulary," and "grammar" subtests. Several explanations for these findings are discussed.

This study compares the language functioning of children who were predicted to differ in their language habits. It was the purpose of the present study to delineate the qualitative differences in the language abilities of the groups examined.

This report is part of a larger study, still in progress, which consists of an examination of the changes in language patterns of predominantly Negro children after one year in an "integrated" school. This larger study follows a traditional pre- post-test design. The present report deals only with a part of the pre-test phase.

The schools under investigation are in a suburban midwestern community of 60,000 people. The ongoing nature of the program of integration makes it desirable to treat this community anonymously in the present report. The median income of this community is $7,550. Approximately five per cent of the population are Negro and 94 per cent Caucasian.

This community, which we shall hereafter call Center City, was faced with the problem of <u>de facto</u> segregation in one of its schools. The Unity School in Center City was declared a <u>de facto</u> segregated school because approximately 70 per cent of its population were Negroes, while less than five per cent of Center City were members of this race. Segregation was to be abolished by transferring the Unity School children to predominantly white schools in the Center City system. This was the decision of the School Board.

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The questions raised by the desegregation procedure were manifold. The opportunity to research them was clear. However, it was also clear that research questions would have to be subordinated to the welfare of the children involved. The community would tolerate no segregated control group to act as a comparison for its integrated experimental group. With this limitation in mind the opportunity to learn from this situation still seemed clear.

It was the purpose of this study to compare the level of linguistic functioning of children in the kindergarten and first grade at a de facto segregated school with children at other schools in the Center City system. Those children who were attending a segregated school in the lower income area of Center City were designated "disadvantaged." These children were predominantly Negro.

A group of predominantly white children living in the suburban areas of Center City were identified as "advantaged" by virtue of the higher income level of the area from which they came.

## Method

Sample. The sample in the present study included the children from three different school populations. Table 1 contains a comparison of the three groups. All of the kindergarten and first grade children attending the Unity School in Center City were included. The Unity School is located in the "ghetto" in Center City where a majority of the Negroes live. The children in this school were

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Insert Table 1 about here

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scheduled to be integrated by being bussed to other schools in the Center City school system. These children are defined as being disadvantaged by virtue of their segregated school and the lower socio-economic status of the area from which they come.

The second sample of children was selected from the Diversity School. This school has children from an area which borders the area of the Unity School. Approximately 50% of the children at the Diversity School are Negro. It is possible that in the future Diversity School will be labeled a de facto segregated school and its children also dispersed throughout the Center City system. The sample of children for this study chosen from Diversity School were all attending the kindergarten and first grade. Since there were more children in the kindergarten and first grade in Diversity School than there were in Unity School, it was necessary to select a random sample from among these children at Diversity School. One restriction was placed on the selection: the children were chosen randomly from the "ghetto" that borders Diversity School. That is, no children were selected for this sample if they lived outside of the Center City "ghetto." It was hoped that by this sampling it would be possible to select children who would be like those at Unity School. The Diversity School would represent a "control" group for the Unity School children, since the Diversity School children would remain in their own neighborhoods attending a local school, while the Unity School children were being bused away from their local neighborhoods.

The third sample of children was chosen from the public schools which were scheduled to receive children from the Unity School. The children of the receiver schools also attend de facto segregated schools since less than 3% of the population of these schools is Negro. However, in this case the segregation is voluntary, since it is possible for white children to live in the "ghetto", while their Negro counterparts are denied the mobility (for economic and social reasons) of living outside the "ghetto." Most of the receiver schools lie in the suburban areas. Four schools scheduled to receive Unity School children were chosen, and then a random selection of kindergarten and first grade children was made from these schools.

Instruments. The Illinois Test of Psycholinguistic Ability (ITPA) was used to assess the language functioning of the children in this study. This test, developed by Kirk and McCarthy of the Institute for Research on Exceptional Children at the University of Illinois (Kirk & McCarthy, 1961), is appropriate for use with children from 2-1/2 to 9 years old. It contains nine subtests. A listing of the subtests and description of the tasks involved in each is contained in Table 2.

Insert Table 2 about here

The ITPA is an unusual test for several reasons. First, it is the only test currently available which has as its goal the comprehensive assessment of psycholinguistic functioning. Second, it is unusual because it was standardized on "normal" children only. These children were all Caucasians with IQs between 80 and 120, living in Decatur, Illinois. This "normal" sample is unusual in that the test was developed by special educators and is intended for use with "deviant" populations as a means of assessing their deviations from normality. The test intends that comparison be made with the "normal" group. A fuller discussion of the test and its standardization, along with critical comment, is available (Weener, Barritt, Semmel, 1965).

Administration. The ITPA is an individually administered test which is designed to be given only by trained examiners. In the present case graduate students at the University of Michigan were trained in the administration of the test during a two-week period in evening sessions. Consultants from the University of Illinois were employed to aid in this training procedure. Each child in the three samples was tested individually in the public school by a trained examiner during a two-week period from April 15 to May 1. In other words, these children were tested during the last month of school at the end of either kindergarten or first grade.

## Results and Discussion

The three samples were combined to compute the intercorrelations for the nine subscales of the ITPA. An examination of Table 3 indicates that three subscales intercorrelate very highly with one another. The Auditory-Vocal

Insert Table 3 about here

Association Test correlates .62 with the Auditory-Vocal Automatic. The Auditory-Vocal Automatic correlates .50 with the Auditory-Decoding. The Auditory-Decoding correlates .54 with the Auditory-Vocal Association. In other words, the "controlled vocabulary" test in which a child is asked to answer yes or no after being read a sentence, the "analogies test" in which a child responds with the correct word to an analogy, and the "grammar test" in which an inflectional ending is required, are the three subtests which intercorrelate most highly with one another.

Table 4 is a comparison of the three school samples on the nine subscales and total score of the ITPA. These are standard scores from norms presented in the ITPA manual. It is interesting to note that the largest significant F values between the three groups occurs on the Auditory-Decoding, Auditory-Vocal Automatic, and Auditory-Vocal Association tests. In other words, the same three tests which intercorrelate most highly with one another are the three tests which draw the lines of distinction most clearly between the three groups.

Insert Table 4 about here

On six of the nine subscales there are significant differences among groups. On only two subscales are there significant differences between the Unity School and the Diversity School groups. The two subscales which distinguish the Unity School and the Diversity School children are the "vocabulary" and "grammar" test, respectively, Auditory-Decoding and Auditory-Vocal Automatic.

An examination of the mean scores in Table 4 shows that the Unity School group scores at the mean on only one subtest, that being the Auditory-Vocal Sequencing. This test is very similar to the Digit Repetition Test on the Stanford-Binet, differing from that test only in the rate of digit presentation.

The three groups do not differ on the Visual-Motor Sequencing Test (requiring the reproduction of a series of geometric forms), the Auditory-Vocal Sequencing (digit repetition), and the Vocal-Encoding Subtest (description of an object). It should be noted that two of these tests are sequential tasks.

One interesting observation which can be made from the present study concerns the performance of the Unity and Diversity School children on tasks requiring sequential habits. The norming group on which these standard scores are based were not disadvantaged children in any sense of the word. The Unity and Diversity school children are not different from the normal sample on sequential tasks. This finding can be related to a study done with retarded and normal children (Semmel, Barritt, Bennett, Perfetti, 1965). A comparison was made of the word-association responses of retarded and normal children. It was found that normal children gave more responses of the same form class as the stimulus words than did retarded subjects matched for age. The retarded subjects of lower intelligence tended to give more responses to word-association stimuli which could occur sequentially in a sentence. It would appear that strong syntactic habits are characteristic of higher-level functioning and that sequential language habits are characteristic of more primitive levels of language ability. The relationship between the findings of these studies can only be suggested from the present data. A future study will be necessary in order to examine the relationships between the sequential subscales of the ITPA and sequential responses on a word-association task. For the present it seems reasonable to explain the lack of difference between advantaged and disadvantaged groups on this type of task as being related to developmental phenomena.

The third test which did not produce differences between groups was the Vocal-Encoding subtest. The task on this test involves the description of a simple object. It should be noted that most responses to this subscale at early age-levels consist of labeling words and simple sentences about the function of the object. Children usually develop facility with nouns earlier than they do with other form classes of words (Templin, 1957). Tasks which require simple labeling responses do not usually distinguish well between different stages of language development. Again the lack of discrepancy is consistent with our knowledge of developmental patterns.

Figure 1 contains a profile of the three school samples, illustrating the discrepancies and convergence of scores on the ITPA.

Insert Figure 1 about here

At least two hypotheses can be suggested for the lack of difference between the groups on sequential tasks. One hypothesis might be called the Interference Hypothesis, and it would go something like this. Since the "educationally-deprived" children have not developed the higher level facility with their language, they are relatively free from hypotheses about learning tasks presented to them. In the case of the present ITPA subscales these children are asked simply to memorize a meaningless series of either objects or numbers. It can be suggested that the Ss do not attempt to impose any structure on this task; rather, they simply get at the business of remembering in rather rote fashion what has taken place, and then attempt to reproduce it as best they can. Children with more sophisticated language habits attempt to impose a structure on this situation in much the same way that they impose structure on meaningful tasks. When faced with a task that is essentially meaningless, their "set" to impose structure interferes with learning.

An alternative hypothesis can be called the No-Difference Hypothesis. This alternative would explain the homogeneity of performance on sequential tasks as a function of their culture-free nature. In other words, performance on sequential subtests is dependent on the relatively fixed capacity of a subject's short-term memory, while performance on other subtests requires the ability to "structure" learning which is relatively more dependent upon experience.

It seems to the authors of the present study that the No-Difference Hypothesis explains the present findings better than the Interference Hypothesis. Although the role of interference in the repetition of a series of digits seems a reasonable explanation, the attempt to impose structure on a series of geometric shapes does not.

The present study, then, finds that three of the ITPA subtests distinguish the language functioning of "advantaged" and "disadvantaged" children. They are most different on a vocabulary task, an analogies task, and a task which measures what appear to be grammatical habits. There are no differences between the groups on tasks which require sequential habits.

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Table 1

Sex, Race, and Grade Distribution in

Center City Public School Samples

| Group | Sex | | Race | | Grade | |
|---|---|---|---|---|---|---|
| | M | F | W | N | K | 1 |
| Unity | 34 | 30 | 11 | 53 | 32 | 32 |
| Diversity | 35 | 30 | 32 | 42 | 31 | 34 |
| (Receivers) | 31 | 31 | 57 | 5 | 30 | 32 |

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Table 2

Description of ITPA Subtests

1. Auditory Decoding--Vocabulary test requiring only "yes" or "no" answer, e.g., Do females slumber?

2. Visual Decoding--Matching a stimulus picture to its perceptual counterpart, e.g., Office table and coffee table.

3. Auditory Vocal Association--A verbal analogies test, e.g., Soup is hot. Ice cream is ________.

4. Auditory Vocal Automatic--Correct grammatical form must be provided in sentences, e.g., Here is an apple. There are two ________.

5. Auditory Vocal Sequencing--Digit repetition as in Binet.

6. Visual Motor Association--Relate pictures on some conceptual basis, e.g., Sock with shoe.

7. Visual-Motor Sequencing--Sequence of geometric shapes must be reproduced from memory.

8. Motor Encoding--Expressing one's ideas in terms of meaningful gesture, e.g., "Show me what you should do with this." (hammer)

9. Vocal Encoding--Describe a simple object verbally, e.g., Block, nail.

Table 3

Intercorrelation Matrix for ITPA Subtests

| | Aud.-Voc. Auto. | Vis. Dec. | Mot. Enc. | Aud.-Voc. Assn. | Vis. Mot. Seq. | Voc. Enc. | Aud.-Voc. Seq. | Vis. Mot. Assn. | Aud. Dec. |
|---|---|---|---|---|---|---|---|---|---|
| Aud.-Voc. Auto. | -- | | | | | | | | |
| Vis. Dec. | 26 | -- | | | | | | | |
| Mot. Enc. | 28 | 38 | -- | | | | | | |
| Aud.-Voc. Assn. | 62 | 45 | 39 | -- | | | | | |
| Vis.-Mot. Seq. | 20 | 22 | 24 | 35 | -- | | | | |
| Voc. Enc. | 28 | 32 | 38 | 38 | 14 | -- | | | |
| Aud.-Voc. Seq. | 23 | 06 | 13 | 37 | 15 | 21 | -- | | |
| Vis.-Mot. Assn. | 22 | 26 | 16 | 31 | 11 | 33 | 10 | -- | |
| Aud. Dec. | 50 | 24 | 32 | 54 | 14 | 21 | 25 | 32 | -- |

Table 4

Comparison of ITPA Mean Standard Scores for

Three School Samples

| Subscale | $Group_1$ | $Group_2$ | $Group_3$ | F | Significant Differences |
|---|---|---|---|---|---|
| Aud.-Voc. Auto. | -.60 | -.06 | .17 | 9.00** | 1,2*<br>1,3** |
| Vis. Dec. | -.26 | -.12 | .19 | 3.44* | 1,3* |
| Motor Enc. | -.71 | -.37 | -.24 | 4.49* | 1,3** |
| Aud.-Voc. Assoc. | -.43 | -.09 | .44 | 8.94** | 1,3**<br>2,3* |
| Vis.-Mot. Seq. | -.28 | -.41 | -.17 | .96 | |
| Voc. Enc. | -.14 | -.38 | -.15 | 1.08 | |
| Aud.-Voc. Seq. | .04 | .24 | .34 | 1.29 | |
| Vis. Mot. Assoc. | -.13 | -.29 | .20 | 3.73* | 2,3* |
| Aud. Dec. | -.44 | .10 | .53 | 10.96** | 1,2*<br>1,3** |
| Total Score | -.53 | -.31 | .21 | 6.19** | 1,3**<br>2,3* |

Group 1 = Unity School
Group 2 = Diversity School
Group 3 = Receiver Schools
* Sig ≤ .05
** Sig ≤ .01

Figure Caption

Fig. 1. A profile analysis of the three school samples, illustrating the discrepancies and convergence of scores on the ITPA. Note that the profiles for the Diversity School and the Receiver School are parallel. The profile for the Unity School crosses the profile of the Diversity School on the vocal encoding and the visual-motor sequencing.

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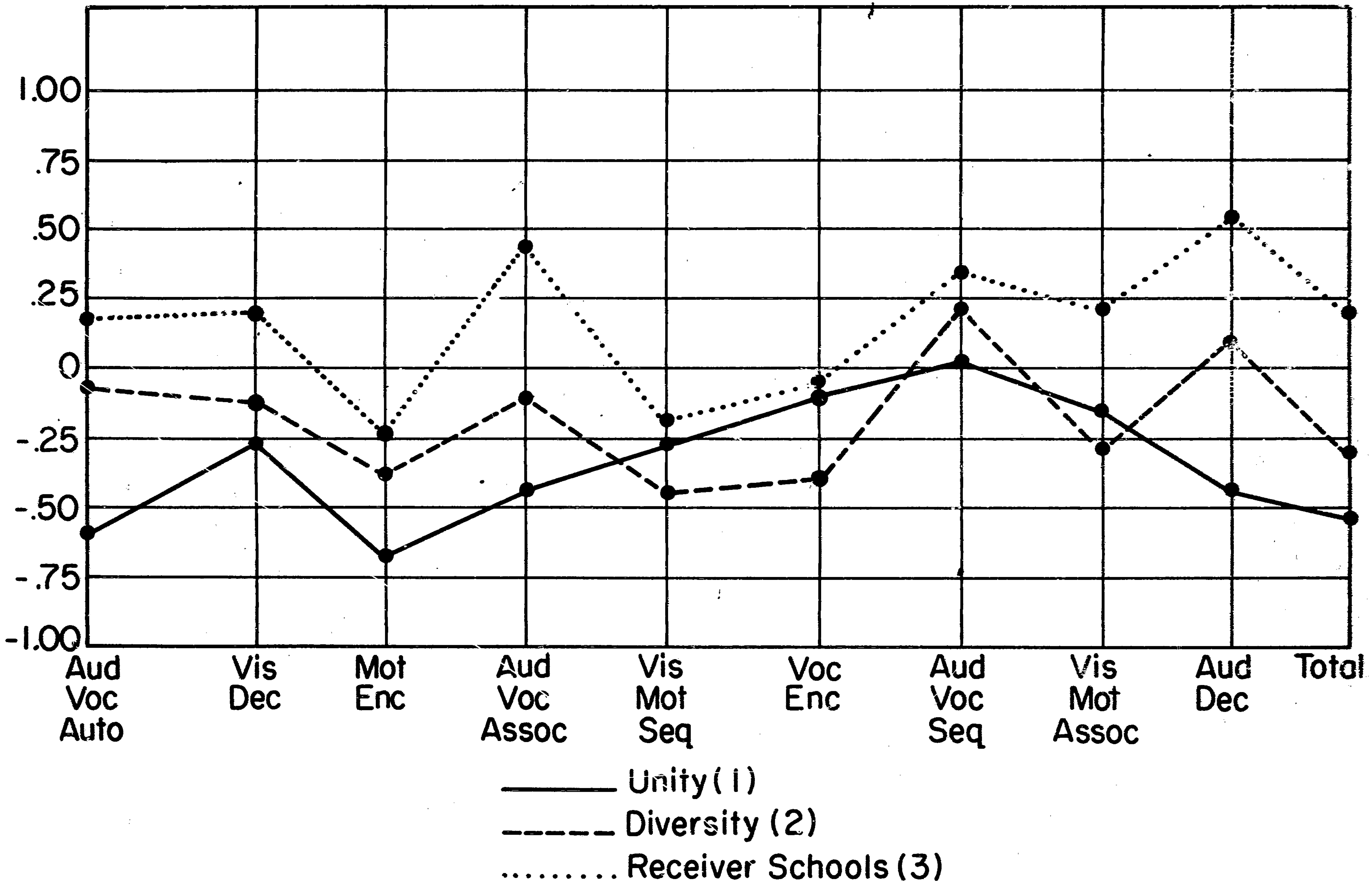
1.00
.75
.50
.25
0
-.25
-.50
-.75
-1.00
Aud Voc Auto
Vis Dec
Mot Enc
Aud Voc Assoc
Vis Mot Seq
Voc Enc
Aud Voc Seq
Vis Mot Assoc
Aud Dec
Total
Unity (1)
Diversity (2)
Receiver Schools (3)

Fig. 1

# Developmental Psycholinguistics

D. McNeill

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Developmental Psycholinguistics[1, 2]

David McNeill

Abstract

The aim of this review of recent empirical work on the acquisition of syntax by children is to examine the intersection of this acquisition with linguistic theory, and then to develop a theory of language acquisition that will be both consistent with linguistic theory and cover the facts of acquisition insofar as they are now known. Among the topics considered are: the nature of early speech, the form of early grammars, the role of linguistic universals, the possibility of an inborn capacity for language acquisition, the development of transformations, the interaction of parental speech and children's capacity for language, and the difference between comprehension and production. Throughout, the explanatory problem is taken to be the rapid acquisition of abstract linguistic structure.

Major developments have been taking place recently in the scientific study of language. The present paper is concerned with two of them: the formulation of linguistic theory, and empirical studies of language acquisition. Linguistic theory and studies of language acquisition have existed side by side, occasionally influencing each other, but in the main the two bodies of work have evolved separately. The intention of the present paper is to examine their intersection in an effort to interpret the empirical studies in the light of linguistic theory. The aim is to develop a theory of language acquisition that will be consistent with linguistic theory and will cover the facts of acquisition as they are now known.

The fundamental problem to which we address ourselves is the simple fact that language acquisition occurs in a surprisingly short time. Grammatical speech does not begin before 1.5 years of age; yet, as far as we can tell, the basic process is complete by 3.5 years. Thus, a basis for the rich and intricate competence of adult grammar must emerge in the short span of 24 months. To appreciate this achievement, we need only compare the child with himself in other departments of cognitive growth, as outlined, say, in the work of Piaget. Add to rapid acquisition the further fact that what is acquired is knowledge of abstract linguistic structure, and the problem of accounting for language development can be seen to pose unusual difficulties for our collection of explanatory devices. The implications of the very rapid growth of grammatical competence will become apparent in the following pages.

The past half-dozen years have seen a great change in the study of child language. In former years, attention was concentrated on surveys of vocabulary, frequency-counts of the various grammatical classes, and case histories of the gradual elimination of errors in speaking. The basic assumption appears to have been that child language was adult language, filtered through a great deal of cognitive noise and impoverished of vocabulary. The scholar supposed that he knew the child's grammar in advance, and that it was reasonable to use the categories of adult grammar to describe child language. The change from this point of view has been simple but fundamental, and mainly methodological. Recent studies look upon the young child as the fluent speaker of an exotic language. The psycholinguist's problem, therefore, is analogous to the problem faced by a field linguist. Both the student of Urdu, say, and the student of child language want to characterize a speaker's grammar, and neither supposes he will profit much by imposing the grammar of well-formed English onto the corpus.

Most of the recent studies have been observational and longitudinal. Typically, a small sample of children is visited, roughly at monthly intervals, during the period of rapid linguistic growth. Usually, everything is tape-recorded in order to obtain a complete record of all speech to and from the child. With the evidence of these records the psycholinguist tries to write a grammar which accounts for what the child was overheard saying; this grammar is the principal object of interest, and changes in successive grammars are the way of picturing growth. For a good account of the technique of writing such grammars, see Brown and Fraser (1964). So far, the bulk of this new work has come from three sources: Brown and his colleagues at Harvard, (Brown and Fraser, 1964; Brown, Fraser and Bellugi, 1964; Brown and Bellugi, 1964); Ervin and Miller at the University of California at Berkeley (Ervin, 1964; Miller and Ervin, 1964); and Braine at Walter Reed Army Hospital (Braine, 1963).

Before describing their work, however, something must be said on the relation between linguistic competence and linguistic performance. These differ profoundly, although the difference is often overlooked. Our concern in the study of language acquistion is with the development of competence; only after we have understood this to some degree can we hope to understand performance. Consider first the general distinction. Competence is an abstraction away from performance; it represents the knowledge a native speaker of a language must have in order to understand or produce any of the infinitely many grammatical sentences of his language; it represents a native speaker's linguistic intuitions--his realization that the man hit the ball is grammatical but the man virtued the ball is not. A grammar is a representation of competence; it is a characterization, therefore, of linguistic knowledge.

Performance, on the other hand, is the expression of competence in talking or listening. One is competent to deal with an infinite number of grammatical sentences; but one's performance may be distracted in various ways. Performance operates under constraints of memory, which is finite, and time, which must be kept up with. Such limitations are irrelevant to competence. We know that one's competence can include grammatical constructions too long or complicated to be remembered, as evidenced by the fact that one can understand longer written than spoken sentences. And we know that competence includes sentences spoken too fast to be grasped, as evidenced by the fact that repetition of a sentence can lead to comprehension.

The same distinction between competence and performance must be honored in the case of child language. We want, first of all, to account for the emergence of linguistic competence itself, something we shall not accomplish by confusing competence with performance. In addition, we are interested in

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eventually accounting for a child's linguistic performance, and this, too, requires that we rigorously maintain the performance-competence distinction. It is possible to describe performance without explaining it, but if we wish to explain performance we must show how it derives from competence, that is, how the regularities in a child's grammatical knowledge produce regularities in his overt linguistic behavior. Nothing short of this will suffice.

There are, of course, serious difficulties that face an effort to discover the linguistic competence of children. The basic trouble is a severe constraint on the kinds of available data. A linguist devising a grammar for adult English has access to many sources of information. In particular, he can consult his own grammatical intuitions and obtain reports from other adults about theirs. In this way, a linguist can easily discover that Adam was naughty and Adam was hit, for example, have quite different structures. The situation for the grammarian of child language is far less convenient. We would also like to obtain grammatical judgments from children, as these would tap their linguistic intuitions if such exist; but, usually, this is impossible, for a reason that can be seen in the following dialogue (Brown and Bellugi, 1964):

Interviewer: "Now Adam, listen to what I say. Tell me which is better...some water or a water."

Adam: "Pop go weasel."

The two-year-old child is recalcitrant and we cannot expect to obtain grammatical judgments from him. Lacking such judgments, however, we must write grammars on a child's observed speech. This makes grammar-writing for children difficult, though not impossible. As we shall see shortly, a good deal has been learned about the process of language acquisition through even these limited means.

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## Early Speech

Sometime between 18 and 24 months, most children begin to form simple two- and three-word sentences. Because our evidence is limited to what a child says, this is the earliest point at which we can study grammar. Before that time, roughly from the first birthday, children utter single words, but they produce none of the patterned speech from which a grammatical account is written.

What are the characteristics of these first sentences? They are greatly cut down, as the following examples show (taken from Brown's records):

Two boot

A gas here

Hear tractor

See truck mommy

There go one

Put truck window

Adam make tower

Brown and Fraser (1963) have called this kind of speech "telegraphic". The name is apt, since one feature of these sentences is that they are reduced in almost the same way that adults reduce sentences for telegraphic transmission. In both cases, articles, prepositions, and auxiliary verbs are likely to be omitted. In these examples, we find an article missing from hear tractor, an article and preposition missing from put truck window, and an auxiliary verb missing from Adam make tower. However, the child also eliminates some things an adult would consider essential in his telegram. An inflection is missing from the verb in there go one; similarly, an inflection is missing, this time -ing, in Adam make tower; and the plural inflection is not on the noun in two boot. There is one further difference, represented here by just one example although it is quite common in child speech. The child combines things that an adult would not, as in a gas here. In sum, telegraphic speech generally leaves out articles, prepositions, auxiliary verbs, and inflections on verbs and nouns, while it adds ungrammatical word combinations. Except for the ungrammatical combinations, all these features of telegraphic speech can be related to the fact that the missing words are unstressed in adult speech. Articles, prepositions, auxiliaries and inflections are all phonetically obscure. Their discrimination in the flow of adult speech presumably is more difficult for the child, and so they do not appear in his own (Brown and Fraser, 1964).

It is tempting to carry the telegraphic analogy farther. Perhaps children abbreviate for the same reason adults do, to save on costs. An adult will eliminate words that do not contribute enough to the intelligibility of the message to justify the price in currency; similarly, a child may eliminate words that cannot be justified in terms of their cognitive cost. It is true that children of two have very limited memory spans. Two digits is the standard performance on mental tests at this age. Thus, it is conceivable that children, like adult telegram writers, try to preserve the informational content of their messages while economizing on length.

However, the telegraphic analogy becomes misleading if we take it so far as to conclude that children are actually abbreviating well-formed sentences. A limitation on memory probably constrains the length of children's sentences, but it does not work simply by eliminating words from sentences that otherwise would be fully grammatical. Rather, the child possesses a simple grammar, the output of which is telegraphic speech. If we found a two-year-old with an adult-sized memory, we would expect him to say such things as "Hear tractor go window not see mommy", and not the well-formed equivalent, "I hear a tractor going by the window, but I can't see it, Mommy."

Telgraphic speech, therefore, is a generic term for the type of speech one hears from young children. It is a result, not a process, and it reflects more than limited memory. In order to account for it, we must look more closely at children's early grammars.

The First Grammars

Brown, Ervin, and Braine have all collected records of the speech of two-year-old children. Braine's transcriptions are probably from a slightly earlier point in development than Brown's or Ervin's; none of Braine's subject had been heard to produce any word-combinations at all before he began to follow them, whereas Brown's and Ervin's subjects were already at the stage of two-, three- and even four-word utterances by the time the studies began. Unfortunately, Braine did not make tape-recordings of his subjects, but relied instead on parental diaries. It is difficult to say what differences there are between a diary-sample and a tape-recorded one, but in most essential respects, Braine's results are duplicated by Brown and Ervin.

In each of these studies, the earliest word-combinations were not random. A very large proportion of the children's utterances conformed to a small number of simple patterns; because they are patterned, these early utterances can be appropriately dignified by calling them "sentences".

In this section, attention will be restricted to two-word sentences. They seem to be composed by selecting words from primitive grammatical classes in a fixed order. One common arrangement consists of the juxtaposition of what Braine has called "pivot" and "open" classes. Sentences of this type have been observed in every study, but terminology differs: Brown uses "modifier" instead of "pivot" and Ervin uses "operator". We shall adopt Braine's terminology for reasons of default. Brown's "modifier" refers to a special grammatical relation that does not always accompany the pivot-open construction, and Ervin's "operator" results in symbolic ambiguity with "open class" when we try to abbreviate. In adopting his terminology, however, we do not subscribe to Braine's theoretical interpretation of the P-O distinction (Braine, 1963).

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The pivot class characteristically has few members compared with the open class, and each pivot word is used more frequently than individual open-class words. Moreover, the pivot class is relatively slow to take in new members. In all these characteristics, as Braine (1963) has pointed out, pivot words resemble function words in adult speech. However, when we recall that function words are generally absent from early child speech, the analogy is somewhat startling, because it means that the statistical imbalance of the P-O distinction cannot be imitated from adults. If the imbalance were an imitation, all pivot words should be function words. But, as we shall see shortly, the pivot class can contain words from adult content classes (adjectives, verbs, etc.). We shall argue later that a P-O distinction could not be inferred from adult speech, either, but thoughts on this subject are best postponed until we are prepared to discuss the role of linguistic universals in acquisition.

The statistical imbalance of the P-O distinction is difficult to explain. Braine's theory is specifically built around this imbalance, but it cannot account for other facts of early child language, particularly the subsequent development of the pivot class. Braine holds that pivots are words for which the child has learned a fixed sentential position, and that the statistical imbalance results from the fact that at first the position of only a few words is known. Thus, any P-O sentence would use a few pivots with high frequency, and many open-class words with low frequency. But basing the pivot class only on word-position would lead to a haphazard assortment of words as members, and that is precisely what the pivot class is not.

Apart from the P-O construction, early two-word sentences can involve the juxtaposition of open-class words. Sometimes this is done with words from a single open class, at other times with words from different classes. It never happens, however, that two-word sentences are made up only of pivots. We shall take as an example the P-O construction, even though the

O-O construction is more frequent in the records of some children's speech (Brown's, for example), because it nicely reveals one basic phenomenon of language acquisition -- the emergence of grammatical classes. We will return to the O-O construction when we discuss children's early grammatical rules.

Consider Table 1, which summarizes some of the speech of one child in each of the three studies. On the left, in each column, are the pivot classes, and next to them are the corresponding open classes. A sentence is formed by selecting one word from the list on the left and following it by a word from the list on the right. Most children have more than one pivot class, which might appear in either first or second position. The position of any particular pivot and open class, however, is fixed. Table 1 reproduces only first-position pivots, since these seem to be more common.

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Insert Table 1 about here

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It is important to recognize the basis for classifying words together into single class. The evidence is always distributional: two words are considered to be in the same grammatical class if their privileges of occurence are the same. If the privileges of occurrence differ importantly, words must be classified differently. Look, for example, at Ervin's list. <u>This</u> and <u>that</u> are classified together because they each occur with <u>arm</u>, <u>baby</u>, <u>dolly's</u> etc. <u>The</u> and <u>a</u> also appear with some of these words, but <u>this</u> and <u>that</u> are not classified with <u>the</u> and <u>a</u> because the two pairs have some unique distributional possibilities. <u>The</u> and <u>a</u> appear with <u>other</u>, whereas <u>this</u> and <u>that</u> do not; and <u>this</u> and <u>that</u> appear with <u>come</u>, <u>doed</u>, etc., but <u>a</u> and <u>the</u> do not. The distributions overlap, but they are not identical.

Inevitably, the distributional procedure becomes vague in application. Once a child's vocabulary is of any size at all, individual open-class words

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are so rarely repeated that mechanically looking for shared privileges of occurrence leads to no classes at all. Thus, Braine sometimes classifies words together as pivots when they have no open-class words in common. He feels justified in doing this because he can find no "systematic" differences in their distributions. Byebye, more and allgone, for example, do not overlap at all in Braine's records if one measures overlap in terms of individual words. But if one measures overlap categorically, the three pivots have nearly identical distributions. Byebye is followed by celery, allgone is followed by lettuce, and more is followed by melon; similarly with another dimension, more is followed by taxi, and byebye is followed by plane. The grammarian necessarily imposes his knowledge of English onto the child's corpus if he wants to use the material at all. The advantage of this procedure over the earlier one of simply using the grammar of English is that the search for distributional similarities and dissimilarities will constrain the distortion of the grammarian's own grammar. It is clear, however, that distributional classification cannot eliminate such distortion entirely.

Table 1 merely summarizes speech, but we are taking it also as a statement of the children's competence. We suppose they really had organized their vocabularies into classes, roughly in the way indicated in the table. And since the children's sentences had the form, pivot word followed by an open-class word, we also suppose their competence included the rule:

(1) $S \longrightarrow (P) + O.$

The rule includes the possibility of not choosing the pivot since open-class words, but not pivot-class words, can stand alone in children's speech. That is, Rule (1) allows for both two-word and single-word utterances.

In every record, sentences 3 and 4 words long also appeared. In the case of Brown's subject, these had a hierarchical structure, and probably the longer sentences in Braine's and E vin's records were similarly produced.

Hierarchical aspects of children's grammar will be discussed in a later section devoted to grammatical rules. The presence of hierarchical constructions does not affect our conclusions about the grammatical classes in the child's repertoire.

There is some support for the assumption that the P-O distinction and Rule (1) reflect children's competence at this early stage. For one thing, the chief alternative hypothesis is that the children had independently memorized each of the strings in the table, and that seems implausible in view of the quantity of the material. For the child in Braine's sample, for example, it would mean the memorization of at least 102 combinations -- that being the size of his corpus -- and surely this is an underestimate since these 102 sentences are only the ones that happened to turn up in Braine's records. Another reason for crediting children with Rule (1) is the presence of combinations of P and O that are very unlikely to be imitations or reductions of adult sentences. Take, for example, the set of sentences with _allgone_ as a pivot word in Braine's list. It includes _allgone shoe_, _allgone vitamins_, _allgone egg_, _allgone lettuce_, etc.. None of these could be an imitation since each is an inversion of the appropriate adult model. Compare _allgone shoe_ to _the shoe is allgone_. Ervin's subject produced sentences such _that doed_, _there pretty_, and Brown's subject, making use of hierarchial constructions, produced _big a truck_ and _a that horsie_. It is unlikely that children hear this kind of fractured English from their parents.

Sentences that cannot be accounted for as reductions of adult sentences provide the best evidence that children know productive rules. The point of these examples is that they are cut from the same pattern as many others in children's speech that are not fractured English. It would be completely _ad hoc_ to distinguish the ones that are fractured from the ones that are not. Instead, it is more parsimonious to assume that children generate all these sentences and that the rules and word-categories we infer from their speech reflect some kind of primitive competence.

The same conclusion is suggested by a striking phenomenon reported by Weir in Language in the Crib (1962). The title is not fanciful. She collected the pre-sleep monologues of her two-and-a-half year old son and subjected them to linguistic analysis. The striking phenomenon is that the boy practiced rules similar to (1). In the following series, for example, the boy repeatedly substituted expressions in the frame go:

go for glasses
go for them
go to the top
go throw
go for blouse
pants
go for shoes

The verb is the pivot word, so the rule is of the form S $\longrightarrow$ P + O, and we can see the child trying one open-class expression after another, exercising the rule. Weir's child was older and had a considerably more elaborate grammar than the children in Braine's, Brown's, or Ervin's studies, and we find him sometimes carrying on more than one substitution at once, as in the first two lines. The fact that not all the substitutions are single open-class words again reflects a hierarchial development.

What can be said of the early competence of children? Note first of all that the pivot and open classes are typically heterogeneous from the point of view of adult grammar. The pivot class in Braine's grammar for example, contains adjectives (big, more, pretty and possibly allgone), verbs (see, and possibly byebye and nightnight), a pronoun (my), and a greeting (hi). Braine's criteria for placing words into the same class may have been too relaxed, so his list might overestimate the variety of adult grammatical classes that is likely to end up in a child's pivot class, but there is no question of the general fact of heterogeneity. It appears just as impressively in Brown's records for the pivot class of his subject, and in the open class of Ervin's subject. Brown's subject had two kinds of pronouns, (my, that), articles, (a, the) and adjectives (big, green, etc.) in his pivot class. Ervin's subject had nouns (arm, baby, etc.) and adjectives (pretty, yellow, etc.) in every open class, and in addition, there were verbs (come, doed, etc.) in one class and a determiner (other) in a second. No child in any of these studies has revealed both pivot and open classes that agree exactly with classes in the adult grammar. Sometimes the pivot class may correspond to an adult category, as apparently was the case with Ervin's subject, and sometimes a child may have an open class that agrees fairly well with an adult class, as Brown's and Braine's subjects apparently did. But even here, there is diversity on a reduced scale: Brown's subject did not honor the adult distinction between mass and count nouns -- producing sentences such as a gas and some milks; and Braine's subject had one adjective, hot, in an open class that otherwise contained only nouns in adult grammar. One suspects that diversity is initially the rule for both the pivot and open classes, but it does not always appear in these studies because the two classes can develop at somewhat different rates. What we find in the case of Ervin's subject, therefore, probably is the outcome of faster development of pivot classes than open classes, whereas in the case of Brown's or Braine's subject, we have the opposite, open classes developing faster than pivot classes. We do not have sufficient information to judge whether or not this suspicion is correct, for no one has kept the extremely detailed records that would be required; but it seems plausible. As we shall see next, the development of grammatical classes takes the form of differentiation, or subdivision, of a child's primitive grammatical classes. Thus, the relative homogeneity of the pivot classes in Ervin's grammar and the open classes in Brown's and Braine's grammars could conceivably be the outcome of differentiation that went on before the studies began.

Differentiation of the pivot class

Differentiation has been described by Brown and Bellugi (1964). Insofar as one can tell, this direction of development is followed by all children. Among Brown and Bellugi's subjects, open classes were relatively well differentiated at the time the children were first observed, so our usable information concerns the history of the pivot class. Moreover, information from different children in Brown and Bellugi's study cannot be combined since the particular words in the pivot class differ somewhat from child to child. Instead, we shall present the developmental history of one child, the same one whose initial P-O distinction is reproduced in Table 1. Essentially the same conclusions are reached from an examination of the records of other children in Brown's project.

We have information from three points in this child's development, the times at which grammars were written from the child's speech. The corpus at the first point was reproduced in part in Table 1. The second point is 2.5 months later, and the third point is 2.5 months later than that; the entire span covers 5 months. As we shall see, the process of differentiation is not complete by the time the third point is reached, but it is far advanced.

The child's progress during these 5 months can be summarized by the diagram in Figure 1. On the left is the actual history of the pivot class after the child was first observed. On the right, are the rules of sentence-formation with which the grammarian was compelled to credit the child in order to account for his sentences.

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Insert Figure 1 about here

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The diagram on the left of Fig. 1 is not a phrase-marker. However, the fact that it is drawn as a tree-structure may have some significance, which will be discussed later.

For the moment, the diagram in Fig. 1 can be taken as chronology of the child's development. As was noted before, at Time 1 the pivot class consisted of <u>my</u>, <u>that</u>, <u>two</u>, <u>a</u>, <u>the</u>, <u>big</u>, <u>green</u>, etc. These words were classed together because they had identical privileges of occurrence in the child's sentences. By Time 2, articles and demonstrative pronouns had unique privileges of occurrence. The child produced sentences such as <u>that a my car</u>, in which the article, <u>a</u>, had a definite position before the pivot word, <u>my</u>. He avoided sentences such as <u>that my a car</u>, in which <u>my</u> and <u>a</u> are not distinguished with respect to sentence position. Similar evidence exists for the demonstrative pronouns. The child produced sentences such as <u>that a horsie</u>, and avoided <u>a that horsie</u>. Demonstrative pronouns thus could appear before articles and pivot words. Both these new contingencies, the positions of demonstrative pronouns and articles, are represented in Rule (2).

By Time 2, the original pivot class had been reduced in membership through subdivision; the child had come to treat articles and demonstrative pronouns as unique classes. As before, we assume this reflects the child's competence, and take the change in privileges of occurrence to indicate that <u>a</u> and <u>the</u>, on the one hand, and <u>this</u> and <u>that</u>, on the other, do indeed belong to separate grammatical classes for the child. However, there remains a residual pivot class, containing <u>my</u>, <u>two</u>, <u>more</u>, and the adjectives, to which <u>other</u> and <u>'nother</u> have been added. It is important to note that this class, too, has definite privileges of occurrence and we suppose that it also represents a part of the child's competence at Time 2. It is still heterogeneous from the point of view of adult grammar.

$P_2$ experienced further subdivision by Time 3. The adjectives now have unique privileges of occurrence in that they can appear after nouns, as in toy big, or penquin big heavy, as well as before nouns. Pivot words are restricted to positions before nouns, so we do not find the child saying toy 'nother, for example. Also, we credit the child with a separate class of possessive pronouns since he no longer produced sentences such as a my cup, which were possible at Time 2.

In five months' time, therefore, five grammatical classes have emerged from one primeval pivot class: articles, adjectives, demonstrative pronouns, possessive pronouns, and a pivot class that contains other, 'nother, one, all, and more. In each case, new classes appeared through subdivision of one of the pivot classes, $P_1$ or $P_2$, and so we can say that the process of development here was differentiation of the pivot class. There is no evidence of independent discovery of the adult grammatical classes; they are merely removed from the pivot class like a bananna peel.

## Universals in Language Acquisition

The preceding characterization raises a fundamental problem. In order for differentiation to yield the grammatical classes of adult English, the original pivot (and, presumably, the open) class must be generically related to the adult classes. By a generic relation, we mean that the competence of the child on which the pivot class is based must now ignore, but potentially admit, some of the relevant distinctions of adult grammar. In terms of actual content, such a relation clearly exists, as the facts of differentiation show. Every adjective in the vocabulary of Brown's subject at Time 1, for example, was within the pivot class, even though adjectives were not yet distinguished as a class. But in order for a generic relation to exist, we must assume that a child honors in advance some of the distinctions on which adult classes are based. This implication seems to have gone unnoticed, so we shall take time to discuss it.

Consider first some difficulties with formulations that do not make this assumption. Braine's theory, for example, implies that the pivot class is merely a random selection of words. But clearly this is not the case. A random selection would make differentiation impossible since a child's pivot class would be as likely to include words from one adult grammatical class as another. Moreover, since the original pivot class appears to be part of a child's competence -- and so has some psychological unity for him -- we would have to conclude that a randomly constituted pivot class would actually be misleading. The best thing a child could do under these circumstances would be to forget the P-O distinction as a bad start and begin afresh. (For other criticisms of Braine's theory, see Bever, Fodor, and Weksel, 1965a and 1965b; see also Braine's reply, 1965).

Nor, to take another theory, could a child infer adult classes from parental speech without knowing in advance the range of possible distinctions. Parental speech would offer useful guidance at this point only if this condition is met. An ability to infer something about language is the capacity to generalize a distinction once its relevance is noticed. It is difficult to conceive of it being a capacity to invent the distinctions themselves. A vast number of distinctions is possible in parental speech -- only a few of which are important in English -- and if a child had to invent, rather than notice them, his chances of progressing to English would be microscopically small. For a complete discussion on this point, see Katz (1965).

Nor, to take a third view, can strictly distributional evidence from parental speech yield a generic classification of adult grammatical categories, even assuming that a child manages to solve the problem of inference just noted. The set of grammatical categories that follows from distributional evidence would presumably be the full adult set, not a generic set; it begs the question to claim that a child observes only those distributional facts that support a generic classification. Asserting, for example, that Brown's subject formed a pivot class of articles, demonstrative pronouns, adjectives, etc., by sorting words according to whether or not they precede nouns is circular, for we still do not know how the child came to use this basis of classification, and that is the question in which we are interested.

The role of distributional evidence seems to have been greatly overrated in speculations on language acquisition. Not only is it impossible for distributional evidence to yield generic grammatical classes for a child, it seems impossible for it to yield a P-O distinction of any kind. The line of development that would follow from distributional evidence would be differentiation of the class of <u>all</u> words in a child's vocabulary, not differentiation of the pivot or open class. Each step of differentiation would consist of percipitating just one adult grammatical category from the total vocabulary. (There is no way to conceive of a child removing two or more adult classes as an undifferentiated set, unless we again beg the question of what criteria the child uses.) Of course, it would be possible to say that the pivot class for Brown's subject <u>was</u> the original undifferentiated set of all words in the child's vocabulary. His open class, then, could be regarded as the outcome of the first subdivision of the total vocabulary; articles and demonstrative pronouns could be regarded as the second and third subdivisions; and so on. This would be differentiation of a single heterogeneous category, and it could rest on distributional evidence alone. In effect, the pivot class would not be a grammatical class at all under this interpretation, but merely a collection of words out of which adult classes arise, and the P-O distinction would cease to exist. However, it is clear that Brown's subject did possess a genuine pivot class and that he did not derive adult grammatical classes through differentiation of his total vocabulary. If the pivot class at any given time really were a residual of the total stock of words, all members of the pivot class would be able to stand alone as single-word utterances. The original undifferentiated vocabulary of children, before there is any grammatical patterning, consists precisely of single-word utterances. But one characteristic of pivot words (for all children who have been studied) is that they never stand alone as single-word utterances; they must always occur in combination with an open-class word. The composition of Rule (1), which has the pivot as an option, reflects this restriction on the occurrence of pivots. We must conclude, therefore, that the P-O distinction is somehow imposed by a child on his vocabulary; it does not arise from the distributional evidence that a child obtains from parental speech; and it does appear to involve a generic classification of adult grammatical categories. In order to account for the P-O distinction, stronger explanations will have to be considered than a child's use of distributional evidence. Some possibilities along these lines will be discussed below.

But let us first be certain that the concept of generic classification is clearly understood. An analogy might help. Suppose we give an adult the problem of discovering into which of two subclasses we have divided the class of English adjectives. He does not know the principles of our subclassification but he does know what adjectives are. His position, therefore, is comparable to a child's. The class of adjectives corresponds to the child's pivot class, and the unknown principle corresponds to some adult distinction -- say the one between demonstrative pronouns and articles. Like a child, our adult subject must discover how to differentiate his class of adjectives into the subcategories we have in mind. Now, suppose that we divide the class of adjectives arbitrarily. We might take them in order from a dictionary, placing all even numbered adjectives in one class, all odd-numbered adjectives in the other. Under these circumstances the class of adjectives -- the adult's competence -- would not be a generic classification of the two subcategories. Our subject knows no relation among adjectives that will allow him to differentiate the class. Probably the only strategy for discovering the two subclasses is to test and memorize each word individually, an exceedingly time-consuming procedure and one that is not differentiation. Certainly, noting distinctions in our speech -- if, for example, we always use even numbered adjectives after be and odd-numbered adjectives before nouns -- will not help this adult, for he will have no basis for recognizing the regularity. Each adjective will be a thing unto itself.

In contrast, suppose we subdivide the class of adjectives on some other principle. For example, we might place all adjectives beginning with the letters A through L into one class, and adjectives beginning M through Z into another. Now there is a basis for segregating the two classes, for what our adult subject knows about the original class of adjectives encompasses the two subclasses. Our adult subject knows the initial letter of adjectives, which is relevant to the subclassification, and once he has discovered this principle, he can split the class of adjectives immediately.

The difference between these two situations is whether or not our subject's original competence includes information relevant to the subdivision of the adjective class. When it does, he can then note the relevance in samples of our speech, and adopt the distinction himself.

The suggestion is that the initial competence of children -- the pivot and open classes -- is similarly relevant to the distinctions honored in adult grammar. In this sense, children's early competence includes a generic classification of adult grammatical classes. The task now is to describe what this relevance is. In so doing, perhaps we shall be able to characterize more fully the nature of children's early competence. Notice, incidentally, that the problem raised here cannot be solved by assuming that the P-O distinction is not the original distinction children make in language acquisition, for that would merely push the difficulty back to an earlier point in the child's career.

Let us take an excursion into an aspect of transformational grammar that has to do with the problem of semi-grammaticality. One interpretation of the P-O distinction and the differentiation of grammatical classes will emerge. The transformational grammar described by Chomsky and others is intended to reflect accurately a native speaker's intuitions about well-formed sentences. However, it is clear that our intuitions are not limited to well-formed sentences. We also can make sense of such semi-grammatical sentences as Dylan Thomas' a grief ago, Veblen's perform leisure, or Chomsky's colorless green ideas sleep furiously. Not only can we make sense of them, but we also know that those sentences do less violence to our grammatical intuitions than a the ago, or perform compel, or furiously sleep ideas green colorless. The ability to judge relative grammaticality seems to be quite general, as the reader can verify by testing himself against the following set of sentences.

| | | |
|---|---|---|
| John plays golf | golf plays John | golf plays aggressive |
| John loves company | misery loves company | abundant loves company |
| sincerity frightens John | John frightens sincerity | John sincerity frightens |
| what did you do to the book, bite it? | what did you do to the book, understand it? | what did you do to the book, justice it? |

Chomsky (1961, 1964b), from whom all these examples are taken, has discussed semi-grammaticality in terms of supplementing generative grammar with a hierarchy of categories. The generative grammar of well-formed sentences can account for only the sentences of the left-most column above. The others fall beyond the grammar's scope. If one's competence included the grammar of well-formed sentences and nothing else, the center and right-most sentences would both be uninterpretable and would seem equally ungrammatical. They would be uninterpretable because neither golf plays John nor golf plays aggressive can be assigned a structural description, and they would be equally ungrammatical because the grammar is capable of registering only the binary decision -- well-formed or not. However, golf plays John is certainly meaningful. Indeed, it is an effectively devastating description of John, precisely because it is grammatically deviant. Golf plays John causes us to impose an interpretation by noting the analogy of golf plays John to the well-formed John plays golf. We see that both are noun-verb-noun sentences, but golf plays John violates restrictions on what categories can be the subject and object of play. Golf plays aggressive, in contrast, is not even a noun-verb-noun sentence. Thus, the two deviant sentences differ in the magnitude of the violence they do to the category-restrictions of the grammar. Golf plays John honors the distinction between nouns and other parts of speech, but does away with a distinction within the noun class, whereas golf plays aggressive obliterates a major distinction between two grammatical classes. Chomsky has maintained that the degree of grammaticalness of a sentence depends on the category restrictions that it preserves.

Imagine that we have before us a complete transformational grammar of English. We would find that the rules are expressed in terms of very narrow categories of words (actually, of morphemes or lexical items) that embody such distinctions as animate and inanimate nouns, or pure transitive and mixed transitive-intransitive verbs, etc.. This is the lowest level of Chomsky's hierarchy of categories; it represents all the distinctions that are necessary to the grammar of well-formed sentences. Suppose that above this level is another that categorizes the same words more broadly. And above this level, suppose yet another that classifies the same words still more broadly, and so on until, at the top, there is just one class containing all the words of English. That is, every level is an exhaustive classification of the lexicon and, moreover, each successively lower level is a refinement of the level just above. The system of levels can be abstractly pictured by the tree-graph in Fig. 2. Every "C" is a category of words. Superscripts represent the level at which a particular category resides and subscripts indicate the particular category we have in mind. Level m is the most differentiated. This abstract diagram skips many levels and many categories; it merely presents a hierarchial arrangement of the sort Chomsky describes in accounting for semi-grammatical sentences. There are, of course, many different ways that the lower-level categories might be combined (see Miller and Chomsky, 1963, for an illustrative example).

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Insert Figure 2 about here

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Such a hierarchy provides a representation of every string of words, whether or not well-formed. The well-formed John plays golf, for example, is represented on all levels of the hierarchy. It honors the most delicate distinctions of level m as well as the broader ones of the levels above. The rules of the grammar, therefore, can produce sentences of the form of John plays golf throughout the hierarchy. On the other hand, the semi-grammatical sentence golf plays John can be represented no farther down in the hierarchy than some intermediate level, say where the categories are undifferentiated noun, verb, and some others. For the sake of an example, suppose that these distinctions are drawn at level 2 in our diagram and

$C_1^2$ is the class of verbs, $C_2^2$ is the class of nouns, and $C_3^2$ includes everything else. Then golf plays John will have a representation on level 2 in common with one of the sentences generated by the grammar, viz., noun-verb-noun. (So, of course, does John plays golf.)

In this way, Chomsky can account for our ability to impose interpretations on semi-grammatical sentences and to judge which of two semi-grammatical sentences is more remote from well-formed English. We can impose an interpretation on Golf plays John because it has the same representation on level 2 as John plays golf. We can judge the degree of grammaticalness by noting the lowest level at which a sentence receives a representation. Thus, golf plays aggressive is less grammatical by this reckoning than golf plays John.

The knowledge represented by the hierarchy of categories seems to be an essential part of our linguistic competence. It may also be an essential part of language acquisition. Perhaps the original P-O distinction of child grammar is one of the distinctions drawn near the top of Chomsky's hierarchy. Moreover, in a child's subsequent development, the differentiation of P and O may consist of moving down the hierarchy to more narrowly defined categories. It is in this sense that we can regard a child's original grammatical categories as a generic classification of the categories of adult grammar. The ever more refined classification of words represented in Chomsky's hierarchy, therefore, suggests a blueprint for the first stages of language acquisition. The tree-diagram for the development of Brown's subject in Fig. 1 may be more than a chronology; it may be the same hierarchy that underlies adults' interpretation of semi-grammatical sentences. On this view, the successful differentiation of children's P and O classes is an automatic result of a basic congruence of children's and adults' competence.

There are two possible explanations of any such congruence. One is that the adult's hierarchy was learned in infancy. If everyone acquires language by the process of differentiation exemplified by Brown's subject, the various levels of Chomsky's hierarchy could reflect adults' retention of the early stages of their own language acquisition. We can be certain that this explanation is false. For one thing, it fails to account for the fact that different adults have the same intuitions about the relative grammaticality of sentences. For another thing, it implies that foreign speakers of English -- persons who learned the language when they were already linguistically mature -- should have intuitions about semi-grammatical English sentences quite different from the intuitions of native speakers. Foreign speakers acquire English from textbooks, so their early stages of acquisition are fundamentally different from the differentiation experienced by native speakers. However, as will be seen later, native and foreign speakers of English are not consistently different in their judgments of relative grammaticality.

An alternative explanation is that the distinctions drawn from Chomsky's hierarchy of categories represent linguistic universals that are part of the child's innate endowment. The role of a universal hierarchy of categories would be to direct the child's discovery of the classes of English. It is as if he were equipped with a set of "templates" against which he can compare the speech he hears from his parents. This speech is a haphazard sample (at least initially), not at all contrived to instruct a child in basic grammatical structure. Indeed, ordinarily a child's parents will be completely unaware of basic grammatical structure. However, parental speech will inevitably conform to some of the linguistic universals registered on the child's templates. We can imagine, then, that a child classifies the random specimens of adult speech that he encounters according to universal categories that the speech exemplifies. Since these distinctions are at the top of a hierarchy that has the grammatical classes of English at its bottom, the child is prepared to discover the appropriate set of distinctions. Since no language exploits all the universal linguistic paraphernalia contained in the general theory of grammar, the child's task is to discover which of the total set of universals distinctions is important in English.

The case is the same as with the adult in our analogy: a child has knowledge of the set of distinctions that define some of the classes of English (or any other language), and his problem is to discover the ones that are relevant. Obviously, a child's knowledge of universal categories will not lead him to completely well-formed English. Learning of a different character must also take place, and something will be said about this phase of acquisition below (p. 58). But in the main, we can agree with Brown and Bellugi (1964) when they write: "The very intricate simultaneous differentiation and integration that constitutes the evolution of the noun phrase is more reminiscent of the biological development of an embryo than it is of the acquisition of a conditioned reflex."

One superficial difficulty with the present line of thinking should be commented on. It looks embarrassing to the hypothesis of a universal hierarchy of categories that children differ among each other on the particular distinctions they draw. For example, Brown's and Ervin's subjects both have adjectives in their simple sentences, yet one uses them as pivot words, the other as open-class words. Probably such disagreements are typical. However, in themselves, they are neutral with respect to the hypothesis that children begin their linguistic careers with linguistic universals. We have spoken of the hierarchy of categories as if it could be arranged in only one way. This is not necessarily the case. There are numerous arrangements, and a number of different distinctions can provide possible starting points. A decision on whether the particular distinctions adopted first by children correspond to universal distinctions in a hierarchy of adult categories must wait until we have a more sophisticated idea of what distinctions are universal;

this is a linguistic problem that is currently under active investigation. However, the linguistic findings are not yet in a form that allow us to compare children's sequences of development to adults' hierarchy of categories on the level of detail that is really needed.

Since that is the case, we must be content for the present with the following imprecise test of the hypothesis. The aim of the experiment to be described was to discover whether or not adults can judge which of two sentences from a child was produced later in development. Since none of the sentences was well-formed, the subjects had to determine the proximity of the child's sentences to adult grammar. The task therefore, was exactly the same as deciding the relative degrees of grammaticalness of <u>a grief ago</u> and <u>a the ago</u>. If adults can make these judgments about children's sentences correctly, we would conclude that they know the hierarchy of categories through which the child had moved: there is no other basis for an adult to succeed in the experiment. (Several of the children's sentences deviate from the word-order of well-formed English; howevever, as far as the experimental materials are concerned, converting early sentences to the well-formed order does not, on the average, require more changes than does converting late sentences.) This result would not prove that knowledge of the child's hierarchy is the same as knowledge of the hierarchy that Chomsky discussed. The fact is, nonetheless, that the sentences children produce later in their careers usually strike adults as obviously more grammatical than earlier sentences, which if it does not prove, at least suggests that the two hierarchies may be the same. This intuition grips adults so forcibly, in fact, that sometimes it is difficult to convince colleagues that the experiment is really a test of anything at all. Such doubts are welcomed, of course, since they support the hypothesis that a child's early grammatical categories are a generic specification of adult grammatical categories.

The experiment was conducted with ten native speakers of English and five speakers of English-as-a-second-language. All the foreign speakers learned English as adolescents, so it can be safely assumed that they did not pass through a phase of differentiation in acquiring English; all became fluent speakers of the language. The native languages were Hindi (3 subjects), Japanese (1 subject) and Spanish (1 subject). Every adult subject judged the relative proximity to well-formed English of 15 pairs of sentences taken from the grammar of Brown's subject. Every pair involved a contrast with the child's grammar at Time 1, when he had only the P-O distinction: four pairs compared Time 2 and Time 1, and 11 pairs compared Time 3 and Time 1. No sentences were well formed by adult standards. Length was constant within each pair, so that was not a cue. Some of the sentences used did not actually occur, but were mechanically generated from the child's grammar; this is not unfair since we are interested in the categories of the grammar, not in the particular sentences the child was overheard producing. Some examples are given in Table 2. All the sentences involved a hierarchical construction.

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Insert Table 2 about here

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Subjects were asked to indicate the member of each pair that came later in the child's career on the basis of how close the sentences were to adult English. There is no question that adults can make these judgments accurately. For native speakers, overall success was 81 percent, whereas chance is 50 per cent. Foreign speakers did nearly as well, correctly ordering pairs 78 per cent of the time. No consistent differences appeared between native and foreign speakers in the sentences that were successfully ordered, except that foreign speakers generally did better than native speakers on pairs involving first-person possessive pronouns.

The hypothesis that the first stages of linguistic development are guided by a universal hierarchy of categories can be considered in relation to an abstract characterization of language acquisition that has been outlined by Chomsky (1964a, 1965) and Katz (1965). They discuss the form of a language Acquisition Device (LAD), or System (LAS). LAD receives primary linguistic data--essentially, a corpus of speech from fluent speakers within hearing range--as input and has grammatical competence as output. It can be represented schematically as follows:

Primary Linguistic Data ⟶ [LAD] ⟶ G

The contents of the box--the properties of LAD--will explain the linguistic intuitions of adults because it determines the properties of G, or grammatical competence. The internal structure of LAD is given by the linguistic universals, one of which, according to the present argument, is the competence that underlies adult judgments of semi-grammatical sentences.

Linguistic universals may be classified into two types, formal and substantive (Chomsky, 1965). The hierarchy of categories would be an example of a substantive universal. It constitutes, as it were, a part of the basic set of concepts that LAD uses to devise the particular grammatical rules of English. The form that these rules take, in turn, is prescribed by the formal universals that are also part of LAD's internal structure. Equipped with both formal and substantive universals, LAD operates something like a scientist constructing a theory. LAD observes a certain amount of empirical data, the primary linguistic data, and formulates hypotheses that will account for them from its knowledge of the formal and substantive universals. Further observations may lead to changes in LAD's hypotheses, but all new hypotheses will also be phrased in terms of the formal and substantive universals. Thus, the universals guide and limit acquisition. In the case of real children, the original P-O distinction would then reflect an initial hypothesis to account for the examples

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of English that the child has heard. With time, the child modifies this hypothesis, presumably to accord better with new observations, and so separates articles, adjectives, demonstrative pronouns, and the like. In a sense, of course, the observations that give rise to these distinctions are not new--they are always present in adult speech. The advantage to a child of having universals such as the hierarchy of categories is that he can progress toward the grammatical classes of adult English step-by-step. He does not have to notice, hypothesize, and test all distinctions at once. A simple dichotomy or trichotomy will serve at first. The rest of the distinctions are taken up in an order determined by the hierarchical arrangement of categories. If the same hierarchy underlies both adult grammar and a child's development, the child would be able to progress rapidly and surely to full linguistic competence.

## Early Grammatical Rules

Some rules that appear to be part of children's early grammatical competence have already been mentioned. In the case of Brown's subject, there were five of them (Fig. 1). Rules (2-5) were derived from Rule (1) by the process of differentiation of the pivot class. All these rules are basically P-O constructions, and there is some question whether we should think of five different rules or just one basic rule operating with different grammatical classes at different times; Brown and Bellugi (1964) favor the latter interpretation. In any case, the P-O construction is not the only rule present in children's early grammars. Children also have sentences of an open-open type, some of which are covered by Rule (6) in Brown's grammar (in which some open-class words were nouns):

(6) $S \longrightarrow N + N$

Rule (6) generates such sentences as <u>Adam car</u>, <u>mommy soup</u>, <u>Urler suitcase</u>, etc., and it was highly productive. Indeed, Brown's early records contain many more sentences produced by Rule (6) than by Rule (1). Sentences from Rule (6) usually strike adults as telegraphic versions of the possessive: Urler suitcase probably corresponds to Urler's suitcase in the adult grammar.

Rule (6), even though it is not a pivot-open construction, is identical to Rules (1-5) in one respect; all are sequential and lack any sort of hierarchical structure. In this, they differ from Rules (7) and (8), which are both hierarchical and generate such sentences as that my coat and want my coat. Rules (7) and (8) can be written as follows:

(7)
$$S \longrightarrow (P) + NP$$
$$NP \longrightarrow \begin{Bmatrix} (P) + N \\ N + N \end{Bmatrix}$$

(8)
$$S \longrightarrow \text{Pred P}$$
$$\text{Pred P} \longrightarrow (V) + NP$$
$$NP \longrightarrow \begin{Bmatrix} (P) + N \\ N + N \end{Bmatrix}$$

The difference between Rules (1-6) and Rules (7) and (8) can readily be seen by comparing their phrase-markers, which are drawn in Fig. 3. The markers generated by Rules (1) and (6) represent the sequential type. (The alternate choice of P or N in Rules (7) and (8) is indicated in the usual way by braces.) Notice that the only difference between the sequential and hierarchical phrase-markers--aside from the appearance of V in Rule (8)--is the presence of NP or Pred P. And notice, also, that the material dominated by NP is the righthand sides of Rules (1) and (6) combined, and that the material dominated by Pred P contains this same NP. We might suspect that Rules (1-6), the sequential set, and Rules (7) and (8), the hierarchical set, are related in some way.

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Insert Figure 3 about here

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At Time 1, Rule (7) was not used frequently. Most sentences came from Rules (1), (6) and (8). The option of choosing P in Rule (8) was rarely taken. Thus most sentences were two words long and consisted of either a pivot-word followed by a noun, or a noun followed by a noun, or a verb followed by a noun. There were also some sentences in which a noun was followed by a verb, such as Bambi go and Adam change diaper. They do not fit any of the rules individually, but seem instead to be a combination of two rules, probably (7) and (8); more is said on this below. Most three-word sentences at this age followed Rule (8), using the (N + N) alternative of NP. By Time 2, the frequency of three-word sentences had increased and Rule (7) had come to play a more important role. No new patterns seem to have crept into the child's grammar at Time 2, all the changes being in the relative frequency with which sentences were generated by these various rules. Time 3 continues the same story: further frequency changes, but no new rules.

Thus, the development of grammatical rules is quite different from the development of grammatical classes. During the same 5-month period that saw great changes in the system of grammatical categories, the basic set of grammatical rules remained more or less constant (disregarding frequency changes, which probably depend on practice, interests, memory span, etc.; that is, on various performance factors). This constancy may indicate another aspect of the child's fundamental linguistic capacity, but before that can be discussed, we must try to establish the psychological reality of hierarchical rules.

Brown and Bellugi (1964) present several kinds of evidence for the psychological reality of the NP constituent in the speech of children. For one thing, the NP and the single N have identical privileges of occurrence, as in the following sentences:

| Positions for single N | Positions for NP |
|---|---|
| That (flower) | That (a blue flower) |
| Where (ball) go? | Where (the puzzle) go? |
| Adam write (penguin) | Doggie eat (the breakfast) |
| (Horsie) stop | (A horsie) crying |
| Put (hat) on | Put (the red hat) on |

These demonstrate that the syntactic position of NP is the same as its head word, N. The NP is "endocentric", as linguists say. The endocentricity of NP itself suggests that such constructions are psychological units for children. Pointing to the same conclusion is the fact that pauses, when they occur, usually bracket NP. A child might say "Put...the red had...on", but not likely "Put the red...hat on". Similar evidence has been described by Huttenlocher (1964). Finally, there is use of the pronoun it. As Brown and Bellugi point out, it is actually a pro-noun phrase, which stands for an NP, not a single N. To quote them,

> "The unity of noun phrases in adult English is evidenced, in the first place, by the syntactic equivalence between such phrases and nouns alone. It is evidenced, in the second place, by the fact the pronouns are able to substitute for total noun phrases. In our immediately preceding sentence the pronoun "It" stands for the rather involved construction from the first sentence of this paragraph: 'The unity of noun phrases in adult English'.... One does not replace 'unity' with 'it' and say "The it of noun phrases in adult English'".

Similarly, in the speech of Brown and Bellugi's subjects, it replaced noun phrases, suggesting that the NP is capable of replacement as a unit, and so, is psychologically a whole.

In the case of one child, the replacement itself did not occur for a time, but instead the child produced both it and the constituent it stood for. For example,

Mommy get it ladder

Mommy get it my ladder

In the first sentence, it and a single N come out together; in the second, it and an NP co-occur. Thus, the child treats N and NP alike in making this quaint error, a fact that provides further evidence for the psychological unity of NP.

However, the psychological unity of NP raises a vexing question about the status of our rules. It has already been mentioned that Rules (1-5) might be regarded as one rule operating with different grammatical categories. If, along with Brown and Bellugi, we decide to group them, we are left with four rules; Rule (1) in its various forms, and Rules (6), (7), and (8). To decide this much is relatively easy, since the grounds for keeping Rules (1-5) apart really have nothing to do with the form of the rules themselves. The hard decision is what to do with Rules (6), (7), and (8). It was pointed out that Rules (1) and (6)--the pivot-noun and noun-noun constructions--are both involved in Rules (7) and (8) as NP. It seems that there are two alternative interpretations of this interdigitation. One is to regard Rules (1) and (6) as basic, and Rule (7) as a later development growing out of Rules (1) and (6), which would imply that a child does not have higher-order constituents in his early sentences. The fact that Rule (7) was not used frequently in Brown's earliest records supports this view.

However, now we must also suppose that Rule (8) is simplified to read merely (S $\longrightarrow$ V + N), which runs afoul of the fact that the most common three-word sentences at Time 1 was VNN, a sentence-type generated by Rule (8) with an NP (NP $\longrightarrow$ N + N, one of the options). We are faced, therefore,

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with the inconsistency that NP is possible in Rule (8) but not Rule (7). If NP is psychologically unitary for a child, he should treat it everywhere alike. Thus, we are led to a second interpretation of the interdigitation of Rules (1), (6), (7), and (8): all the rules, (1) through (8), make use of NP. NP is psychologically unitary from the outset. But, now we must account for the fact that sentences with single N occur more frequently than ones with a developed NP. One possibility here is that a child tends to restrict himself to using just one pivot-position in each sentence. This makes Rules (1) and (6) into variants of Rule (7). Rule (1) comes out of Rule (7) when a child picks the P dominated by S, or the P dominated by NP, since whichever he chooses, the other would be suppressed. Rule (6) comes out of Rule (7) when a child elects the N under NP. The first pivot-position would then be suppressed and the second pivot-position is already occupied by N. The advantage of this scheme is that it lets Rule (8) have its NP. It may also account for the fact that PNN and PPN sentences were infrequent at Time 1 whereas VNN sentences were the most numerous of all three-word utterances (two pivot positions are used in PNN or PPN, as against one in VNN). It was the low frequency in PNN and PPN from Rule (7) that seemed to support the view that was first described. Therefore, the inclination is to accept the second interpretation, and assume that the child generated all his sentences by either Rule (7) or (8).

These rules do not generate well-formed sentences according to adult grammar. The basic paradigm for adults is NP + Pred P and neither Rule (7) nor Rule (8) results in this structure. However, Rules (7) and (8) are, roughly, the two halves of the basic adult pattern. With the exception of the initial pivot-word, Rule (7) defines an NP, and Rule (8) produces the Pred P of adult grammar. Thus, although the rules of the child's grammar do not result in well-formed sentences, they do appear to generate major constituents of well-formed sentences. All the child lacks is the simultaneous application of both rules in the generation of a single sentence. This seems to have happened in about 15 per cent of the two-word sentences and in about 10 per cent of the three-word sentences recorded at Time 1. These are the percentages of NV (e.g., Bambi go), NNV (e.g., Adam Panda march), and NVN (e.g., Adam change diaper) sentences. By this line of reasoning, one is led to conclude that a child's first grammatical productions are the NP's and Pred P's of adult grammar. Most often he produces them independently, though occasionally they are brought together to result in the skeleton of a well-formed sentence, and the child says NV, NNV, or NVN.

With time, of course, the frequency of NV, NNV, and NVN sentences increases. In part, this may result from the relaxation of some restrictions on performance. A child's growing memory span is a very good candidate here. But it is also possible that the basic NP + Pred P paradigm is not part of the child's earliest grammatical competence. He may still have to discover, after Rules (7) and (8) are within his repertoire, that in English they are to be used together. There is no way at present to decide this question.

Nonetheless, the facts now available are consistent with the view that the earliest grammatical constructions are at least noun and predicate phrases, and on occasion, possibly full sentences. The early appearance of the basic structures of adult grammar is a finding of considerable interest, since it gives some insight into what might be another aspect of the innate linguistic capacity of children.

If one tries to account for the origin of the NP or the Pred P in child's grammar, one immediately encounters a shroud of mystery. Expressions like "somehow" abound in the literature. The difficulty lies in describing a reasonable mechanism by which children might arrive at hierarchical structures. Imitation is obviously inappropriate, since it cannot account for the emergence of a constituent with psychological unity, and that is what we are concerned with here. Appealing, as some do, to the child's "creative abilities" is too vague to be of much help. We want to explain these abilities, if we can. Inference, or the formation of structures on the basis of analogy, is of little assistance, either; there is nothing in overt speech to suggest a hierarchical arrangement of sentences, so it is difficult to see on what basis a child could draw an analogy. The only evidence available to a child is his parents' distribution of NP's or Pred P's in the same sentence-positions as nouns or verbs. This could lead a child to imitate, but he would then be wedded to examples that his parents provided him, and the problem of productive and psychologically "real" hierarchical structures would not even be approached; we would still have no theory of what a child does to obtain these structures. But distributional evidence from parental speech can give a child nothing more than examples to imitate. The essential feature of hierarchical structures--that they are hierarchical--is abstract and completely unmarked in overt speech, yet children always discover these structures. In order to account for this feat, a principle fundamentally different from inference is required.

It has already been argued that knowledge of the hierarchy of categories directs children to discover the classes of adult grammar. The fact that all a child's early sentences seem to be produced by Rules (7) and (8) leads to a parallel hypothesis that the basic grammatical relations also are part of innate linguistic capacity.

The grammatical relations are the concepts "subject of a sentence--predicate of a sentence", "main verb of a predicate phrase--object of a predicate phrase", "modifier of a noun phrase--head noun of a noun phrase." Each relation is defined in terms of the deep structure of sentences, by which is meant that they exist in competence as configurations in underlying phrase markers. Thus,

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the subject of a sentence is the NP immediately dominated by S; the predicate of a sentence is the Pred P immediately dominated by S; the object of a predicate phrase is the NP immediately dominated by Pred P; the main verb of a predicate phrase is the V immediately dominated by Pred P; the modifier of a noun phrase is the determiner immediately dominated by NP; the head noun of a noun phrase is the N immediately dominated by NP. By these definitions, each basic grammatical relation is uniquely specified by a configuration in the underlying phrase-marker of a sentence. They account for the fact, for example, that native speakers of English can correctly distinguish subject from object in the pair of sentences John is easy to please and John is eager to please, which have identical surface structure but quite different base structures. The subject in both cases is the NP immediately dominated by S--an unspoken "someone" in the first sentence, and "John" in the second, whereas the object is the NP immediately dominated by Pred P--"John" in the first case, and an unspoken "someone" in the second (Katz and Postal, 1964).

Suppose that a child has these basic concepts as part of his biological endowment. Suppose that he knows, for example, what the relation is between main-verb and object. Then we credit him with the realization that in order to have a noun, say ball, operated on by a verb, say hit, the two words must both be part of a single sentence-constituent; and that if the noun and verb are not part of a single constituent, the meaning of the verb does not interact with the meaning of the noun. We can then see Rules (7) and (8) as inventions by the child that give the basic grammatical relations expression. They are the child's solution to the problem of exploiting the concepts of main-verb, object-of-verb, etc. Rules (7) and (8), indeed, express the basic grammatical relations very economically. Rule (7) defines what a modifier and a head noun are, and Rule (8) defines main-verb and object. Moreover, if we assume that children's competence includes using Rules (7) and (8) simultaneously, so as to generate NV, NNV, and NVN sentences, the two rules also define subject and predicate.

By assigning the basic grammatical relations a place in the child's innate linguistic endowment, we assume them to be universal. Greenberg (1963), in a survey of some 30 languages, has found these grammatical relations to hold in every case; there appears to be no language lacking such concepts. Thus a child who knew them could commence acquiring any natural language by striving to discover how each of these relations is expressed locally.

Brown's subject seems to have done this for English by Time 1. His sentences at this point show a perfect match with the patterns one would predict on the assumption that he was trying to express the grammatical relations. To appreciate the degree of constraint this places on a child's speech, consider the following arithmetic. As noted before, Brown's subject had three grammatical categories at Time 1: pivots, nouns, and verbs. There are $(3)^2 = 9$ different two-word sentences and $(3)^3 = 27$ different three-word sentences that can be constructed from these three classes. However, only four of the two-word sentences and eight of the three-word sentences are consistent with the basic grammatical relations; the remaining patterns are inadmissable from this point of view--and none of them occurs in the child's speech.

Insert Table 3 about here

In Table 3 are all the sentences that express the basic grammatical relations under Rules (7) and (8). Opposite each is the frequency of the pattern in the corpus of Brown's subject at Time 1. As the frequency distribution shows, sentences of every admissable type appeared in the child's corpus. This fact is not conclusive, of course, since we would expect most patterns to appear in a large sample of speech from a child who is trying out combinations at random. However, there is the additional fact that all the child's sentences had these patterns; there were no others. The entries in Table 3 include all the child's corpus at Time 1. Thus, the child seems to confine his efforts to sentences that express the grammatical relations; but within these limits, he tries every possibility.

It might appear that a child's sentences would reveal the patterns in Table 3 almost as a matter of course, perhaps even through imitation, since each pattern is present in adult speech. The difficulty is that there are many other two- and three-word patterns in adult speech as well, none of which correspond to the basic grammatical relations. A verb-verb-noun sequence, for example, is contained in <u>come and eat your pablum</u>; however, VVN is not consistent with the basic grammatical relations, and it does not appear in the speech of Brown's child. Such inadmissable patterns, although presented to a child in abundance, are either suppressed or ignored--presumably because a child looks for ways to exemplify the basic grammatical relations.

Throughout Table 3 it has been assumed that the child can apply Rules (7) and (8) together. Without this assumption, we would lose NV, NNV, NVN sentences, as well as the relation of subject and predicate. Striking these sentence-types from the record would reduce the size of the corpus, but it would not change the perfect agreement between the basic grammatical relations and the sentence-types that the child produced. Another assumption made in Table 3 is that pivot words never stand alone in a child's speech. This seems to have been true of every child studied. The assumption eliminates such patterns as PVN (e.g., <u>that bounce ball</u>) as admissable expressions of the basic grammatical relations. Finally, it has been assumed that verbs can be omitted from Pred P's as in <u>Adam two boot</u>, which to most adults, means <u>Adam has two boots</u>. This assumption accounts for NN, NPN, and NNN as patterns all corresponding to the subject-predicate relation.

We can now return to LAD and summarize what is known about the process of acquisition. We have said, following Katz (1965) and Chomsky (1965), that the internal structure of LAD consists of the various linguistic universals, both substantive and formal. We pointed out that the hierarchy of categories is a substantive universal. So now are the basic grammatical relations. Undoutedly, more universals than these two make up the internal structure of LAD; however, we can be most clear about the two that have been discussed, and attention will be restricted to them.

We can imagine LAD going about its assigned task roughly as follows. Two things are done simultaneously, both of which make possible the remarkable "induction of latent structure" that numerous psycholinguists have observed in children. LAD receives a certain amount of preliminary linguistic data, which it scans for distinctions that match the distinctions drawn in the universal hierarchy of categories. Since LAD is exposed to a natural language, some of the universal distinctions are bound to be present. Thus, we can imagine that whenever LAD observes such a distinction in the preliminary linguistic data, it is incorporated into LAD's own version of the underlying grammar. The function of the preliminary data, therefore, is to give LAD a basis for selecting among various universal distinctions. The function of the universal hierarchy of categories is to organize the preliminary linguistic data. Moreover, since it is a hierarchy of categories, distinctions can be drawn successively and LAD embarks upon its career by differentiating gross categories to obtain refined ones.

At the same time, LAD searches the preliminary linguistic data for sentence-patterns that correspond to the basic grammatical relations. Presumably LAD recognizes sentence patterns within limits set by the grammatical categories it has differentiated, so LAD's activity here is not independent of what it does with the universal hierarchy of categories. Each pattern in the preliminary linguistic data that corresponds to a basic grammatical relation will suggest one or another hierarchical structure to LAD. However, the basic grammatical relations leave open only a few possibilities, so LAD has a very good chance to hit on the locally appropriate structures soon after it begins to collect data. It is committed to the NP + Pred P format for sentences, and within this limit there are only two possible orders of constituents: (NP + Pred P) and (Pred P + NP). There are only two possibilities for Pred P: (V + NP) and (NP + V). Likewise, if LAD has only pivot and noun classes, there are just two variants of NP: (P + N) and (N + P), plus a third, (N + N), where order is irrelevant. LAD must discover from the preliminary linguistic data the particular orders of constituents used in its local language. Distributional evidence of various sorts could be useful at this point, and a certain amount of hypothesis-testing will become necessary. That is, LAD's first choice may not predict later sentences. However, the only possible error, if this hypothesis is correct, is inversion--for example, using Pred P + NP for S when trying to learn English. This inversion is, in fact, a common pattern in early speech--c.f., allgone shoe in Braine's subject. However, LAD does not have to discover from the preliminary linguistic data the fundamental fact that hierarchical structures exist; that is implied--indeed, required--by the definitions of the basic grammatical relations.

The role of the preliminary linguistic data in acquisition, therefore, is essentially directional. They help LAD to choose among a narrow set of possibilities defined by the linguistic universals. To quote Katz (1965, P. 47, footnote 36), "...the role of experience is primarily to provide the data against which predictions and thus hypotheses are judged. Experience serves not to provide the things to be copied by the mind, as on the empiricists' account, but to help eliminate false hypotheses about the rules of the language." LAD must be equipped with knowledge of just those specific aspects of linguistic competence that cannot be extracted from overt speech, namely, appropriate generic grammatical classes and hierarchical structures. (There are other requirements that have not been treated; for a more extensive discussion, see Katz, 1965.) We might turn this assertion around and say that languages have deep features, unmarked in overt speech, precisely because children (like LAD) have the specific linguistic capacities that correspond to them. A language with different features would be unlearnable by LAD and, presumably, by children. The evolution of language so as to include particular universal features, therefore, is necessarily tied to the linguistic capacities of language learners.

It has already been argued that adults can interpret the speech of children because it is, in effect, at some intermediate level of grammaticality; the reasoning there had to do with the hierarchy of categories through which children move. We have in the basic grammatical relations, another reason that adults find children's speech interpretable: all children's sentences are generated by simple rules--or their inversions--that also exist in adult grammar. Indeed, the basic grammatical relations and the hierarchy of categories, taken together, almost guarantee that everything children say can be understood by adults (problems of pronunciation aside, that being a different matter), even though the speech is very telegraphic. Every sentence will be constructed by Rules something like (7) and (8) operating on classes generically related to the classes of adult grammar. Children's sentences, in fact, are semigrammatical and exactly comparable to the examples from Chomsky that we saw above. This fact has important consequences for the reaction of adults to child speech: it makes possible "expansions" of child speech into completely well-formed English. Expansions often occur in child-parent dialogues, and they may be an important source of information by which children choose among the possibilities offered by the linguistic universals.

Expansions have been discussed by Brown (1964); we return to them later when we take up the role of parental speech in acquisition.

Early speech of children, so much as we have seen of it, reflects a severely limited grammatical competence. They have a few grammatical classes, which are used in simple hierarchical rules, and the rules reflect the basic grammatical relations; there is little else. However, it is important to note that these aspects of children's competence--classes, rules, and relations--are all properties of the base structure of sentences. On the other hand, children's earliest speech does not reflect the operation of transformational rules; those come into children's grammar only later. Full adult competence includes semantic interpretation of base structures to obtain meaning; transformations of base structures to obtain surface structures; and phonological interpretation of surface structures to obtain a representation of speech. Therefore, it is not too unreasonable to think of children "talking" base strings directly. We can conceive of their phonological rules as interpreting base structures rather than surface structure in the generation of sentences. Children, according to this view, begin their grammatical careers with the part of syntax that is necessary to semantic interpretation, and only later attach the grammatical machinery that in mature grammar provides input to phonological interpretation. The phonological interpretation of base instead of surface structures might help explain some characteristics of infant pronunciation since presumably not every phonological rule can be applied directly to simple base structures. The absense of surface structure might also help account for the wide-spread impression that children's early speech is exclusively semantic, an assertion that overlooks the features of base structure that are present in children's early competence, but is correct in that relation between sound and meaning is much more rigid and (in a way) immediate for children than it is for adults. The often remarked-upon

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identification of the sound of a word and its meaning, which seems to be most typical of children, might be another aspect of this condition.

An interpretation of Vygotsky's (1962) concept of inner speech is suggested by this view of early competence. If phonological rules apply to deep structure directly, it should be difficult to avoid saying whatever you think. The privacy of inner speech may be afforded by the existence of transformational rules; and until they are added to the grammar, inner speech would not occur. That situation is roughly what Vygotsky observed in young children. Perhaps, therefore, these children were pre-transformational, not necessarily excessively social, as Vygotsky thought. Vygotsky said that inner speech is "speech almost without words",made up almost entirely of psychological predicates. The fact that inner speech is almost without words would follow naturally from the assumption that it consists of the untransformed base structure of sentences. In fact, inner speech should be completely without words, since phonological interpretation is not applied directly to base structures for mature speakers. However, Vygotsky's claim that inner speech is largely reduced to predication is harder to account for; perhaps, like some early sentences from children, inner speech generally follows Rule (8).

One conclusion implicit in all the preceding paragraphs is sufficiently important to be made explicit. If children begin their productive linguistic careers with a competence limited to the base structure of sentences, it is difficult to see how it can be explained by any theory of language acquisition that restricts attention to what a child might obtain from the observable surface characteristics of parental speech. Such theories would have to predict the opposite course of development: first, surface structure; then base structure. Most behaviorist theories have assumed this order, with notable lack of success; failure is inevitable when children produce only the base structure, and behaviorist theories produce only the surface structure of sentences. What is needed is either a child who commences acquisition with surface structure or a theory that focuses on base structure. Since it is easier to change theories than children, the latter course has been followed here.

A widely accepted generalization about languages is that there is a close connection between phonology and syntax, especially in the imposition of intonation contours. The existence of this connection has caused some psycholinguists to suggest that intonation--which is observable in speech--might be the vehicle on which children arrive at the rudiments of syntax. At first glance, this is a plausible view. In its favor is the fact the children, even before the first birthday, imitate intonation contours in parental speech. There is also the fact that early grammatical speech is telegraphic in that it leaves out the unstressed elements of well-formed sentences, thus indicating that children are sensitive to intonation differences. However, this view can be questioned on logical grounds. Lieberman (1965) compared the ability of linguists to transcribe the intonation contours of real speech with their ability to transcribe physically identical contours of simulated speech that consisted of a single prolonged vowel sound. He found that the linguists' transcriptions matched the actual physical contour only on the simulated speech. When the linguists transcribed real speech, the actual and the perceived intonation contours often differed strikingly, which suggests that structure is an important source of information about perceived intonation, but not vice versa. A pre-lingual child listening to adult speech is in a position comparable to Lieberman's linguists transcribing a simulated vowel. A child is not comparable to Lieberman's linguists transcribing real speech. Infants could note only the physical contour in parental speech, not the perceived contour that is correlated with grammatical structure. It is difficult, therefore, to see how intonation could guide a child to syntax; for no matter how strong the tendency is for children to imitate speech they receive from their parents, they will not imitate the appropriate features unless important parts of the syntax have already been acquired.

## Growth of Transformations

If children's earliest syntactic competence comprises the base structure of sentences, then obviously the major portion of acquisition after this point will be taken up with the growth of transformations. We know little about this phase of development, aside from the fact that transformations appear relatively late in a child's career. The late appearance of transformations, of course, is one reason we know little about them. Most projects have not yet continued long enough to cover the period during which transformations develop. However, one study of two children has recently been completed by Bellugi (1964), and is reported elsewhere in this volume. Her work--while limited to negation-- is the only complete history of the development of transformations that is familiar to this writer, although scattered bits and pieces have been described by Ervin (1964) and Menyuk (1963, 1964) has published the results of several surveys.

To discover the exact point at which a child's grammar contains transformational rules is a difficult, obscure problem. In the case of negation, we probably are safe in assuming that the earliest sentences with negative import are not generated by transformational rules. Rather, they seem more like base-structure sentences with an underlying NEG morpheme that the child pronounces. Bellugi gives such examples as: no wipe finger, not fit, no singing song, no drop mitten. These sentences probably were produced by simply prefixing no or not to Rule (8); hence, their close relation to base structure.

Such untransformed negative sentences are an example of what seems to be a general phenomenon in the acquisition of language. It is the appearance in child speech of forms that are analogous to adult forms, but with very different structure. In some cases, as in the present one, we feel confident that the child's form is essentially the base-structure on which a transformation will ultimately operate. Perhaps this is always the case, although we cannot invariably tell. But regardless of that, the analogy of form raises a difficult question--namely, why do transformations develop? In part, the task of this section will be to seek an answer to that question.

Bellugi divides the growth of the negative system into four periods. The essentials of the first period (roughly Time 1 above) are what we have just seen. The only other feature at this point is a rudimentary negative question (NQ), why not? Since why appears in no other context, the pair of words, why not, are probably a single vocabulary item for the child. On the other hand, why not? seems to be a construction. The ? makes the difference. A rising intonation is a child's only form of query at this time, and he applies it to any declarative sentence, as in that Urler suitcase? Thus NQ, even at this early stage, can be broken into two parts: negation (why not) and query (?), in much the fashion of the NQ transformation of adults (Miller, 1962; Mehler, 1963). Again, however, a child's sentences have a form appropriate to the base structure of English grammar; the rising intonation, ?, seems to result from direct application of phonological rules to a base structure that can be regarded as containing the query morpheme, Q. Thus NQ does not come from application of either a negative or a query transformation, and Period 1 appears to be pre-transformational.

Period 2, which comes some 3 to 6 months later, depending on the child, still contains no signs of transformations. There is, nonetheless, a considerable flowering of negative forms. Altogether, they appear in five different and unrelated grammatical settings: they occur with Rules (7) and (8), as in that no fish school; they occur as why not plus negative sentence to form

NQ, as in why not cracker can't talk; they come up as separate vocabulary, don't and can't, as in I don't sit on Cromer coffee; they appear in imperatives, don't eat daisy; and they appear, as in Period 1, in base structures seemingly printed out directly as in no Rusty hat. The situation is cumbersome and inelegant, two characteristics that might lead to the events of Period 3.

Period 3 is again 3 to 6 months later, depending on the child. If one characterizes the negative system as in Period 2, there is even more diversity, cumbersomeness, and inelegance. Negation appears in full adult form--with terminal contour and juncture--in no, it isn't. It continues to appear in the form of can't and don't, as in I can't see it. However, now can also occurs as an auxiliary verb in the child's sentences (I can do it), so we have grounds for assuming that -n't is a negative element in its own right. Negation appears in copular sentences, sometimes with a form of the verb be (I am not a doctor), sometimes not (that not a clown). The verb be thus appears to be an option for the child. Also, there are telegraphic versions of be-auxiliary sentences that contain the negative (I not crying). In this case, however, be is never included, so the environment for negation differs in auxiliary and copular sentences. Negative questions are changed from Period 2, being now only an inversion away from the full adult form (why I didn't see something?). The formula why not has disappeared. Negation is used for the first time with an indefinite determiner and pronoun: you don't want some sugar. Such negative sentences are parallel to affirmative sentences with the same determiner and pronoun (you want some supper), and both types are probably generated by the same rules that produce I can see it, and I can't see it. Finally, negative imperatives (don't touch the fish) continue unchanged, and in adult form, from Period 2.

In all, negatives appear in seven different environments. Considered superficially, these require seven (or, taking determiners and pronouns as instances of the negative declarative, six) different rules. The child's mind appears to be a clutter of special cases.

However, there is reason to believe that the child's sentence-generating rules are not as they have just been described. Sentences such as no wipe finger, no Rusty hat, and not fit have disappeared altogether by Period 3. These sentences were interpreted to be the result of a child applying his phonological rules directly to base structures. Assuming this interpretation to be correct, the fact that these sentences have disappeared suggests that the child is now transforming base structures and applying phonological rules to the resulting surface structures. Thus, a fundamental change may have taken place in the system of negation by Period 3. For the first time the child may use transformational rules and so produce sentences with both base and surface structures. It is significant, then, that there is in Period 3 the first indication of an auxiliary transformation, as evidenced by affirmative sentences with can (e.g., I can see it). Bellugi's paper should be consulted for many more examples that document the emergence of transformations at this point in a child's development.

What causes a child to develop transformations? Since transformations do not affect the semantic content of sentences, their growth cannot be ascribed to some desire to express, say, the concept of negation. Moreover, in the case of this particular transformation, we found the child in possession of the appropriate semantic apparatus before he had any transformational rules at all. What, then, propels a child to devise sophisticated transformational rules such as NEG-repositioning or the auxiliary transformation (Klima, 1964)?

The answer reflects a basic fact about language acquisition which goes beyond the transformations themselves. It is convenient, however, to introduce the argument first in terms of transformational rules, and point out the implications for other departments of language acquisition later.

At Period 2, the child's negative system did not appear to involve transformational rules. Instead, negation was derived directly from the base structure in five independent grammatical settings. We characterized this system as cumbersome and inelegant. These adjectives would apply with even more force in Period 3, except that by then, the child showed signs of using transformational rules. That is, and this is the point, the transformation achieved some economy of rules for the child. Rather than seven (or six) different rules for placing the negative, the child has only two--both transformations.

The child seems to operate like a professional grammarian who takes advantage of the fact that transformations are intrinsically more powerful than base-structure rules, and so can express grammatical concepts more economically. The pressure--or, if you prefer, the motivation--to devise rules of transformation may come from the cognitive clutter that results from not having them. In Period 1, the child had to remember only two rules for the placement of the negative. In Period 2, he had to remember five. By period 3, if it were not for transformations, he would have had to remember six or seven. It is possible, then, that the load on the child's memory by Period 2 was so great that the two transformational rules we observe in Period 3 were precipitated. The pressure here to change must be considerable. The child needs to process sentences in short intervals of time; presumably, it takes less time and a child tends to forget less when the placement of the negative is done by transformational rules rather than by independent base-structure rules.

This hypothesis, of course, is not complete. It provides a motive for the development of transformations that is purely aversive. We can suppose that a child wants to escape the mess into which his base-structure grammar places him, but escape to where? By now, this is a familiar problem. Once again we can appeal to linguistic universals to guide the child. This time we must evoke formal universals; some of these will specify the general form that base-structure rules, such as Rules (7) and (8), must take; others will describe in a general way the form of transformations. One part of the formal universals pertaining to transformations, presumably, would be a characterization of appropriate input, viz., a phrase-marker from the base-structure. Thus, the clutter of special purpose rules in Period 2 would present exactly the conditions a child would need to formulate transformational rules--providing that he knew roughly the format of transformations and the fact that they take base-structure as input.

This basic schema--developing the simplest possible grammar, experiencing pressure from too many special cases, reducing the pressure by resorting to new grammatical devices that accord with the linguistic universals--can be applied to all the steps of language acquisition that we have discussed so far. In so doing, we can raise the problem of the motivation for language development.

## Why Does Child Language Change?

The earliest vocalizations of infants and the evloution of babbling during the first year of life are matters of maturation (Lenneberg, forthcoming), and the original impetus to language acquisition probably lies in this maturational process. However, our interests are now in the developments that take place after the child first begins to produce single-word utterances; we may take it for granted that the child is already moving in the direction of language by this time. The problem we shall consider is analogous to the one discussed with the transformations: a child always moves on to a new system, even though his original system appears to meet the purely functional purpose of expressing his needs, desires, and interests. From a strictly functional point of view, there is little reason for child language to change.

Let us assume that compiling a sentence dictionary would be one way to meet the requirement that linguistic competence include the ability to assign semantic interpretations to sentences (Miller, personal communication). If we were to undertake this task, we would try to construct a list of all the simple sentences of English and pair them with their interpretations. However, such a dictionary, while feasible in theory, would not be possible in practice. There are simply too many grammatical sentences that must be included. In this light, the semantic theory described by Katz and Fodor (1963) and Katz and Postal (1964) can be regarded as a substitute for the dictionary. It has, as Miller pointed out, the same effect as a sentence dictionary but not the same bulk.

Children between the ages of 12 months and 18 to 24 months produce only one-word utterances. Most often these are nouns in adult grammar, but verbs and adjectives appear in some numbers also. Many observers consider these single-word utterances to be "holophrastic", by which is meant that each word has a much broader and more diffuse meaning for a child than it does for adults (McCarthy, 1954). In effect, holophrastic words stand for sentences. The utterance "milk", for example, can mean for a one-year old "I want some milk", "The milk is on the floor", "Don't give me any more milk; I want pablum", etc. A range of meanings, at least, is the impression one gets from the range of circumstances in which the child produces these single-word utterances. If they are holophrastic, it is conceivable that single-word utterances indicate that the child is trying to construct a dictionary in which each word corresponds to a sentence-interpretation.

But if that is the case, why do children change? If each word expresses the meaning of a whole sentence, why abandon this simplicity for the contraptions of English syntax where the same content is expressed in a more complex manner? There might be two reasons. One is that the child is constantly adding new words to his vocabulary, and soon the list becomes too long; it is the same difficulty that causes us to reject a sentence dictionary in semantic theory. It is true that a child's vocabulary increases from one or two words when he is a year old to approximately 200 words by the time he is two years old (Smith, 1926). However, this number is not yet so great as to force a child to abandon his lexicographic project; no matter what grammatical developments occur, he will still need a dictionary. Indeed, he will have to increase it further by a very large factor. So it cannot be the number of entries that motivates him to change his strategy. A second factor is probably more important. In the beginning, each entry, although it sounds like a word to adults, is a sentence for the child, which means that each entry actually has a great number of different interpretations, is highly ambiguous, and can only be disambiguated by knowledge of its context. If we measure memory load, not in terms of the number of entries, but in terms of the number of interpretations a child would have to remember if he persisted in his attempt to construct a holophrastic dictionary, then the size of the project would actually be much greater than it might seem, and communication efficiency would be impaired by its intrinsic ambiguity. By resorting to a word dictionary supplemented by syntactic and semantic rules, a child not only reduces the number of interpretations he will eventually have to remember, but also gains precision of expression by increasing the variety of his sentences and thus decreases the overall ratio of interpretations per sentence.

According to this view, the driving force behind language development is the rapidly growing variety of semantic interpretations for which the child must find some means of differentiation and expression. (A similar idea has been under development by Gloria Cooper [personal communication].) A holophrastic dictionary fails both on grounds of size and ambiguity; a sentence dictionary fails on grounds of size; a word dictionary supplemented by syntactic and semantic rules provides the eventual solution. If we imagine a child beginning with a holophrastic dictionary, shifting to a sentence dictionary for greater precision, and finally shifting to a word dictionary to reduce the memory load as his vocabulary grows, then we would expect to find initially a very intimate relation between sound and meaning which would first give way to mediation by simple base-structures of the syntax and ultimately to mediation by the whole complex structure of transformational grammar. Which is, of course, exactly the sequence that has been described in the preceding pages.

To say that a need for precision and cognitive economy motivate the developmental sequence is not to explain how a child is able to meet these needs, or why he chooses the particular manner of meeting them that he does. For this we can only appeal to the child's innate faculté de langage. Since all languages have this general structure, and since all children seem able to acquire its local manifestation in their own communities, we assume that this ability is part of a child's natural endowment as a human being. This claim is much stronger than most would care to make, but nothing less seems adequate to account for the facts as they are known at the present time.

## The Role of Parental Speech in Language Acquisition

It was said above that parental speech serves the function of helping a child to choose among a narrow set of possibilities defined by the linguistic universals. The basic grammatical relations, for example, commit a child to an NP + Pred P format for sentences, but they leave the order of these constituents unspecified; it might be NP + Pred P or Pred P + NP, and a child must discover which it is from parental speech. The role of parental speech is essentially directional; it provides a child with some basis for choosing among the options offered by the linguistic universals. The purpose of this section is to discuss what is known about this process of choice.

There are many points in grammar at which we might study the role played by parental speech. We could, for example, look at a child's decision to use NP + Pred P rather than Pred P + NP; or we could examine the pairing of words with entries in the dictionary as a child develops his lexicon; or we could study a child's discovery of the significance of the distinction between mass and count nouns in English, etc. Indeed, parental speech will play the role of arbitrating choice at every point in acquisition, for it is probably true that linguistic universals never so determine competence that there are no alternatives open to a child. The basic grammatical relations--where evidence from parental speech must decide between just two possibilities--probably represents the maximum degree of constraint imposed by the universals. Elsewhere, the degree of constraint appears to be less. One such case is the acquisition of noun and verb inflections in English. The importance of linguistic universals in a child's learning to use these inflections is not less than in the development of hierarchical rules, but the number of possibilities consistent with the universals is much larger. In the case of the plural inflection on nouns, for example, any number of phonemes situated anywhere on a word would be consistent with the universal requirements that phonemes must be constructed out of distinctive features and that the rules for adding plural inflections to sentences must correspond to the formal universals. Given these universal constraints, there is still an enormous number of possibilities from which a child must choose, including the option of not marking plurality in the surface structure at all. Thus, we might expect that the use a child makes of parental speech will be more obvious, since parental speech must perform a larger task, in acquiring noun and verb inflections that in acquiring the NP + Pred P order for sentences. It is fortunate, therefore, that much of the recent work on language acquisition has focused on precisely this problem.

Two techniques have been commonly employed to study the development of noun and verb inflections. One is simply to note the occurrence of inflections in a child's speech. With such data, we can inquire whether regular or irregular forms appear first, whether the order of appearance of inflections corresponds to the frequency with which they are used in speech, etc. The other technique is to introduce a child to nonsense nouns, verbs, and the like, to see if he can apply inflectional rules to "words" that are completely novel, ones for which there are no parental models. The advantage of the second technique is that it eliminates the possibility that a child will place an inflection appropriately merely by imitating parental speech. As always, we are interested in the productive use of linguistic forms, but so long as actual words are used to test a child's grasp of inflectional rules, correct performance through imitation is always a theoretical possibility. The fact that a child says glasses does not necessarily indicate that the rule for forming plural nouns is part of linguistic competence. There are other ways to assure ourselves that children have productive inflectional rules, the main one being the occurrence of systematic errors (e.g., foots), but the introduction of nonsense words is one of the easiest techniques to use.

Berko (1958), in a well-known paper, was the first to study children's inflectional rules by introducing children to nonsense words. She presented 4 and 5-year-old children with monosyllables such as wug, saying "Here is a wug; now there are two of them; there are two...", her voice trailing off, hoping to elicit from the child the plural, wugs. If that is what she got, the child would be credited with knowledge of the inflectional rule that governs the addition of plurals to nouns. To test for verb inflection, she might have said "Here is a man who knows how to wug; today he is wugging; yesterday he...", looking for the past tense, wugged. In general, Berko found that most 4- and 5-year-olds had mastered the inflectional rules of English, though her 5-year-olds did better on most items than her 4-year-olds, so some growth continues as late as age 5.

Although Berko's results show that 4- and 5-year-old children have largely mastered the inflectional rules of English, her findings indicate nothing about how acquisition proceeds. For this, we must turn to studies where the development of individual children is followed over time. It is in the emergence of noun and verb inflections that we can see the role played by parental speech in acquisition.

The role of overt practice

The assumption that practice somehow plays a determinative role in language acquisition is, perhaps, the original psycholinguistic theory. It has figured in one or another psychological speculation since at least the 1920's (e.g., Allport, 1924), and the tradition continues unbroken, though not unmodified, up to the present time (e.g., Jenkins and Palermo, 1964). The basic assertion in all such theories is always that there exists a fundamental continuity between language acquisition and the forms of learning studied in the psychological laboratory. This view has been questioned on general grounds by Miller (1965). However, our concern is now more specific: does practice-theory characterize what children do in order to find the locally appropriate expression of the linguistic universals? This question, it should be noted, already represents a considerable reduction in the customary scope of practice-theory. Some authors seem to believe that all of language acquisition can be attributed to the gradual strengthening of responses. It is clear, however, that this sanguine view is condemned to frustration, for there are no responses to be strengthened in the base structure of language, and in any case, practice-theory cannot explain how a child bridges the gap between elevated response-strength and linguistic competence. But it is conceivable that practice is important within the restricted portion of language acquisition that has to do with the discovery of the locally appropriate expression of the linguistic universals. Perhaps a child is able to integrate into his innate linguistic competence just those surface features that have developed some degree of response-strength. One hypothesis, therefore, is that response-strength is a child's criterion for choosing among the possibilities offered by the linguistic universals.

Any version of practice-theory, including the one just suggested, rests on two fundamental assumptions. One is actually the basic assertion of all such theories, the assumption that linguistic forms can be strengthened by practice. The other is that the forms that a child practices are novel in his grammar. The consequences of both assumptions are important. Suppose, for example, that practice does not strengthen a child's grip on linguistic forms; then the value of practice (as a criterion, or whatever) would be completely lost. Suppose, on the other hand, that practiced forms are not novel, that a child practices only forms that have arrived in his grammar from some source other than practice; then the effects of practice, however great they may be in strengthening responses, cannot cause a child's grammar to change. This second assumption--that practiced forms are novel to a child's grammar--is the familiar theory that acquisition proceeds through imitation. It is only through imitation that practice could influence the introduction of new forms into a child's grammar. Obviously, a child could not <u>acquire</u> a form by spontaneously practicing it; in that case, the form has already been acquired. We can evaluate the hypothesis that a child enlarges his grammar by imitating adults by inquiring if imitations contain features of adult grammar that are otherwise absent from a child's speech. Ervin (1964) has made this comparison for the imitations of five children. For each child, she compared the spontaneous imitations in her records to the grammars written from her subjects' unimitated free speech. She found that imitations and free speech were identical for every subject except one, and in this case imitations were grammatically more primitive. The children's imitations were not, as Ervin put it, "grammatically progressive". If a child was not producing the progressive inflection, for example, he would not imitate it: Adam is running fast might be imitated as Adam run or run fast, but not as Adam running or running fast. In short, children assimilated adult models to their current grammars; when there was no place for -ing in the grammar, -ing did not appear in imitation. But, of course, assimilating imitations to current grammar means that imitation cannot change the grammar. The suffix -ing must enter a child's competence in some other way.

The signs are that sometimes a child's tendency to assimilate adult models into his current grammar is so strong that even when he makes a deliberate effort to copy adult speech, the effort may at first fail. One child, who was in the phase of producing double negatives (cf., Bellugi, 1964), while developing the negative transformation, had the following exchange with his mother:

Child: Nobody don't like me

Mother: No, say "nobody likes me"

Child: Nobody don't like me

.
.
.
.

(eight repetitions of this dialogue)

.
.
.
.

Mother: No, now listen carefully; say "nobody likes me"

Child: Oh! Nobody don't likes me

The exchange is interesting because it demonstrates the relative impenetrability of the child's grammar to adult models, even under the instruction

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(given by the mother's "no") to change. The child behaves at first as if he did not perceive the difference between his mother's sentence and his own, though later, when the mother supplied great emphasis, the child recognized a distinction. With this much delay in introducing changes, spontaneous imitations are bound not to be grammatically progressive since they consist only of a single exchange. The fact that a change ultimately was made, however, illustrates that children can profit from adult models. We shall return to this possibility below when we discuss parental expansions of child speech.

In any case, it seems clear that one assumption of practice-theory is not supported by the facts of language acquisition. Let us now examine the second of these assumptions, the basic assertion that practice increases response-strength. Since we know that practice does not lead to the incorporation of novel forms, changes in response-strength could affect acquisition only in stablizing grammatical features already acquired. Perhaps new forms, whatever the manner by which they enter the grammar, are at first unstable and practice is essential for their solidification as smoothly running grammatical skills. The question in this case becomes one of inquiring if forms that receive much practice are more stable than forms that receive little practice. Practice may be given through imitation or through spontaneous use. Ervin (1964) again has appropriate observations. She was interested in the emergence of the past-tense inflection on verbs. In children's earliest speech, verbs are unmarked for tense. A child will say Adam go, regardless of whether the event referred to took place yesterday, or will take place tomorrow, or is taking place while the child speaks. Ervin searched through her records for the first occurrence of any verb marked for the past tense, and found that these were always strong verbs, that is, ones that form the past tense irregularly. It is well known that children regularize the past tense of strong verbs: they say comed, goed, and sitted, on analogy with such regular verbs as looked, walked, and laughed, a tendency that often persists into grade school. However, Ervin found that the initial past-tense inflections of strong verbs took the correct adult form. The first occurrence of the past tense were words such as came, went, sat, etc.; the regularizations come later in a child's career. The same order of events--past tense appearing first in correctly inflected strong verbs--appears also in Brown's records. There is nothing surprising in this fact when we take into consideration the high frequency with which the strong verbs occur in parental speech, and their early emergence probably indicates that they are learned as vocabulary items, picked up independently of the corresponding unmarked verbs. The strong verbs are frequent in child speech as well, and once a child possesses came, went, sat, etc., he finds many opportunities to use them. Many more opportunities, in fact, than he finds to use the weak, regularly inflected, verbs. Consequently, a child receives much more practice on individual strong verbs in the past tense than he does on individual weak verbs, with or without inflections. If practice offers stabilization of linguistic forms, the correctly inflected strong verbs ought to be fairly well anchored in a child's repertoire. However, they are not. Indeed, they turn out to be far less stable than the weak verbs that receive little practice. Ervin searched her records for the first occurrences of the regular past-tense inflection, -d, and discovered what at first seems to be a paradox: the first regular inflections appeared on the strong verbs. She observed the children in her sample saying comed, goed, sitted, etc., before she observed them saying looked, walked, laughed, etc., as if the children were able to generalize before there was anything to generalize from. The explanation of this apparent anomaly is that Ervin's samples of speech, being of small size in relation to a child's total output, failed to pick up any of the correctly inflected weak verbs that must have existed. Because the strong verbs are frequent and the weak verbs are infrequent, the regular past-tense inflection had a better chance of appearing in the speech records on the strong verbs; chance so worked out in Ervin's samples that the miraculous appeared to happen, and strong verbs registered the regular past-tense inflection before weak verbs did. But none of this robs Ervin's findings of their force; the very difference in frequency that favored the appearance of the strong verbs means that highly practiced forms, the strong verbs, were so unstable as to be swept away by a few occurrences of the regular past-tense inflection on weak verbs. Indeed, the number of occurrences of these verbs was so small that they did not appear in Ervin's records.

What is the cause of this remarkable instability of the strong verbs? It seems to be that each strong verb, although frequent, is unique unto itself. In contrast, the weak verbs, although infrequent, all exemplify a pattern. Apparently patterns weigh more heavily with children than frequency of repetition does. In the case of the past-tense inflection, therefore, it seems that response-strength is not the criterion by which a child chooses among the possibilities offered by the linguistic universals; rather, a child's criterion appears to rest on the occurrence of the same form in analogous constructions in parental speech. The appearance of /t/ and /d/ as suffixes on verbs in parental speech apparently suggests to a child a rule that converts the "past" morpheme of the underlying structure, which may be a possibility offered by the universals, into /t/ or /d/, which is a feature unique to English. A child's criterion for adopting features from parental speech, therefore, may be to accept only those parental features that can be produced by a rule, a criterion that only patterned features, such as the weak verbs, will meet. On this criterion, the amount of practice given to a feature is less relevant to language acquisition than the ability of a child to notice that a feature is part of a pattern. Insofar as verb

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inflections are representative, the paradigm for finding the locally appropriate expression of the universals is the concept-attainment experiment, not the rote-learning experiment. Other features of English should be examined from this same point of view; it may turn out that practice plays some role in acquisition, although on present evidence, this role appears to be peripheral.

We have seen that imitation is not the means of introducing new forms into a child's grammar; now we see that whatever salutary effects on practice imitation might offer, practice may not be very important to language acquisition. The fact is, nonetheless, that children imitate adult speech a good deal. Roughly ten percent of all utterances recorded in Ervin's project were imitations (Ervin, 1964), and similar proportions of imitations have been found in Brown's records (Slobin, 1964). We can barely even speculate on why children imitate so much. Part of the mystery may be removed, however, if we note that the difficulty in explaining imitation is probably not unique to imitation. Aside from its potential for introducing novel forms, imitation does not seem to be different from the spontaneous verbal play that Weir observed in her son's bedtime soliloquies (Weir, 1962). It may be unimportant that parental speech happens to initiate the play that we call imitation; by seeking some special function for imitation, we may have allowed children to deceive us. That a child is actually at play when he imitates is the compelling suggestion of the following fugue by one of Brown's subjects (mentioned by Slobin, 1964):

Adult: That's the tattoed man

Child: Tooman. Tattoo man. Find too tattoo man.
Tattoo man. Who dat? Tatoo. Too man go,
mommy? too man. Tattoo man go? Who dat?
Read dat. Tractor dere. Tattoo man.

This example, while exceptional for its virtuosity, is typical of many imitations, and suggests that imitation as well as bedtime soliloquies are examples of children's tendency to play with the skills at their disposal. If that is the case, they should be afforded no more (or no less) significance in language acquisition than children's play with blocks, crayons, etc., has in motor development. Hockett and Ascher (1964) have suggested that verbal play may have served a crucial function in the origin of language by introducing the property of displacement, the capacity to talk about things not present (cf. Hockett, 1959). It is conceivable that the play of Weir's child and the play of children imitating serves a similar function. Part of the fun, in fact, might be saying things that bear no relation to the situation in which a child finds himself, a necessary condition for future talk about scientific hypotheses, theological dogma, shopping lists, etc.

## Expansions

We have said that the speech of adults from which a child discovers the locally appropraite manifestation of the linguistic universals is a completely random, haphazard sample, in no way contrived to instruct a child on grammar. Although this statement is true of adult speech in general, there is one respect in which parental speech is not random. Quite often adults repeat the speech of small children, and in so doing, change the children's sentences into the nearest well-formed adult equivalent. Brown has called this phenomenon "expansion of child speech" (Brown, 1964). It is a kind of imitation in reverse, in which the parent echoes the child and, at the same time, supplies features that are missing from the child's sentence. About 30 per cent of the children's sentences in Brown's records were expanded, forming such exchanges as: Child: Papa name Papa; Adult: Papa's name is Papa, uh-hum (mentioned by Slobin, 1964). In this case, the adult filled out the child's sentence with the possessive inflection (*s*) and a form of the copular verb;

other expansions might add missing articles, prepositions, etc.. Some change word order: Child: table hit head; Adult: no, the head hit the table. Adults probably perform these expansions in order to check their understanding of what children say (thus making the assumption that children can comprehend more grammatical features than they can produce (Slobin, 1964), a possibility that is discussed later).

Aside from the motivation of parents to expand child speech, however, expansions can be considered from the point of view of influencing the course of language acquisition. It is possible that they play an important role in a child's discovery of the local manifestation of the linguistic universals. Children, we have said, produce semi-grammatical speech. They generate speech by simple base-structure rules that operate on generic grammatical classes defined in terms of a universal hierarchy of categories. Since these rules--or their inversions--are part of adult competence, it is possible for adults to impose interpretations on child speech by a process that is exactly the same as the imposition of an interpretation on a grief ago or golf plays John. A child's sentence will have a representation at some level of the universal hierarchy of categories in common with the set of well-formed sentences that can be generated by the base-structure rules. Presumably, an adult's expansion of a child's sentence is one of the well-formed sentences in this set. Moreover, there is good reason to believe that the particular sentence that an adult uses as an expansion will be the one member of the set that best exemplifies distinctions that a child has not yet marked in his grammar. Suppose, for example, that a child produces the telegraphic Adam cry. It has a representation at some (fairly high) level in the hierarchy of categories in common with a set of well-formed sentences that includes Adam is crying, Adam cried, Adam will cry, Adam's crying..., and probably more. Each of the well-formed sentences honors the distinctions preserved in Adam cry, and the rules for generating the child's sentence are all involved in the generation of the well-formed sentences. In addition, however, the well-formed sentences embody distinctions that are not honored by Adam cry, and most of them involve transformation rules that are not included in the child's grammar. The situation is propitious for demonstrating to the child a locally appropriate manifestation of one or more of the linguistic universals.

Suppose that context indicates to the parent that Adam is talking about an event that took place yesterday. The only appropriate expansion, then, would be Adam cried, and so the child would be presented with an example of how the category "past" is expressed in English, viz., by the suffix -d. Expansions, in short, may present suitable conditions for children to discover the local expression of linguistic universals and do so in a way that imitation and practice do not. Not every expansion, of course, will be appropriate. A parent must judge from extra-linguistic considerations which member from the set of well-formed sentences should be the expansion, and sometimes this judgment will be wrong. Adam might have meant that he is about to cry. However, it is doubtful that inappropriate expansions occur frequently, and in any case, the child must be able to discover the locally appropriate form of the universals from sources other than expansions, so he can check his information from one source against the other. The role of parental expansions, therefore, would be to facilitate a child's acquisition by presenting models tailor-made to exemplify the parts of competence not completely determined by the universals. It may be, as Brown (1964) has written, that "by expanding the child's words into the nearest sentence appropriate to the circumstances a mother may teach a child to conceive of these circumstances as they are conceived in our community and to code them as we code them."

Because expansions are a means of facilitating a child's discovery of local features, one would suppose that children whose parents expand a great deal would show more rapid acquisition of language than children whose parents expand little. A difference in the amount of parental expansion, in turn, might depend on the amount of interest parents have in understanding what their children say. We mentioned before that parents' motivation to expand is probably to verify their understanding of child speech, so we might expect that the tendency to expand is greatest among those parents with a conviction that children do have something to say, parents who believe that the behavior of children is worthy of attention, parents who are, in short, subscribers to middle-class values and middle-class child rearing practices. As a matter of fact, the expansion-rate of 30 per cent in Brown's records came from academic parents. In contrast to these parents are the parents of another child in Brown's project, whose background is more proletarian. They expand their child's speech far less often, and the child's rate of development is strikingly slower than the development of the middle-class children. We can speculate, therefore, that the lower-class child is retarded at least in part because he must work out the appropriate English manifestation of the linguistic universals on his own. He must discover such features as noun and verb inflections from the haphazard stream of speech, not at all contrived to instruct on grammar, that happens to issue willy-nilly from his parents. Such children, in short, may not be deficient in their innate linguistic competence, but merely deficient in opportunities to test linguistic hypotheses.

A project that studies the usefulness of expansions in language acquisition has recently been completed by Cazden (1965). She assembled three groups of 2.5-year-old children: one was an expansion group; another, an expatiation group; and the third a control group. Children in the expansion group were seen in daily sessions of 40 minutes each, during which time everything they said was systematically expanded by an adult. These sessions continued for 3 months. Children in the expatiation group also were seen in daily 40 minute sessions for 3 months. However, unlike the first group of subjects, the speech of the expatiation children was never expanded; rather, everything they said was commented and enlarged upon by an adult. The two groups of children were thus alike in that each of their utterances was followed by an utterance of an adult. They differed in whether or not the adult's utterance contained the child's utterance as a component part. In expansion, dog bite might be followed by the dog is biting, whereas in expatiation, it might be followed by yes, he's angry. Control subjects did not participate in daily sessions at all, but were merely given Cazden's tests of linguistic advancement at the beginning and end of the three-month experimental period. Since all children in this study were from culturally disadvantaged homes, it was hoped that such expansions and expatiations as they experienced would come mainly from the daily experimental sessions.

Compared to children in the control group, both expansion and expatiation children showed advancement after three months. However, the surprising result is that the expatiation children showed considerably more advancement than the expansion children. One difference between these situations is that a greater variety of speech is given by an adult when expatiating than when expanding, since in the second case but not in the first, the adult must employ words provided by the child. The conclusion seems to be, therefore, that although expansions help somewhat, their influence pales when compared to the influence of increased variety of speech from an adult.

However, there is another way of looking at Cazden's experiment, and one that makes its outcome less surprising. Middle-class parents, to judge from Brown's records, expand roughly 30% of what children say. We may wonder why they do not expand more. Why should the expansion rate level off at 30% rather than 50%, or 70%, or even 100%? One reason must be that extra-linguistic context does not always indicate to a parent which sentence, among all the well-formed alternatives corresponding to the child's utterance, is the appropriate expansion. If a child says dog bite, and there is no indication from the general situation that he is talking about present time, for example, as opposed to past or future time, an adult probably would not expand the utterance. In the expansion situation of Cazden's experiment, however, all a child's utterances were expanded. Only some of these could have been clear cases, utterances for which extra-linguistic context dictated an appropriate expansion. Again, judging from Brown's records, the proportion of clear cases would have been about 30%. This means that many of the expansions in Cazden's experiment were made without guidance, without any means of deciding which of the several well-formed alternatives was appropriate. It seems inevitable therefore, that many of these expansions would have been inappropriate and would have misled a child who had some linguistic feature in mind, for which he was attempting to discover the local means of expression. Thus, although some expansions might have helped in Cazden's experiment, others must have interfered, so the net result was only marginal improvement over the control condition where there were no expansions at all. The expatiation condition, in contrast, could not possibly mislead children in this way. An expatiation contains none of a child's words; the adult says nothing relevant to the linguistic hypotheses a child may hope to test, so it is impossible for a false hypothesis to be confirmed. On the other hand, in expatiating an adult does present a large variety of well-formed speech, a condition that probably is (as Cazden concludes) helpful to language acquisition. What remains unclear is the usefulness of expatiation compared to appropriate expansion.

Comprehension Versus Production of Speech

It is common in discussions of child language to distinguish active and passive linguistic skills. The distinction is sometimes drawn in terms of a child's development of vocabulary, sometimes in terms of his command of syntax, and most often in terms of both. The gist of the distinction is that comprehension of features of language (passive control) occurs earlier in development than does production of the same features (active control). The emphasis here is on the word "same"; the hypothesis is uninteresting if all that is meant is that some features are comprehended before any features are produced. But if every feature is first under passive control, and only later under active control, a significant claim is being made about the course of language acquisition. Much ink has been spilled on this distinction, and the issue continues very much alive today. It is all the more remarkable, therefore, that almost no one has tried systematically to study it. Aside from numerous anecdotal accounts (e.g., Jesperson, 1921; Kahane, Kahane, and Saporta, 1958), there is only one experimental study that is known to this writer (Fraser, Bellugi, and Brown, 1963).

However, before describing their work, a word must be said on the theoretical significance of the distinction between comprehension and production. Discuscions of the topic are often made difficult because of a confusion of this distinction with the distinction between competence and performance. Competence and performance on the one hand, and comprehension and production on the other, are different although related distinctions, and it is important to see what both the differences and relations are. Competence, as we have said, is the knowledge of linguistic rules, categories, etc., that accounts for a native speaker's intuitions about his language. Performance is the expression of competence in talking and listening. In these terms, production and comprehension of speech are both categories of linguistic performance; both involve the expression of competence, the one in producing or encoding speech, the other in receiving or decoding speech. The claim that passive control precedes active control in development, therefore, can be rendered to mean that comprehending speech somehow involves fewer distorting and obstructing factors in the passage from competence to performance than producing speech does. Accordingly, an explanation of the comprehension-production difference will come from a performance model that states, among other things what the "parameters" of conversion are for production and comprehension, and how they differ. In this framework, a distinction between active and passive _grammars_, which some have wanted to draw, is not necessary; a grammar is a statement of competence, whereas comprehension and production are parts of a theory of performance, and we can assume that there is but one grammar that feeds into both kinds of performance.

The experiment of Fraser, Bellugi and Brown (1963) compared children's production and comprehension of grammatical contrasts. We can regard the experiment as a study of the relative difficulty of converting syntactic competence into the two kinds of performance. They devised an ingenious test built around pairs of sentences that contrasted on single grammatical features. Associated with each pair of sentences was a pair of contrasting pictures, the contrast in this case hinging on the referential distinction that corresponds to the grammatical contrast. One pair of sentences, for example, was "The sheep is jumping" vs. "The sheep are jumping", which had associated with it two drawings, one of a single sheep jumping over a fence while a second sheep looked on, and the other showing two sheep jumping over a fence. The two sentences differed only in whether the auxiliary verb, _be_, was singular or plural; the two pictures differed only in whether one or two sheep performed the action. This set of pictures and sentences, therefore, provided a test of a child's control over the plural-singular distinction on auxiliary verbs. Fraser et al. were able to find contrasting pictures for ten grammatical contrasts: for example, singular-plural marked by inflections ("the boy draws" vs. "the boys draw"), present progressive-past tense ("the paint is spilling" vs. "the paint spilled", which involves more than a minimal contrast), subject-object in the passive voice ("the car is bumped by the train" vs. "the train is bumped by the car"), etc. In order to test comprehension, a child was asked to point to the picture that corresponded to one of these contrasting sentences; he was scored right or wrong, according to which picture he indicated. The test of production was roughly the mirror image of the test of comprehension. The experimenter pointed to one of the contrasting pictures and requested a child to say the corresponding sentence; he was scored right or wrong depending on whether or not his response included the appropriate grammatical feature. In addition to tests of comprehension and production, other children were asked to imitate contrasting sentences. In this case, a child saw no pictures and merely heard the sentences. His response was the same as in the production test, but it was not necessary for him to relate grammatical and referential contrasts.

The results of these tests can be simply stated: in the case of every grammatical contrast, comprehension exceeded production, often by a large margin; moreover, imitation exceeded comprehension on every contrast except one, again often by a large margin. The results of the experiment, therefore, strongly support the assumption that passive control appears earlier in development than active control. The superiority of comprehension over production might tell us, as Fraser, et al. suggest, that one difference between the two kinds of performance is that production places a greater load on a child's memory. Production and comprehension both operate under various constraints, among which, as we have said, is the need to remain within the limits of memory span. It is conceivable that there is more than one such

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span, resulting from production and comprehension having to pass through different systems, with the system for comprehension having a greater capacity. This would cause a child to forget features in production that he remembers in comprehension, as apparently occurred in the test of Fraser, et al.

The fact that imitation exceeded comprehension probably means that there is a third span, larger yet, associated with a child's phonological performance. As Fraser, et al. commented, in their study imitation appeared to be a perceptual-motor skill, not operating through the meaning system. Thus, the results of their experiment lead us to conclude that there are at least three memory spans of different capacities involved in linguistic performance: one for phonological production, which appears to be largest; one for grammatical comprehension, which appears to be next largest; and one for grammatical production, which appears to be smallest. Whether or not a child will perform accurately in a given task will depend on the length of the sentence on which he is required to operate in relation to the size of the appropriate memory span. The principle would be: if a sentence is shorter than a given span, the corresponding performance can occur; if a sentence is longer than the memory span, the corresponding performance cannot occur with complete accuracy. The performance in every case is preservation of a given grammatical feature, such as plural marking on the auxiliary verb. We can imagine, therefore, four different relations among imitation, comprehension, and production, all depending on the length of the required sentence. (1) If sentences are short in relation to the grammatical production span, imitation, comprehension, and production should be equivalent, because underlying competence--phonological or grammatical--can be expressed in every task. (2) If sentences are long in relation to the grammatical production span but short in relation to the grammatical comprehension span, comprehension and imitation should be equivalent, and both should be superior to production. Presumably, many of the sentences used by Fraser, et al. fell into this category. (3) If sentences are long in relation to both the grammatical comprehension and production span but short in relation to the phonological production span, imitation should be superior to both comprehension and production, which in turn, should be equivalent. Such sentences can be imitated, but they are not understood or spontaneously produced. Presumably, some of the sentences used by Fraser, et al. fell into this third category, hence causing an overall superiority for imitation. (4) Finally, if sentences are long in relation to the phonological production span, all three types of performance--imitation, comprehension, and production--should again be equivalent, since underlying competence is not likely to be expressed in any task. These four relations are illustrated in Fig. 5.

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Insert Figure 5 about here

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One advantage of this scheme is that it accounts for the apparent contradiction between the finding of Fraser, et al. that imitation was more accurate than production, and the finding of Ervin (1964) that imitation was not grammatically progressive. As Slobin (1964) has pointed out, the two studies differed in exactly the respects illustrated in Fig. 5. Ervin's subjects were very young (two years) and so had small memory spans, and they spontaneously imitated adult sentences, which on the average are longer than the test items used by Fraser, et al. Thus, it is likely that many of the sentences in Ervin's study were characterized by relation (4) in Fig. 5, a condition in which imitation, comprehension, and production are equivalent. In order to imitate sentences longer than the phonological span, subjects would either have to recode them grammatically or parrot as much of the sentence as remained in the phonological span. In neither case would the crucial grammatical features that mark imitations as "progressive" be likely to be preserved. Since there was no particular reason for Ervin's subjects to strive for accuracy, it is probable, as Slobin noted, that they recoded the adult sentences before repeating them. On the other hand, the subjects of Fraser, et al. were older (three years), and were given short sentences (average of four morphemes; maximum of eight morphemes) to work with. Most of the sentences in Fraser, et al., therefore, were probably characterized by relations (2) and (3), where imitation exceeds production. This analysis, of course, does not affect Ervin's conclusion that imitations are not the means of entry for new features into a child's grammar.

A great deal more work is necessary on the difference between production and comprehension, for it occupies an important position in studies in language acquisition. The study of comprehension is, first of all, methodologically important. There is no reason to assume that production and comprehension differ only on size of memory span. Indeed, every aspect of a linguistic performance model is a point of potential difference between comprehension and production; it is conceivable that these various factors constrain the two kinds of performance in nonparallel ways--it is theoretically possible that some even constrain comprehension more than production--and there may be qualitative differences as well as quantitative ones. Without a reasonably clear vision of the form of a performance model, therefore, we cannot tell what differences there are between production and comprehension; yet all that we know about language acquisition is based on children's production of speech. It is possible that the inferences we draw about children's competence will be different when based on comprehension.

There is a second, more basic reason to study children's comprehension. If, as Ervin's findings indicate, children gain little from overt practice, a child's own production of speech will not be critically involved in the process of acquisition. On the other hand, children appear to profit from examples of well-formed sentences that are presented (through expansions or otherwise) by parental speech, which means that a child's additions to competence are made through his comprehension. Study of the competence-comprehension cycle, therefore, may turn out to be a study of the principal avenue over which a child acquires the local form of the linguistic universals, and the problem of how children comprehend language may be inseparable from the problem of how they acquire it.

The technical difficulties of studies of comprehension are formidable. One must try to devise non-linguistic techniques that will register a child's comprehension; the techniques must be usable with very young children if we want to catch acquisition at its most active time; and the techniques must be sensitive to a wide range of grammatical features. Perhaps the last requirement is the most difficult. Fraser, et al. used correctness of pointing as a test of comprehension, which works well enough when the grammatical contrast has a picturable correlate. But how does one get a child to point to the correlate of a basic grammatical relation or a differentiated pivot class? For that matter, is it correct even to speak of the correlates of such fundamental linguistic features? The answer is not obvious. Probably, therefore, the most difficult part of the study of comprehension will arise in the development of useful non-linguistic responses. On the other hand, there is one signal advantage in the study of comprehension that is totally lacking in all studies of production. As one of the linguists participating in the Fourth Conference on Intellective Processes (Brown and Bellugi, 1964, p. 42) pointed out, we always know in a comprehension task what the input is--it is the sentence being understood. In production this is not the case; the input is completely obscure. We have no conception of what input from (to?) competence leads to the generation of a sentence. What input leads to want milk mommy or where doggie?

Perhaps future research will find ways to exploit this advantage while solving the problem of obtaining sensitive indicators of comprehension.

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## Footnotes

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Table 1

Pivot and Open Classes from Three Studies of Child Language

| Braine | | Brown | | Ervin | |
|---|---|---|---|---|---|
| allgone | boy | my | Adam | this | arm |
| byebye | sock | that | Becky | that | baby |
| big | boat | two | boot | | dolly's |
| more | fan | a | coat | | pretty |
| pretty | milk | the | coffee | | yellow |
| my | plane | big | knee | | come |
| see | shoe | green | man | | doed |
| night-night | vitamins | poor | mommy | | . . . |
| hi | hot | wet | nut | the | other |
| | mommy | dirty | sock | a | baby |
| | daddy | fresh | stool | | dolly's |
| | . . . | pretty | tinker-toy | | pretty |
| | | | . . . | | yellow |
| | | | | | . . . |
| | | | | here | arm |
| | | | | there | baby |
| | | | | | dolly's |
| | | | | | pretty |
| | | | | | yellow |
| | | | | | . . . |

Table 2

A Child's Sentences at Two Stages of Development

| Time 1 | Time 2 |
| --- | --- |
| dats your a car | dats a your car |
| a dats cheese | dats a cheese |

| Time 1 | Time 3 |
| --- | --- |
| fast the car | the car fast |
| dis hammer other one | dis other one hammer |
| big Eve toy | Eve toy big |

Table 3

Sentence Patterns that correspond to

Basic Grammatical relations

| Child's Speech | | Corresponding Grammatical Relations |
|---|---|---|
| Pattern | Frequency | |
| P + N | 23 | modifier, head noun |
| N + N | 115 | modifier, head noun, subject, predicate |
| V + N | 162 | main verb, object |
| N + V | 49 | subject, predicate |
| Sum | 349 | |
| P + N + N | 3 | modifier, head noun |
| N + P + N | 1 | subject, predicate |
| V + P + N | 3 | main verb, object |
| V + N + N | 29 | main verb, object |
| P + N + V | 1 | main verb, subject, predicate |
| N + N + V | 1 | main verb, subject, predicate |
| N + V + N | 4 | main verb, object, subject, predicate |
| N + N + N | 7 | subject, predicate |
| Sum | 49 | |

Figure captions

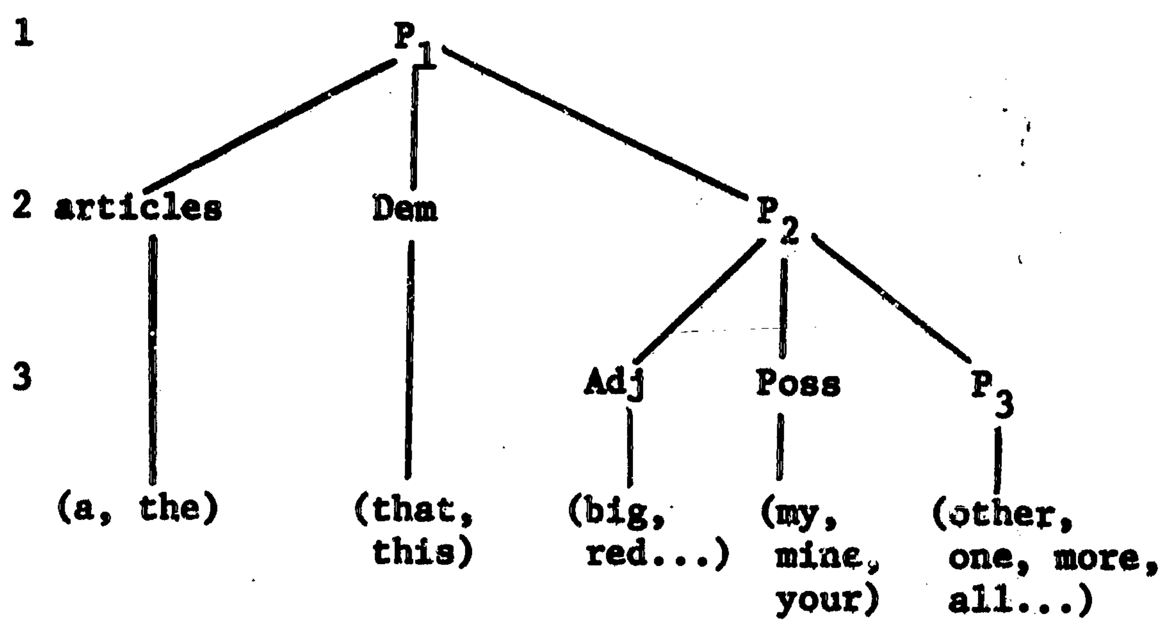
Fig. 1. Differentiation of the Pivot Class. Abbreviations are as follows: N = noun, that is, one of the open classes for this child; Art = articles; Dem = demonstrative pronouns; Adj = adjectives; Poss = possessive pronouns; $P_1$, $P_2$, and $P_3$ = pivot class at Times 1, 2, and 3 respectively.

Fig. 2. An abstract hierarchy of syntactic categories.

Fig. 3. Phrase markers generated by early grammatical rules.

Fig. 5. The Relations among Imitation (I), Comprehension (C), and Production (P) depend on sentence-length and size of memory span. Numbers refer to the relations mentioned in the text.

Time




$(P_1) + N$ (1)

$(Dem) + (Art) + (P_2) + N$ (2)

$(Art) + (Adj) + N$ (3)

$\begin{Bmatrix} P_3 \\ Poss \\ Dem \end{Bmatrix} + N$ (4)

$(Art) + N + (Adj)$ (5)

Fig. 1

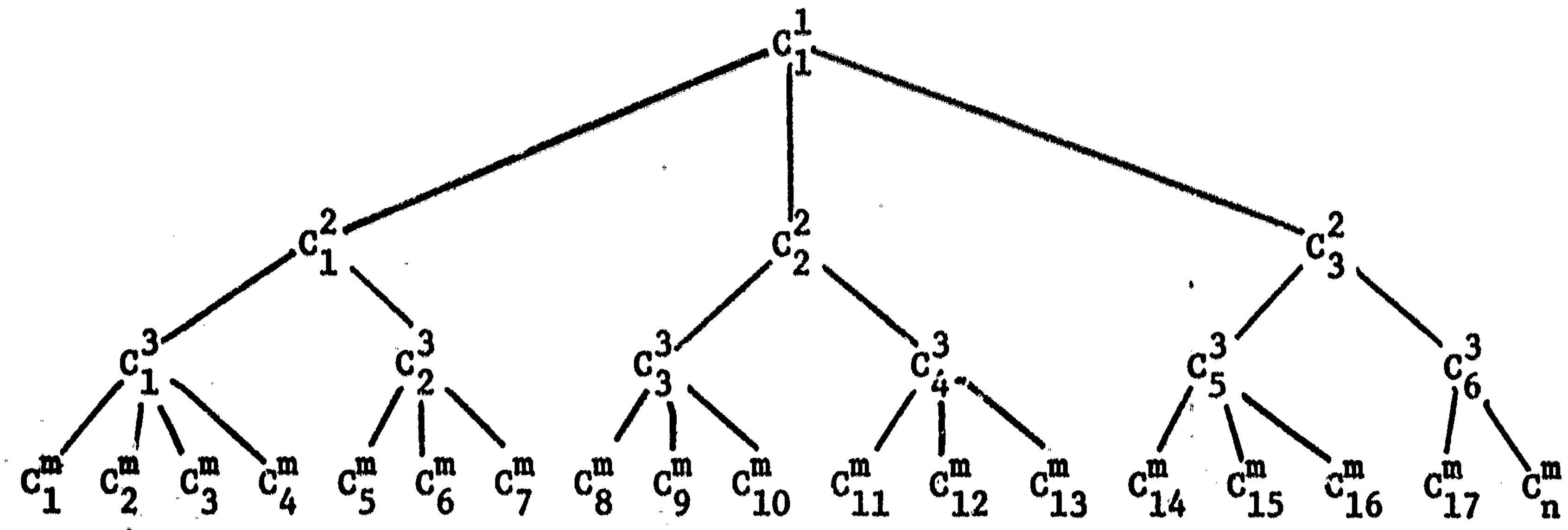

C^1_1
C^2_1
C^2_2
C^2_3
C^3_1
C^3_2
C^3_3
C^3_4
C^3_5
C^3_6
C^m_1 C^m_2 C^m_3 C^m_4 C^m_5 C^m_6 C^m_7 C^m_8 C^m_9 C^m_10 C^m_11 C^m_12 C^m_13 C^m_14 C^m_15 C^m_16 C^m_17 C^m_n

Fig. 2

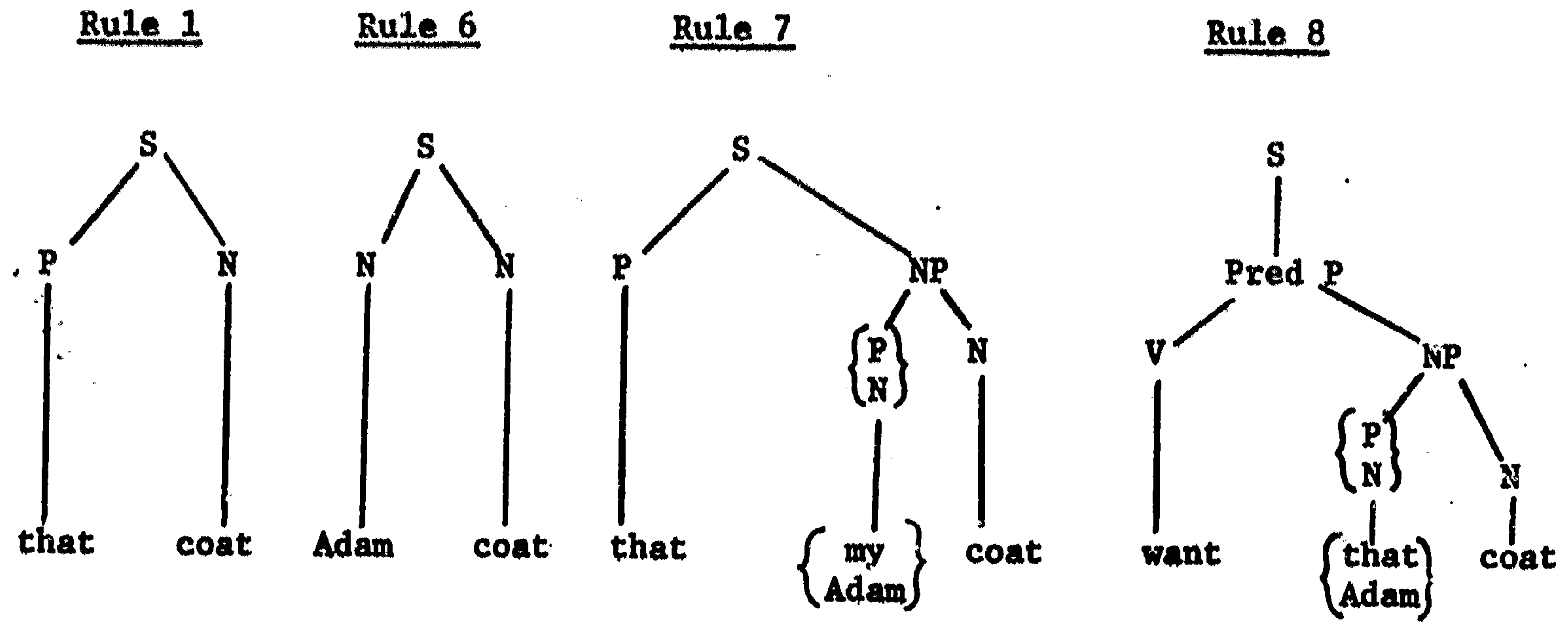

Rule 1
S
P
N
that
coat
Rule 6
S
N
N
Adam
coat
Rule 7
S
P
NP
P
N
N
that
my
Adam
coat
Rule 8
S
Pred P
V
NP
P
N
N
want
that
Adam
coat

Fig. 3

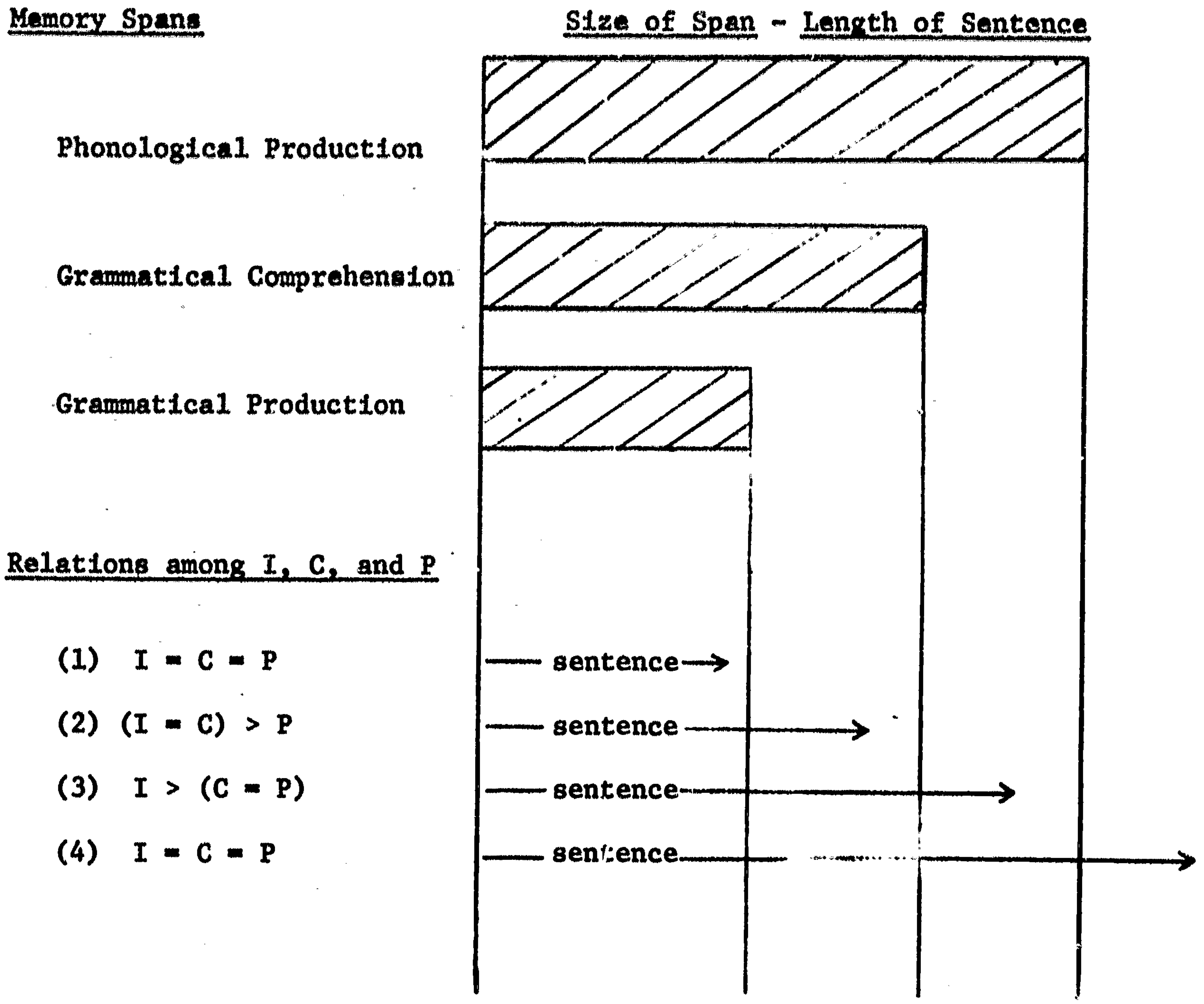

Memory Spans
Size of Span - Length of Sentence
Phonological Production
Grammatical Comprehension
Grammatical Production
Relations among I, C, and P
(1) I = C = P
(2) (I = C) > P
(3) I > (C = P)
(4) I = C = P
sentence
sentence
sentence
sentence

Fig. 5

# Some Universals of Language Acquisition

D. McNeill

# Some Universals of Language Acquisition[1]

David McNeill

Center for Research on Language and Language Behavior

Abstract

Nearly all children learn to speak their native language with remarkable speed. A pressing theoretical problem is to account for this extraordinary achievement. One point of view for doing so is to credit children with an inborn capacity for language acquisition, a capacity that consists of expectations as to the general form taken by natural languages. According to this view, children have prior knowledge of the so-called linguistic universals. There are several ways to evaluate this hypothesis, but one particularly accessible technique is to compare the acquisition of totally unrelated languages. Features that are common to the early speech of children learning different languages--that is, features universal among children regardless of the local linguistic environment--probably can be attributed to a capacity for the task of language acquisition. The first results of such a comparative study are presented and discussed, Japanese and English being the languages compared.

In recent years, there have been major and, for the psychologist, profoundly interesting changes taking place in linguistics. Chomsky (1965), Katz (1965), and their colleagues have been developing a theory of language that has as its goal an explicit statement of linguistic knowledge, the sort of knowledge one has when able to speak, for example, English, or Mohawk, or Japanese. These grammars have been called transformational. Some insight into the technical literature on transformational grammar can be obtained from the references cited above. For present purposes, however, it is necessary only to consider two general facts revealed in this literature. The first is that linguistic knowledge is highly complex; the second is that much of linguistic knowledge is abstract. The first fact probably needs little documentation. That languages are complex seems obvious enough, the merit of transformational grammar being that such complexity is stated explicitly and fully. The second fact, that linguistic knowledge is abstract, is perhaps less obvious. By abstract, it is meant that there

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are aspects of linguistic knowledge not directly exemplified in sentences as we perceive and produce them. In traditional psychological terminology, there are aspects of linguistic knowledge, crucial to the understanding of speech, that are neither stimuli nor responses. To make these assertions clear, consider the sentences in the left-most column of Table 1.

Insert Table 1 about here

Superficially, these sentences have the same structure. In every case, it is they + are + V-ing + N-s, where V-ing is a progressive verb and N-s is a plural noun. This identity can be shown in various ways. For example, pauses, if they are introduced, are located at the same points: they - are - boxing gloves and they - are - matching gloves. Similarly, if the definite article, the, is inserted in these sentences, it goes always at the place: they are the drinking glasses and they are the drinking companions. Pauses can be introduced only at constituent boundaries, and articles can be inserted only before noun phrases. The four sentences in the left-most column of Table 1, therefore, have the same constituent structure, as evidenced by the pauses, and all treat the V-ing + N-s string as a noun phrase, as shown by insertion of the definite article.

Despite these superficial identities, however, the four sentences are not truly identical. They differ in a way that affects their meaning, as can be shown by the fact that when paraphrased, sentences with very different structures result. The middle column of Table 1 contains paraphrases of the sentences in the left-most column; the right-most column, in turn, contains non-paraphrases. Thus, we see that they are boxing gloves is paraphrased by they are gloves for boxing, whereas they are matching gloves is paraphrased by they are gloves that match. Conversely, a non-paraphrase of they are boxing gloves corresponds in structure to the paraphrase of they are matching gloves, and vice versa. We

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conclude that they are boxing gloves and they are matching gloves differ importantly in structure. It is a difference in structure recognized by speakers of English despite the identity of surface structure noted above. In short, there is a difference between the abstract structural features of the two sentences.

Obviously, such differences in abstract structure are cued by features in the surface structure. The two words, boxing and matching, perform this function here. However, boxing and matching cannot represent the structural differences because the two sentences differ in ways not presented in the differences between the two cue-words. The second pair of sentences in Table 1, they are drinking glasses and they are drinking companions, reveal the same abstract difference in structure as the first pair, but the critical word, drinking, has a meaning different from the two previous cue words, boxing and matching. The structural difference between the sentences, therefore is not represented by the differences between the words, but merely cued by them. The same structural difference can be signaled by different words (boxing/drinking versus matching/drinking), and the same word, depending on context, can signal different structures (drinking glasses versus drinking companions).

Thus, one learns from transformational grammar that linguistic knowledge is both abstract and complex. Somehow, such knowledge is acquired by small children. Moreover, it is acquired very rapidly. Beginning with simple two- and three-word combinations at age 18 months, a child develops virtually all English grammar by age 3.5 or 4 years--a total period of some 24-30 months. The central problem is to account for this remarkable achievement.

## The biological basis of language

One line of thought, the one to be considered here, begins with the truism that man alone among all creatures possesses language. At some point in the evolution leading to homo sapiens, something developed to make language possible. It is not known, of course, what this evolutionary event was, but the fact of its occurrence suggests some biological basis for language. This is not a novel idea. Biological support for language was taken for granted in the 19th Century (e.g., Hale, 1886), but as usually stated, this assumption has been an empty claim, nothing more than a restatement of the observation that man is the only talking animal. What it needs in addition is specification of the biological basis of language. It is necessary to establish that there is a specific capacity for language, a capacity largely unrelated to other aspects of human cognition; and it is necessary to clarify the features of language that are, in fact, biologically based.

Lenneberg (in press) argues persuasively in support of the first of these points, that the capacity for language is specific and largely unrelated to other aspects of cognition. However, work on the second point has barely begun. The purpose of this report is to introduce research undertaken to discover particular linguistic features, if any there be, that correspond to the biological basis of language.

## Linguistic universals

If language is possible because of special developments in man's evolution, the effects of these developments must be manifested in the acquisition of language by children. The hypothesis of a biological capacity for language is necessarily a hypothesis for language acquisition; it is difficult to interpret it otherwise. In order to see how such a capacity could influence the acquisition of language, imagine a linguistic feature x that corresponds to some aspect of this capacity; imagine also a child who, because of his endowment, expects languages to present feature x in one form or another. Such a child could examine speech received from his parents for exemplification of feature x; whenever a putative example is found, he could test its status as an instance of x against further examples of parental speech. The merit of such tests is that they allow a child to reject incorrect hypotheses about the form taken by x in his local language. In abstract form, this cycle--first expectation, then formulation, test, and, if necessary, rejection of hypotheses--has been proposed as the process by which a child exploits his biological endowment for language (Chomsky, 1965; McNeill, in press). One consequence of this process is that every language must present features corresponding to children's capacity. X must be linguistically universal. A language that failed to include some variety of x would constantly refute a child's expectations; it would present an endless number of incorrect possibilities, and would, in truth, be unlearnable.

One strong prediction can be derived from the theory just outlined. It is that children acquiring different, historically unrelated, languages should show basic similarities in their early linguistic attainments. Among the linguistic features that children first acquire presumably are features they are endowed to acquire, that is, features that are universal. Linguistically unique features may also be acquired from the outset of language development, but because a child's total grammar is initially small, the linguistically universal will necessarily bulk large. Moreover, if children acquire language quickly because of biological endowment, most universal features must be among the first aspects of language acquired, whereas most unique features must be among the last, *ex hypothesi*.

## Evidence from children acquiring English

Only one aspect of child language will be discussed, and this is the emergence of grammatical classes. Children acquiring English typically begin acquisition with sentences constructed on the basis of a simple grammatical dichotomy (Brown and Bellugi, 1964; Ervin, 1964; Braine, 1963), the dichotomy consisting of what Braine has called Pivot (P) and Open (0) grammatical classes. Table 2 contains representative P and 0 classes from each of the projects mentioned. In all three, the P class is on the left, the 0 class is on the right, although the opposite order can occur also. For particular P and 0 classes, however, order is fixed. A P class is always small in membership and slow to take in new words. An 0 class is the opposite, being large in membership and the receptacle for most new vocabulary. In forming two- and three-word sentences, individual P words are used with high frequency whereas individual 0 words are used with low frequency. These three characteristics--the size of the class, receptivity to new vocabulary, and the frequency with which individual members are used--serve to distinguish P and 0. A further and important characteristic of the distinction is that single-word utterances always consist of 0 words. That is to say, P words occur only in combination with 0 words, a fact reflected in the following rule for generating these children's sentences:

$$S \rightarrow (P)\ 0$$

The rule says that to form a sentence, these children first selected a word from a P class, then a word from an 0 class, always in that order. Thus Brown and Bellugi's subject said such things as my boot, a Becky, and poor sock; Ervin's subject said such things as this doed, the dolly's, and here pretty; and Braine's subject said night-night plane; bye-bye shoe; all gone boot.

Insert Table 2 about here

The usual interpretation made of the P-0 distinction is that these classes represent a child's earliest linguistic competence, his most primitive grammatical knowledge. They are held to be crude grammatical classes out of which the

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refined grammatical classes of adult English will eventually emerge. There is some evidence in support of this interpretation.

For one thing the main alternative hypothesis is that each two-word combination summarized in Table 2 is a memorized routine. This hypothesis is made implausible by the number of combinations children produce. Brown and Bellugi's subject, for example, produced some 100 different pairs. To claim that these are memorized routines is to claim that this child, at age 18 months, had committed to memory at least 100 paired-associates, and surely this number is an underestimate since these 100 were only the ones that happened to appear in Brown and Bellugi's samples. Moreover, if the combinations summarized in Table 2 are routines, it must be assumed that most of this vast quantity of material was learned in one trial since individual pairs are infrequently repeated in parental speech.

A second reason for crediting children with true grammatical classes is that they frequently utter strings that are not likely to be imitations or reductions of parental speech. Such sentences appear in the records of all three children. Ervin's subject said <u>here doed</u>, Brown and Bellugi's said <u>a that car</u>, and Braine's subject said <u>allgone boat</u>, inverting English word order. It is unlikely that children receive such fractured English from their parents, but each of these sentences fits the P-O pattern, either directly or (in the case of Brown and Bellugi's subject) with minimal elaboration. The indications are, therefore, that the P-O distinction represents a genuine grammatical classification, and the question arises: From where does it come? The remainder of the present report is concerned with an examination of this question.

In order to consider an answer, however, it is necessary to present one further fact concerning the P-O distinction. In the case of every child studied, either the P or the O class has been heterogeneous from the point of view of adult grammar. The P class of Brown and Bellugi's subject, for example, contained demonstrative pronouns (this, that), possessive pronouns (my, your), articles (a, the), and some half-dozen adjectives (big, red, poor, wet, dirty, pretty, etc.). The 0 classes for Ervin's subject were similarly heterogeneous, containing nouns, adjectives, verbs, and determiners (other). The classes of adult grammar must ultimately arise out of such heterogeneity. The process by which they do, it would appear from Brown and Bellugi's work, is differentiation.

Consider Fig. 1. It is a chronology of the development of grammatical classes by one of Brown and Bellugi's subjects, the same child represented in Table 2. In this case, the P class is the one differentiated. Time 1 corresponds to the original P-0 distinction as presented in Table 2. Time 2 is 2.5 months later, and Time 3 is 2.5 months later than that. By Time 2, three grammatical classes have emerged from the original P class. That is, the child came to use certain words from the original P class in unique positions in his speech whereas before all words were used in all positions. Two of the new classes, articles and demonstrative pronouns, correspond to adult grammar; the third is another heterogeneous P class, a residuum of the P class at Time 1. By Time 3, two additional adult classes have appeared in the child's speech, adjectives and possessive pronouns, and there remains a third, still grammatically heterogeneous P class. Thus, in five months' time, five grammatical classes have emerged from one. The line of development was differentiation: first one class, then another was removed from the P class at each stage, much as one peels a banana.

Insert Fig. 1 about here

Differentiation raises a peculiar problem. The fact that Brown and Bellugi's subject was able to form adult grammatical classes in this manner means that his original P class had been a generic specification of the adult classes that eventually arose out of it. Somehow, his original P class was appropriate. Although the child ignored relevant distinctions in adult grammar, he nonetheless admitted them as potentialities when forming the original P class. For example, every adjective in the vocabulary of Brown and Bellugi's subject at Time 1 was within the P class, even though adjectives were not yet distinguished as a class. Thus a puzzle arises: in order for differentiation to occur at all, a child must honor grammatical distinctions in advance of drawing them.

There is nothing in parental speech that would lead to a generic P class. A distributional analysis of adult speech, if that is what children attempt to do, would yield the grammatical classes of adult speech, not a generic P class. It begs the question to suggest that children consider only those distributional facts of adult speech that support a generic classification, for it is just such selective consideration that needs to be explained. We may suspect, rather, that the distinction between P and 0 is a grammatical invention on the child's part, a division of his vocabulary based on information obtained elsewhere than from parental speech. The suggestion to be considered here is that it reflects some aspect of the biological capacity for language and so corresponds to some universal aspect of grammar. The problem is now to provide a preliminary characterization of this universal. After doing so, a small amount of evidence will be presented for its existence in the early speech of children acquiring Japanese and Russian, as well as English. At the same time, certain difficulties will be pointed out.

## Semi-grammaticality in relation to language acquisition

A complete transformational grammar of English, as of any language, draws a great many distinctions among categories of words. There are many more classes than the traditional eight parts of speech. These fine distinctions are involved in the representation of well-formed sentences such as John plays golf or sincerity frightens John. But it is clear that understanding sentences does not require that all possible distinctions be honored. A sentence may violate some distinctions and yet be comprehensible. Golf plays John, for example, is grammatically deviant but nonetheless a devastating comment on John. More distinctions are honored in John plays golf than in golf plays John, but the latter is understood on analogy with the former. On the other hand, there are sentences that violate even more distinctions than golf plays John, and so are even more grammatically deviant. Golf plays aggressive is one example; golf eye aggressive is another.

The ability to rank-order sentences according to grammatical deviance is a well-established aspect of the linguistic competence of adults. Somehow we can tell, as we move from John plays golf to golf plays John to golf plays aggressive to golf eye aggressive, that we are moving into regions of ever increasing deviance. In order to account for this ability, Chomsky (1964) suggested that knowledge of English included, in addition to the grammatical categories necessary for a complete transformational grammar, knowledge of a hierarchy of grammatical classes whereby the most finely drawn grammatical classes are regrouped on higher levels, each higher level being a less refined grouping than the level below. Thus golf plays John belongs to some intermediate level in the hierarchy, whereas golf plays aggressive belongs to a higher level.

The suggestion to be made here is that this hierarchy, at least the upper reaches of it, is linguistically universal. Every language may have the same broad superordinate categories, of which the categories involved in well-formed speech are sub-cases. Such a hierarchy, if it is part of a child's linguistic endowment, would explain how a P or O class could be generically related to adult classes, and hence how differentiation is possible. The P-0 distinction would be one of distinctions drawn near the top of the hierarchy; differentiation would be progression down the hierarchy. By this interpretation, children's sentences are semi-grammatical, in the technical sense. Sentences produced later in a child's development are less deviant than sentences produced earlier, in precisely the same sense that golf plays John is less deviant than golf plays aggressive. An earlier experiment (McNeill, in press) offers support for this interpretation.

If the P class of Brown's subject, or the 0 classes of Ervin's subject, are generically related to the grammatical classes of adult English because they are drawn from a universal hierarchy of categories, the P and 0 classes would, in fact, be generically related to the grammatical classes of every language of the world. Generic P and 0, therefore, should be universals of language acquisition.

## The acquisition of Japanese as a native language

Brown and Bellugi's, Ervin's, and Braine's projects have all been longitudinal and observational. A small group of children is visited repeatedly in order to tape record everything they say and everything said to them. On the basis of the tape-recorded corpora, grammars are periodically written to account for the patterns observed in the children's speech. The P-0 distinction, for example, is one such pattern. The same procedure is being employed to study the acquisition of Japanese as a native language.

Two children are involved, both girls, both living in Tokyo. Their speech is tape-recorded twice a month for two hours each visit. Transcriptions of the tapes, rough translations, and the tapes themselves are mailed to Ann Arbor, where, when a sufficient amount of patterned speech has accumulated, grammars are written. The children were 18 and 19 months of age when the study began; at present writing they are 21 and 22 months of age. Only one of the two children produces patterned speech in amounts large enough to support a grammar, and from even this child, the required number of utterances (ca. 700-800) has accumulated only during the week preceding this writing. A grammar for the child's speech, therefore, has not yet been constructed. What follows, instead, is a list of the contents of her P and 0 classes on the assumption that P and 0 classes are, in fact, part of the child's grammatical competence. This assumption will be checked when a grammar is written for the child.

As noted before, the P class for Brown and Bellugi's subject contained demonstrative and possessive pronouns, articles, and adjectives. The syntactic function served in common by these various classes is some kind of modification or specification of a noun. The P-0 construction corresponds, therefore, to one of the basic grammatical relations discussed by Katz and Postal (1964), namely modifier-head, which itself may be an aspect of children's capacity for language (McNeill, in press). Ervin's subject, on the other hand, had a heterogeneous 0 class, containing, as already noted, nouns, verbs, adjectives, and determiners. Again, however, the P-0 distinction seems to correspond to the basic grammatical relation of modifier-head, so the grammatical function served in common by the words in the child's 0 class is that of grammatical head, that is, syntactic classes capable of being modified. In Japanese the grammatical relation of modifier-head is carried by some of the same classes as in English. However, Japanese lacks articles and determiners, and possessive pronouns are themselves constructions. Accordingly, identity on the level of words between early English and Japanese speech cannot be expected. Universal features, if they exist, must hold on the level of grammatical function; and on this level there is striking similarity between the Japanese child and <u>both</u> Ervin's subject and Brown and Bellugi's subject, as can be seen in the following lists:

| Pivot | Open |
| --- | --- |
| this | lady |
| this-one | baby |
| that-one | cat |
| good | mama |
| not (Adj) | milk |
| hurtful | school |
| dirty | hold |
| pretty | look |
| little | do |
| | good |
| | ⋮ |

The P class contains the only possibilities for overlap with the P class of Brown and Bellugi's subject, namely, demonstrative pronouns and adjectives; the 0 class contains nouns, verbs, and adjectives, which are the only possibilities for overlap with the 0 class of Ervin's subject. Thus, children exposed to English and children exposed to Japanese achieve very similar solutions in their first efforts to acquire grammar. In addition to these Japanese-English similarities, Slobin (in press) describes a child exposed to Russian who developed a P class much like the P class of Brown and Bellugi's subject.

The P-0 distinction, therefore, may reflect the unfolding of a linguistic universal, and so may reveal an aspect of man's biological capacity for language. The universal may be a hierarchy of grammatical categories of the sort discussed before, in which words are distinguished and classified together according to their role in the modification relation. There is, however, a complication. Adjectives appear in both the P and the 0 class of the Japanese child. One of Ervin's subjects (different from the child represented in Table 2) did the same thing. Such cross-classification means that neither the P nor the 0 class is completely generic and the phenomenon may require abandonment of the notion of a hierarchy of categories. Further observation will be necessary to estimate the prevalence of cross-classification. If it should prove to be the rule, the universal underlying the P-O distinction must be conceived in a way fundamentally different from a hierarchy of categories, quite possibly as a set of universal syntactic features (Chomsky, 1965). Any one such feature would yield generic classification, as with Brown and Bellugi's subject; any two, when applied disjunctively, would yield cross-classification; the same two, when applied conjunctively, would yield differentiation (cf., Harvard University, 1965, pp. 55-56). Aside from deciding the form of the universal, however, the similarities that exist among children acquiring radically different language offer strong support for the hypothesis of a specific capacity for language acquisition.

Footnote

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Table 1

Sentences Illustrating Differences in Abstract Structure

| Sentence | Paraphrase | Non-paraphrase |
| --- | --- | --- |
| They are boxing gloves | They are gloves for boxing | They are gloves that box |
| They are drinking glasses | They are glasses for drinking | They are glasses that drink |
| They are matching gloves | They are gloves that match | They are gloves for matching |
| They are drinking compahions | They are companions that drink | They are companions for drinking |

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Table 2

Pivot and Open Classes from Three Studies of Child Language

| Braine | | Brown | | Ervin | |
|---|---|---|---|---|---|
| allgone | boy | my | Adam | this | arm |
| byebye | sock | that | Becky | that | baby |
| big | boat | two | boot | | dolly's |
| more | fan | a | coat | | pretty |
| pretty | milk | the | coffee | | yellow |
| my | plane | big | knee | | come |
| see | shoe | green | man | | doed |
| night-night | vitamins | poor | mommy | | . . . |
| hi | hot | wet | nut | the | other |
| | mommy | dirty | sock | a | baby |
| | daddy | fresh | stool | | dolly's |
| | . . . | pretty | tinker-toy | | pretty |
| | | | . . . | | yellow |
| | | | | | . . . |
| | | | | here | arm |
| | | | | there | baby |
| | | | | | dolly's |
| | | | | | pretty |
| | | | | | yellow |
| | | | | | . . . |

## Figure Caption

Fig. 1. Differentiation of the Pivot Class. Abbreviations are as follows: N = noun, that is, one of the open classes for this child; Art = articles; Dem = demonstrative pronouns; Adj = adjectives; Poss = possessive pronouns; $P_1$, $P_2$, and $P_3$ = pivot class at Times 1, 2, and 3 respectively.

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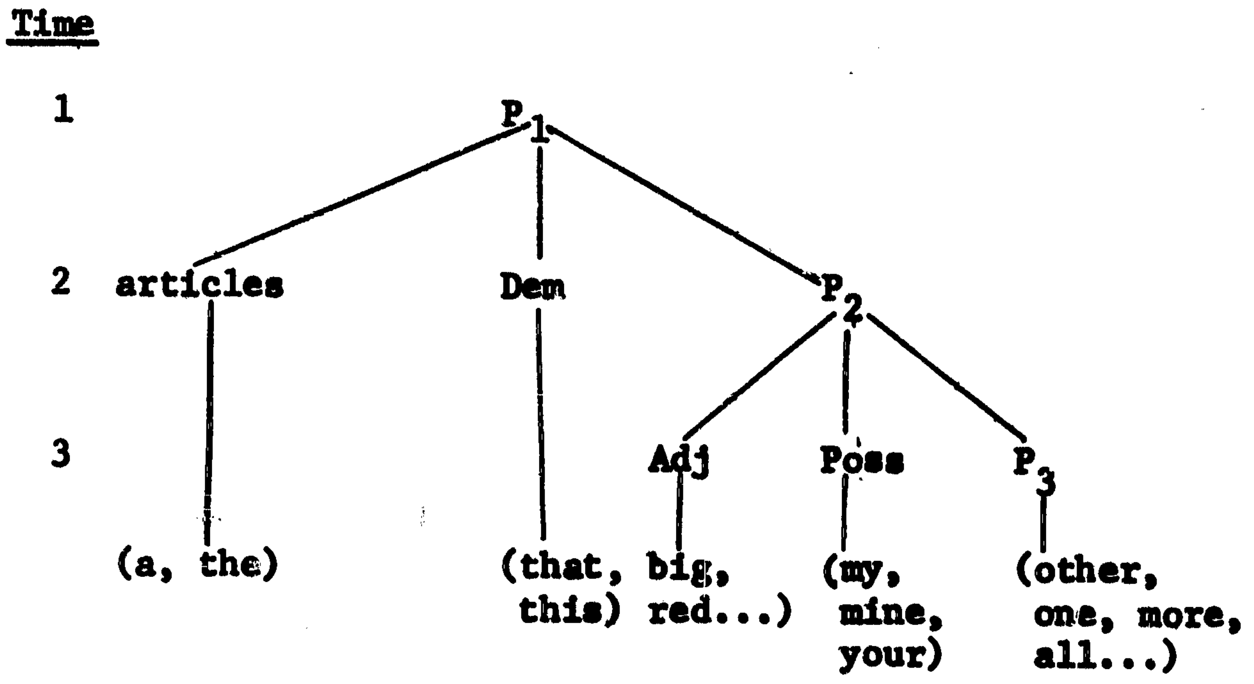


$(P_1) + N$ (1)

$(Dem) + (Art) + (P_2) + N$ (2)

$(Art) + (Adj) + N$ (3)

$\left\{\begin{array}{c} P_3 \\ Poss \\ Dem \end{array}\right\} + N$ (4)

$(Art) + N + (adj)$ (5)

Fig. 1

# Development of the Prosodic Features of Infants' Vocalizing

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# Development of the Prosodic Features of Infants' Vocalizing

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The vocal behavior of an infant during the first few months of life is the matrix for later language development. Therefore, the differentiation and organization of infant vocalizing as a function of maturational and environmental factors holds considerable interest.

Previous research in this area consists almost entirely of descriptions by a single observer transcribing the utterances of a single infant in naturalistic settings. Two abridged biographical reports will be samples: one from a "pre-objective" period, that of the late 19th century, and one from recent decades, employing "more refined techniques" (McCarthy, 1946). The earlier writer, a keen observer of behavior, is Charles Darwin. The contemporary writer, a linguist, is W. F. Leopold.

"The noise of crying is uttered in an instinctive manner... After a time the sound differs as to the cause, such as hunger and pain...he soon appeared to cry voluntarily... When 46 days old he first made little noises without any meaning to please himself, and these soon became varied....At exactly the age of a year, he made the great step of inventing a word for food, namely mum...and now, instead of beginning to cry when he was hungry, he used this word in a demonstrative manner...implying 'Give me food'" (Darwin, 1877, p. 285).

"During the first few weeks the only sounds produced were cries of dissatisfaction... In the seventh and eighth weeks the sounds ceased to be purely incidental. She uttered more arbitrary sounds of satisfaction...cooing as an articulated expression of feelings of satisfaction was therefore well established by the end of the second month... By the seventh month there was a good deal of babbling prevalently ranging from [a] to [e], long, without many tongue movements... At the end of the eleventh month, her active vocabulary consisted of two words" (Leopold, 1939, p. 72).

Linguistic studies in this field have focused on providing a description of the language of a particular child at different levels of development. The units of analysis have been phonemes, morphemes, words and sentences. The procedures for data collection usually begin with phonetic transcription of the infant's vocal behavior by a trained observer. The most extensive studies of this type are those of the linguists Gregoire, Leopold, Cohen, and Velten. The work of Irwin and Chen in the 1940's is notable for the réfinements they introduced. These investigators began the practice of using two observers rather than one; this allowed them to obtain measures of observer agreement. They also increased the numbers of subjects observed and selected a more adequate sample of subjects.

Psychologists working in this area have tended to study more molar aspects of language development. The main interest has been to provide normative data on various indices of development, e.g., use of form class, size of vocabulary, mean sentence length, and the like. The procedure for data collection is again transcription (usually alphabetic) by a trained observer using cross-sectional and longitudinal sampling. Among the classic studies of this type are those of Davis, Fisher, McCarthy, Shirley, Templin, and Lewis.

The most striking feature of the research literature on infant vocalizing is the lack of advancement in the field. The basic drawback is the reliance on transcriptions obtained by observations in naturalistic settings. Consider the difficulty of transcribing infant speech sounds. Because the infant is in the process of learning to articulate, the sounds he utters are unlikely to fit neatly into any classificatory system. There is the danger that the trained observer filters the variagated vocal behavior through his own classificatory categories--categories developed with adult vocal behavior--and thus rejects much of importance. Moreover, the infant utters sounds rapidly and sporadically, making it difficult for the observer to keep an accurate or complete record.

The obvious sampling problems have also limited the generality of the findings of previous studies. It has been recognized that when investigator and subject are also mother and child, experimental rigor receives little nourishment. In those less numerous studies in which the investigator has intruded into the home, the schedule of observation and transcription usually has been to be most charitable, unsystematic. In summing up the results reported up to 1941 Irwin says:

"It will be apparent from this review of the more important studies...that there does not exist a large body of data secured from adequate samplings of infants for purposes of a statistical analysis....Usually no systematic research methods were formulated; statistical techniques essential to the analysis of mass data are practically absent, no reliabilities of observers have been established, many observers used alphabetical rather than phonetic systems of symbols for recording; and most reports indulge in an inordinate amount of interpretation supported by very little empirical material." (Irwin, 1941, p. 285).

In her classic review of the literature on language development in the child, McCarthy writes: "Although this wealth of observational material has proven stimulating and suggestive for later research workers, it has little scientific merit, for each of the studies has employed a different method, the observations have for the most part been conducted on single children who were usually either precocious or markedly retarded in their language development; the records have been made under varying conditions, and most of the studies are subject to the unreliability of parents' reports" (McCarthy, 1946, p. 478).

Attempts to ameliorate one or more of the methodological problems that we have reviewed have waited upon advancements in instrumentation. In Part II of her 1929 review McCarthy described some of the early attempts to record speech by means other than transcription by an observer. The first device she described was the manometric flame, invented by Koenig in 1862. With this device, the flame of a gas jet is disturbed by the sound wave and these disturbances are recorded photographically. The phonautograph, invented by Scott in 1859, recorded the speech wave by means of a stylus attached to a diaphragm. The best device of this general type was the phonodeik, which consisted of a horn and a diaphragm; a small platinum wire attached at one end to the diaphragm was passed around a jewel-mounted spindle to a delicate spring. Attached to the spindle was a tiny mirror which reflected a fine beam of light onto a moving photographic film. The phonodeik could respond up to 10,000 cps but the horn and diaphragm introduced a certain amount of distortion.

In 1893 Blondel had devised the oscillograph and with improvements in amplifiers it promised to be a very useful piece of apparatus. However, even before the oscillograph had been developed to the point where it gave a practically perfect representation of the sound wave, it became clear that, once recorded in all its complexity, the waveform was virtually impossible to analyze in ways that were useful for studying speech.

Sound recording devices, the phonograph and later the wire and tape recorders, even when developed further than they were in 1929, solved only part of the problem. The actual speech sounds could then be recorded and replayed, but an observer still had to rely on his judgment as a perceiver of sound and speech in order to analyze the data.

Two years after the introduction of the sound spectrograph, in 1949, Lynip published a report of the use of this device in the study of infant speech. He recorded the speech sounds of a little girl, beginning with the birth cry and sampling at intervals ending at 56 weeks when intelligible speech began. A spectrographic analysis of these recordings revealed nothing which resembled the spectrograms of phonemes produced by adults.

In 1960, Winitz published a data-garnished polemic on the subject of the spectrographic analysis of infant vocalization. He argued that the fact that the infant's spectrograms didn't look like spectrograms of adult speech simply proved that the spectrograph isn't a good device for the study of infant vocalizations. "The basic data against which any instrumental method of phonetic analysis must be validated are the phonetic analyses made by competent observers whose validity Lynip questions" (Winitz, 1960, p. 173).

Without resolving the question of the validity of spectrographic description, it must be acknowledged that for each two-second sample of vocalization approximately fifteen minutes are required to process, calibrate, crudely quantify, and classify each spectrogram--and that the problems of observer interpretation remain, although transferred from auditory to visual modes.

This brief account of the techniques that have been employed so far for collection and acoustic analysis of infant vocal behavior indicates that an extension of our knowledge of vocal development requires new techniques. Accordingly, the Center for Research on Language and Language Behavior undertook, a year ago, to collect permanent, complete and continuous records of all vocalizations of two infants, and then to process these records by novel electro-acoustic techniques.

Recording and sampling of vocalizing. During the deliveries of the infants whose vocalizing is the subject of this study, medical personnel wore lapel microphones whose outputs were recorded on magnetic tape. All subsequent vocalizing by the infants at the

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hospital was recorded by placing them in private rooms containing a microphone wired to a fast-acting voice-operated switch (Miratel) and to a tape recorder (Tandberg). After leaving the hospital, both children were cared for at home in plexiglass "air cribs" (T.M.I.) that provided no sources of sound within the crib and attenuation of external sounds--hence, a good recording environment. The parents of the children (research assistants at the Center in both cases) were paid to keep a detailed record on prepared forms of major environmental events affecting the infant. These records were synchronized with the tape recordings by writing down the reading of the footage indicator on the tape recorder.

Complete recordings of all vocal behavior during the first five months of life constitute a formidable tape library, which was sampled for analysis in the following way. A master tape was prepared for each child which contained three 95-sec samples of the vocal behavior during every fourth day of life for the first 141 days. For the samples taken from the first month (in which the infant had no regular sleeping times) the three daily samples were excerpted from the recordings for 12 a.m. to 8 a.m., 8 a.m. to 4 p.m., and 4 p.m. to 12 p.m., respectively. This was accomplished by listening to the recording, beginning at the start of each period, and copying the first 95 sec onto the master tape. In some cases undesired noises intruded and the first 95 sec excluding these intrusions was copied. For the samples of vocalizing in the following three months, the three daily periods from which 95-sec samples were taken were: time at awakening (T) to T + 4 hours; T + 4 hours to T + 8 hours and T + 8 hours to T + 12 hours. These sampling procedures yielded 108 95-sec samples for the initial acoustic analysis.

Analysis of the prosodic features. The development of the prosodic features of the infant's vocal behavior was analyzed by extracting three acoustic parameters of the vocalizing during each of the 108 samples, using analog electronic devices. The outputs of these parameter extractors were sampled every 25 sec by an analog-to-digital converter, then processed by an on-line digital computer (PDP-4, Digital Equipment Corp.).

The changing fundamental frequency of the vocalizing was extracted by filtering tape-recorded signals into two frequency ranges. Since the harmonics of the fundamental frequency often have more energy than the fundamental itself, a range-control voltage is generated when there is energy in the lower range which turns off the upper range to exclude the harmonics. If no energy exists in the lower range, however, the fundamental frequency in the upper range is processed unimpeded. In either case, the nearly sinusoidal output from the filters is amplified in a mixer and read on a frequency meter which provides a DC voltage output proportional to the frequency of the fundamental sine wave at its input. A DC amplifier then adjusts the voltage range and polarity for input to the computer.

The changing amplitude envelope of the vocalizing was extracted by applying the recorded signals to a full-wave rectifier followed by a low-pass filter. The output of this device is a DC voltage that is proportional to the absolute value of the amplitude of the vocal waveform (integrated over approximately one period of the fundamental).

The duration of each utterance within a sample, the third prosodic parameter, was determined in the computer by processing the input from the amplitude extractor. When the amplitude dropped below a threshold value and remained there longer than the silence threshold ($\underline{t}_o$), four out of five samples, the end of an utterance was logged at the time of the initial drop. The start of a new utterance was recorded when the amplitude exceeded threshold again.

In addition to defining the beginning and end of utterances, the computer performed the following preliminary processing. Whenever the amplitude fell below a minimal threshold value $\underline{a}_o$, or the frequency fell below a minimal value $\underline{f}_o$, in a 25 msec sample, the values of $\underline{a}$ and $\underline{f}$ were set to zero. This eliminated spuriously low readings due to noise as well as vocal sounds without voicing at the glottis and hence without prosodic value. It also eliminated false frequency readings that would result from the rise-decay time of the frequency meter in response to instantaneous onset or cessation of voicing.

After sampling and then correcting the amplitude and frequency inputs in this fashion, the digital values were reconverted to voltages and plotted as a function of time on a strip-chart recorder. These records of the amplitude and frequency contours, after preliminary processing, were compared with those obtained directly from the parameter extractors (before computer processing) so as to choose values of $a_o$, $f_o$, and $t_o$ that did not distort the original records.

After the preliminary processing, the computer determined, for each 95-sec sample, the number of utterances as defined above, the duration of each utterance; and the mean and standard deviation of the fundamental frequency and amplitude of each utterance. Pooling these statistics for each of the utterances in a sample, the computer determined next their frequency distributions over the entire sample. These frequency distributions were found to be highly right-skewed. A logarithmic transformation was then applied in order to eliminate the skewness and thus to normalize the distributions. Hence, all statistics were computed using the logarithms of the frequency, amplitude or duration values. The computer determined next the means and standard deviations associated with these transformed composite distributions. Consequently, there were two kinds of statistics reported for each 95-sec sample: (1) within utterance measures of central tendency and variability, averaged over utterances, and (2) between utterance measures of central tendency and variability. All in all, these composite statistics for each sample were printed out along with their frequency distributions:

(let M = mean, S = standard deviation, f = fundamental frequency, a = amplitude, d = duration.)

M(MF) - overall fundamental frequency

S(MF) - variability between utterances in fundamental frequency

M(Sf) - overall variability within utterances in fundamental frequency

S(Sf) - variability between utterances in the variability within utterances in fundamental frequency

M(Ma), S(Ma), M(Sa), S(Sa) - as above but for the amplitude parameter

Md - mean utterance duration

Sd - variability in utterance duration

These statistics, describing the three prosodic features of the vocalizing in each sample, are then plotted separately as a function of age at time of the sample, with the time of day (in three intervals) as a parameter. In this way, developmental trends may be discerned in the prosodic features of the infant's vocal behavior.

Results. In Fig. 1 the average fundamental frequency of utterances, M(Mf), and the coefficient of variation between utterances in fundamental frequency, $CVF_{bU}$, [=S(Mf)/M(Mf)] are presented as a function of sample number. An examina-

Insert Fig. 1 about here

tion of the developmental changes over the first 108 samples (141 days) shows that the average fundamental frequency M(Mf) at birth was approximately 450 cps, that it decreased to 370 cps by sample number 33 (approximately 45 days), and that it then rose and stabilized at about 450 cps for the duration of the study. The coefficient of variation between utterances remained small and constant at between .01 and .03 over the entire study.

In Fig. 2 the average duration of utterances in msec and the coefficient of variation of duration ($CVD_{bU}$ = Sd/Md) are presented as a function of sample number. The average duration ranges from 100 msec to 800 msec over the 108 samples. No developmental trend is apparent although the variability from sample to sample does decrease with age. The coefficient of variation of duration remains constant at about .20 over the entire sample.

Insert Fig. 2 about here

Further examination of developmental trends awaits the completion of further statistical computations now in progress with the present data.

Footnote

[1]This paper was presented at the First Symposium of the Development of Language Functions, sponsored by the Center for Human Growth and Development, University of Michigan, on October 20-22, 1965.

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Figure Captions

Fig. 1. Developmental trends in fundamental frequency. For each sample of vocalizing by this infant: the average fundamental frequency of each utterance was computed and converted to logarithmic units. These scores for the utterances were pooled, and the mean and coefficient of variation (σ/M) of the distribution were determined and plotted. For convenience, the vertical axis of the former plot is labelled in units of fundamental frequency rather than its log transform.

Fig. 2. Developmental trends in utterance duration. For each sample of vocalizing by this infant: the duration of each utterance was converted to logarithmic units. These measures for the utterances were pooled, and the mean and coefficient of variation (σ/M) of the distribution were computed and plotted. For convenience, the vertical axis of the former plot is labelled in milliseconds rather than its log transform.

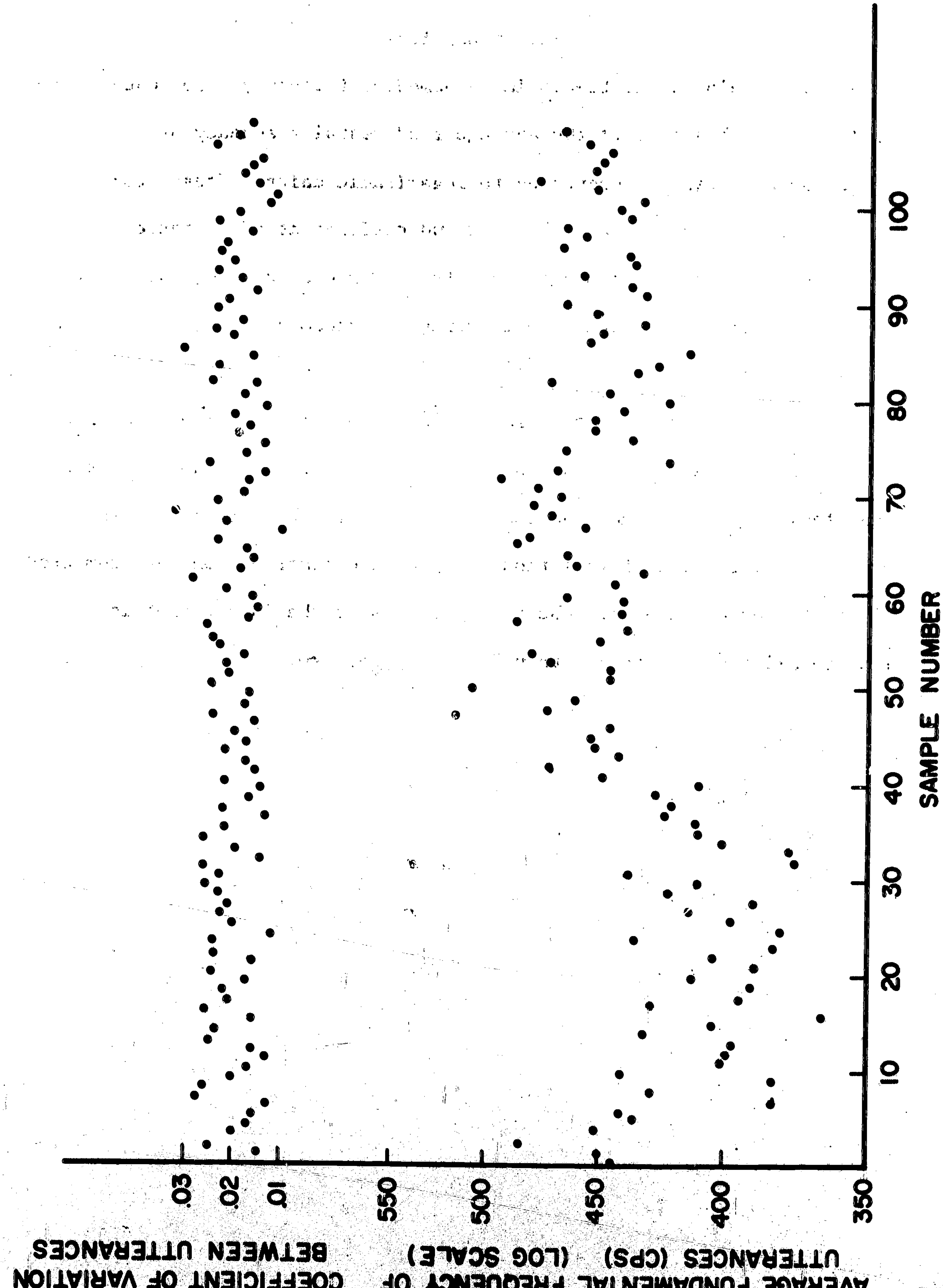
AVERAGE FUNDAMENTAL FREQUENCY OF UTTERANCES (CPS) (LOG SCALE)
350
400
450
500
550
COEFFICIENT OF VARIATION BETWEEN UTTERANCES
.01
.02
.03
SAMPLE NUMBER
10
20
30
40
50
60
70
80
90
100

Fig. 1

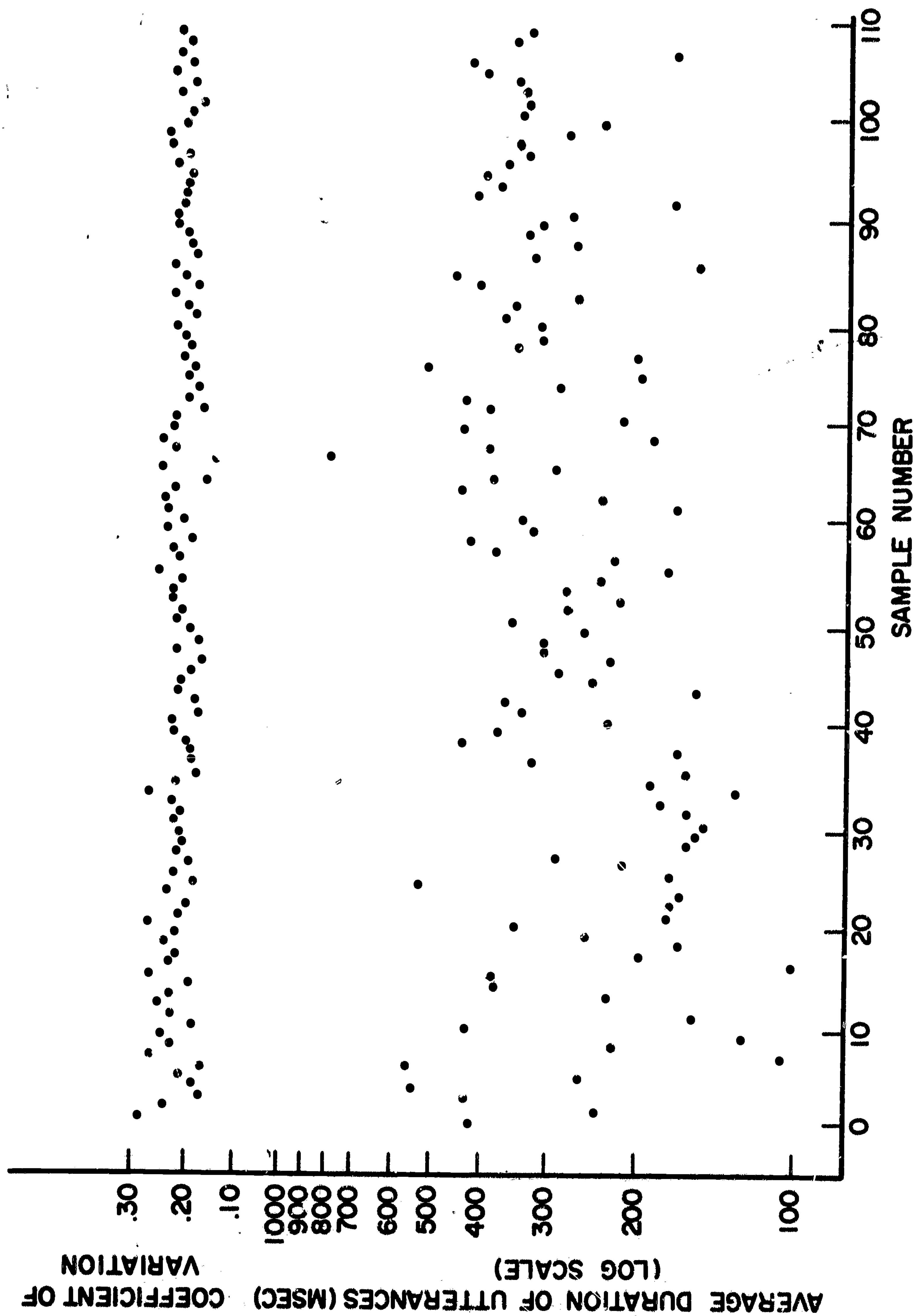
COEFFICIENT OF VARIATION
.30
.20
.10
AVERAGE DURATION OF UTTERANCES (MSEC) (LOG SCALE)
1000
900
800
700
600
500
400
300
200
100
SAMPLE NUMBER
0
10
20
30
40
50
60
70
80
90
100
110

Fig. 2

Some Influences of "Speed Set" on Rate of Comprehension

D. M. Brethower

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Some Influences of "Speed Set" on Rate

of Comprehension During Testing[1]

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Abstract

The rate of comprehension score of students taking the Diagnostic Reading Test can be influenced by: (1) speed work immediately prior to the test; (2) setting time limits; and (3) instructing students to read more rapidly.

A measure used to help determine the effectiveness of reading improvement classes at the Reading Improvement Service (RIS) of the University of Michigan and of many other classes across the nation is the rate of comprehension score from the Diagnostic Reading Test.[2] Pre- and post-test scores on alternate forms of the test are obtained and gains are interpreted as indicators of reading improvement.[3] The interpretation rests upon the assumption that the pre- and post-tests are administered in the same way and under similar conditions. At RIS the tests are administered to the same students in the same classroom by the same person. However, from the student's point of view, the pre-test is administered in strange surroundings, among strangers, by a stranger, while the post-test is administered in familiar surroundings, among acquaintances, by a familiar instructor. Gains in rate of comprehension scores (R·C) might be due, in part, to differences in test conditions.

Three experiments were completed to investigate the size of apparent R·C score gains due to manipulations of test conditions.

## Experiment 1

### Method

The <u>Ss</u> were 100 University of Michigan students who voluntarily enrolled in one of six non-credit reading improvement classes which met two hours per week for 6-1/2 weeks. The majority were freshmen, followed in number by graduate students, sophomores, juniors, and seniors, respectively.

The control group comprised three classes taught by different instructors. All were pre-tested using Part 1 of the <u>Diagnostic Reading Test</u> (DRT). The 12 students in one class were tested using Form A of the test. The other 34 students were tested using Form B.

The experimental group comprised three classes taught by different instructors, one of whom also taught one class in the first group. The 16 students in one class were tested with Form A and the other 38 with Form B. The students were first pre-tested using the following instructions instead of those on page three of the DRT booklet:

DRT Part 1 Speed Set

Directions: Write your name, the date, and section number on the answer sheet. This is a test of reading skill. To start the test everyone will read together the lines at the bottom of page 3. I will read orally and you should follow, reading silently. When we come to the last word on the page, I will stop, and you will simply turn the page and keep right on reading. Read the next four pages very quickly. At the end of <u>one minute</u> I will say '<u>Stop</u>.' When I say 'Stop,' turn to the comprehension questions and answer them by marking X's over the appropriate numbers on the answer sheet.

Note to Instructors: (In answer to the question, "What if we don't finish?" say "If you can't read it all in one minute, just try to read the most important parts to get all the information you can during the minute.") (If they don't ask this or a similar question, you should give them the answer anyway.)

They were then retested with the alternative form of the test, administered in the usual manner.

Results

The R·C scores taken from the tests which were administered in the usual manner were compared for the two groups. The average R·C score for the experimental group was 266, while the average R·C score for the control group was 236, a difference of 29 ($t - 1.79$, $p. < .05$).

For the one instructor who was common to the two groups, the class in the experimental group ($n = 16$) had an average R·C score of 260. His other class had an average R·C score of 189, a difference of 71 ($t = 2.9$, $p < .01$).

Administering a test under a time constraint (which would require reading at approximately 1700 words per minute to complete reading the selection) and then administering the test according to the usual directions results in a significantly higher than normal R·C score.

At the RIS a pre-test is administered, followed by approximately ten hours of reading instruction, which frequently involves reading under time constraints. A post-test is then administered. The average per cent R·C gain for 850 students was 85 during the year in which the experiment was conducted. Only a 12 per cent R·C gain as calculated by ($\frac{266-236}{236}$ X 100) was obtained artificially. Other factors are required to account for most of the per cent R·C gains shown in the reading classes.

## Experiment 2

### Method

The Ss were 24 students enrolled in a graduate course for training reading specialists (Practicum: Diagnosis and Treatment of Reading Problems). They were in a reading improvement class as one of the course requirements. The majority were elementary and secondary school teachers doing summer work toward an advanced degree in education.

Form A of the DRT was administered as a pre-test. Then the instructor administered Form B, with these directions:

"The test you have in front of you is an alternate form of the test you just took. The directions are the same except that you will have only three minutes to read the selection. At the end of three minutes I will say 'Stop'. When I say, 'Stop', stop reading and answer the comprehension questions at the end. If you finish in less than three minutes, record your time and go on to answer the questions just as you did before. Are there any questions?"

### Results

The time constraint established a reading rate of 419 words per minute. (Data from the two students who read faster than that on the first test were not analyzed.) The R·C scores of each of the remaining 22 Ss increased for the test taken under the time constraint. The average R·C was 326, which was higher by 82 than the average R·C of 244 obtained from the results of the first test.

The average comprehension score on the first test was 82 per cent, slightly higher than the average of 76 per cent obtained under the time constraint. Figure 1 shows the frequency distribution of changes in comprehension from the first to the second test.

Insert Fig. 1 about here

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The comprehension score of 50 per cent of the students dropped 10 per cent or more. The average R·C score for these students was 244 for the regular test, 281 for the test given under time constraint, and 431 for the post-test given at the end of the course.

For the other 50 per cent of the students comprehension score dropped 5 per cent, not at all, or increased. The average R·C score for these students was 263 for the regular test, 370 for the test given under time constraint, and 363 for the post-test at the end of the course.

The apparent R·C gain (pre-test to pre-test under time constraint) for the entire class was 34 per cent. The average R·C score after 10 hours of instruction was 397, a gain of 63 per cent. However, the test given under time constraint seems to be a reasonable measure of reading skills of 50 per cent of the class, since comprehension dropped only slightly (four students), stayed the same (three students), or increased (4 students). If this pre-test is used as a baseline, these students showed no gain on the post-test. If the regular pre-test is taken as the baseline they showed a 40 per cent R·C gain. The other 50 per cent of the students showed a gain of 77 per cent, using regular pre-test as a baseline, and a gain of 61 per cent using the time constraint pre-test as a baseline.

## Experiment 3[4]

### Method

The _Ss_ were 34 students taking reading improvement courses. Thirteen were in a RIS class. Twenty-one were in a class at Jackson, Michigan, offered by the Adult Education Department of the Jackson Public Schools.

Students were pre-tested with Form A of the DRT. At the last class meeting Form B was administered as a post-test. Following the post-test, Form D was administered, the students being told to read it "just the way you've been reading the timed exercises in class."

Results

The per cent R·C gains from Form A to Form B made by each student were averaged, resulting in an average R·C gain of 93 per cent. The statistic was computed again for the gain from Form A to Form D, the test taken under instructions to read the way they'd been reading class exercises. The average per cent R·C gain was 131. Twenty-eight students had their highest R·C scores with Form D, 5 with Form B, and one had the same R·C score with Forms B and D.

Instructors frequently report that students read more slowly while they are taking the test than while reading class exercises of equal or greater difficulty. The results of Experiment 3 suggest an interpretation of this difference in reading in terms of differences in the instructions given to the students. Students adjust their reading according to the instructions given. When given the test instructions to read as rapidly as they can and still understand, they read in one way. When instructed to read the way they've been reading class exercises, their reading is influenced by instructions they've been given for class exercises. In courses taught by the staff of the Reading Service, students are often instructed to "Read very rapidly--don't be too concerned with comprehension. It will be all right."

Another interpretation of the result is that the students are more anxious and therefore less competent while taking the real test. One would have to argue that though they are not told that results of the second test are experimental and confidential, etc., they somehow know it and are less anxious. While this latter interpretation is sometimes appealing, in this case it seems a bit tenuous.

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## Discussion

The results of the three experiments illustrate once again that the conditions under which tests are administered influence test results. Changes in instructions influence results, as do the conditions immediately prior to taking the test.

Experiment 1 showed an apparent R·C gain of 12 per cent as a result of taking a test under time constraint just prior to taking the regular pre-test. Experiment 2 showed an apparent R·C gain of 34 per cent at the beginning of a course as a result of taking the test under a moderate time constraint.

No control experiment was conducted to see whether the results of the experiments were due to the test plus the time constraint. The tests alone might produce the same results. The issue is not particularly relevant to these experiments but it seems highly unlikely that merely reading under normal conditions would produce the enhanced scores. If reading without a special time constraint were effective in improving reading rates, we should all be reading much more rapidly than we do. For example, if the difference in R·C of 29 in Experiment 1 were due solely to reading the 1700 words, we would expect to increase our individual rates of reading by about 29 words per minute each time we read 1700 words. We don't seem to do that. Any gain from reading the tests seems attributable to reading them under time constraints imposed by the instructions for the speed tests.

Experiment 3 showed an apparent average R·C gain of 38 per cent at the end of a course as a result of taking the post-test with instructions to read the test as if it were a class exercise. Since the class exercises are frequently done under moderate time constraints, this instruction is very similar to the instruction used to produce a similar result in Experiment 2.

The results of the experiments might be interpreted as indicating that both the pre- and post-tests underestimate what the student can do. Since they both underestimate by about the same amount they serve as an accurate measure of gain.

The results might also indicate that since it is so easy to change the scores one should be very careful about administering the tests in the prescribed manner. Even advising students to read the test the way they've been reading class exercises, then giving the directions in the prescribed manner, is likely to distort the results. Giving a speed exercise as a "warm-up" just before giving the test (as was done in Experiment 1) also distorts the results.

A third way of interpreting the results is to say that gains of less than approximately 40 per cent cannot be considered gains in skill but merely possible uncontrolled variations in the way the students approach the test. For example, the following is likely to produce good pre- to post-test gains while still carefully following the instructions for administering the test:

1. Have some unbiased person administer the pre-test.
2. Just before the post-test, give some speed reading exercises under time constraints. Say to the students, "That's the way to read rapidly! If you zip along like that on a reading test, your scores will really be good!"
3. Have some unbiased person administer the post-test.

While one would be unlikely to do anything so blatant, one has no guarantee that students are unable to figure out Step 2 above without aid from the instructor. Experiment 2 is a possible example. The class average gain was 63 per cent. Yet, for half of the class at least, there is no evidence that they had done anything other than change their approach to the test.

Another point should be considered. If a student's comprehension is low on a post-test, any R·C gain is suspect. For example, if a student enters a course reading at 200 wpm with 100 per cent comprehension or an R·C of 200 and leaves with an R·C score of 400, it looks like a substantial gain. But it is of dubious value if it comes from reading at 800 wpm with a 50 per cent comprehension score. (The "chance" level on the test is 25 per cent.) Reading at 200 wpm would enable him to get about 25 per cent of the way through the test in the time he apparently took to read the test. Assuming that he knew something about the material covered in the article before he read it, his score can be accounted for without hypothesizing a gain in reading skills.

The question remains as to which ways of administering the tests are the more valid as predictors of future achievement. The procedure outlined above would lead to scores which correspond more closely to scores students typically get on class exercises. One does not know whether that procedure would lead to better predictions than would administering the test under the usual instructions. (The usual instructions have the student read knowing he's going to be quizzed beofre he has a chance to re-read and organize the material.)

These experiments have shown that the test scores can be influenced in a variety of ways. They provide little if any information as to whether the influenced scores are either more or less valid than test scores routinely obtained with the tests. They do, however, make R·C gains of less than about 40 per cent highly suspect, even when the student's comprehension is high.

Footnotes

1. A version of this paper was presented at the North Central Reading Association Meeting, Minneapolis, October, 1965.

2. Diagnostic Reading Tests, Survey Section, by the Committee on Diagnostic Reading Tests, Inc., F. O. Triggs, Chairman.

3. The rate of comprehension score (R·C) is equal to the reading rate (in words per minute) times the comprehension score (in per cent correct).

   $$\text{Per cent R·C gain} = \frac{(\text{R·C post-test}) - (\text{R·C pre-test})}{\text{R·C pre-test}} \times 100$$

4. Experiment 3 was conducted by Carl Semmelroth of the Center for Research on Language and Language Behavior and the Reading Improvement Service of the University of Michigan.

Figure Caption

Fig. 1. A frequency distribution of the changes in reading comprehension when two forms of the Diagnostic Reading Test were administered, the second under time constraints.

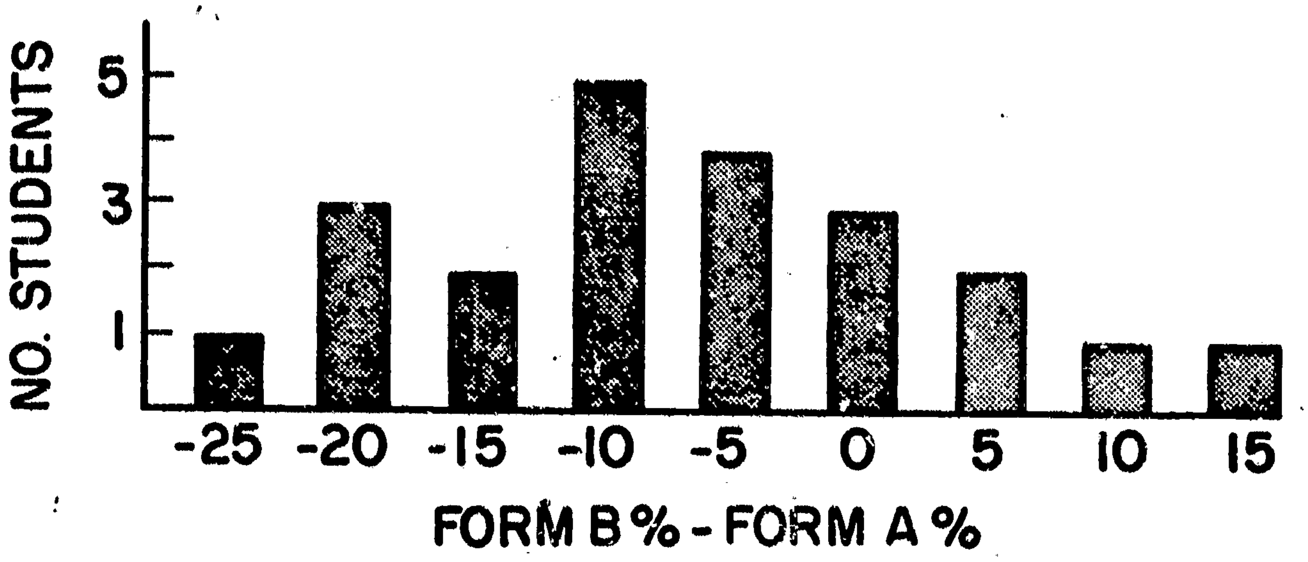


Fig. 1

Thoughts on Designing Language Courses

D. M. Brethower

# Thoughts on Designing Language Courses

Dale M. Brethower

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Abstract

This paper offers a general approach to development of foreign language courses. The approach involves five phases: (a) determining general practical constraints, (b) general specification of terminal behavior, (c) analysis of behavioral and linguistic content, (d) curriculum design, and (e) development of instructional materials. Goals of the second and third phases are the construction of a comprehensive test for the curriculum and a cataloguing of the linguistic and behavioral content.

Though language courses may have the same objectives, seven different designs (presented and briefly discussed) demonstrate that the type of achievement at any given level prior to final achievement may differ drastically.

Two criteria for sequencing the introduction of linguistic content are discussed. They are: (a) expandibility and (b) establishment and maintenance of contrasts.

Implications are suggested regarding ways of <u>aiding</u> the development of sound foreign language courses.

## Introduction

"Archimedes asked for a lever long enough, and a fulcrum, and he promised to move the world....the programmer asks for an analytical breakdown of a set of skills, or a complex of behavior, into sufficiently small, linearly connected bits, and he can promise to shape a student's behavior to a desired pattern ....the task of a FL programmer as he first confronts the vastly complex system of behavior that language represents, can be likened to a small boy with a screwdriver, gazing up at the Empire State Building which he has been ordered to dismantle. His task is further complicated by the fact that his dismantled building must be laid out in such a way that it can be re-assembled." (Sapon, 1961)

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The quotation gives an indication of the magnitude of the problems in preparing a foreign language course. This paper presents a systematic five phase approach to the task.[1]

Phase I Determining practical constraints

The purpose of Phase I is to make a rough assessment of a) the potential users of the course to determine what the course must be like for them to use it, and b) the constraints of time, money, and personnel. The rough assessment would be refined in subsequent phases.

Phase II General specification of terminal behavior

During Phase II the designers would decide what they want the students to be able to say and do at the end of the curriculum. Statements such as "a proficiency equivalent to that of a 4th year student" are not sufficient. The goal is to design a comprehensive achievement test which measures all skills to be taught in the course. The test would serve as a content guide for design since only the skills tested would be included in the course.

One way to begin constructing a test for a "comprehensive" course might be by tape recording samples of conversations that would occur in situations the designers expect the student to encounter after leaving the course. It would also be necessary to gather material the students would be expected to read, topics they would be expected to write about, and so forth. This method might require extensive field work.

Phase III Analysis of behavioral and linguistic content

In practice, Phase III would blend with Phase II. As materials were collected, syntactic structures and vocabulary items would be analyzed.

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[1] The approach is modified from an unpublished paper, "Techniques and procedures: Thai," written by the author as part of Contract #OE-3-14-012 between The University of Michigan and the Language Development Section, U.S.O.E.

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Samples of conversations and written materials would be collected to the point of diminishing returns, i.e., until few or no new structures were found and until relatively few new words were encountered.

Currently available linguistic knowledge would, of course, be available to aid in the analysis. However, it should be kept in mind that much current information is based upon the written language and upon linguistic folklore, and cannot be relied upon to be adequate for the spoken language.

At this point the designers would construct the actual comprehensive test for the course. It might require the students to hear, read and understand materials which contain all the structures. Understanding might be checked by requiring the student to write and speak about the materials. A variety of objective standards would be set to determine pronunciation, fluency, active command of structure and vocabulary, and receptive command of structure and vocabulary.

Phase IV Curriculum design

Table 1 contains a summary of several possible designs for language courses and/or curricula. The designs are presented as evidence for the argument that there are several different and sensible designs for language courses.

More detailed descriptions of the designs and a discussion of them are included as an appendix.

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Insert Table 1 about here

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For any of the designs the criteria of a) expandability and of b) establishment and maintenance of contrasts would prove useful. These criteria provide guidelines in sequencing the introduction of linguistic content and are independent of the design employed.

The criterion of expandability implies that structures and words which readily lead to introduction of other new structures and words should be taught first. This is a powerful guideline but in practice requires a good deal of ingenuity to apply. (cf. Sapon, 1961)

The guideline is probably easier to apply to lexicon than to syntax since data on statistical frequency of occurrence of spoken words can be used as a rough guide. While expandibility and frequency are by no means the same they are probably highly correlated. However some very frequent words (and structures) such as those used in common forms of greeting simply do not lead readily to introduction of new material.

An example of applying the expandibility criterion is found in part of a Thai course written by the author. Simple questions requiring affirmative and negative answers were introduced very early in the course. "Yes" is said by repetition of the Thai verb, "No" by a negative word plus the verb in answer to many questions. Use of these structures provides a powerful device for introducing new verbs, checking comprehension, etc. Introduction of another question pattern usually requiring a noun in answer provides an additional tool for expansion.

Criterion #2, establishment and maintenance of contrasts, applies most simply and directly to acoustical and visual contrasts. It implies that whenever a phoneme, grapheme, or intonation pattern is introduced, similar "emes" or patterns with which it contrasts should also be introduced at that time. Further, it implies that whenever a new word is introduced later in the program, acoustically similar words which occur in the same ordinal and grammatical position (in sentences or phrases) should also be introduced.

It may be seen that the two criteria place formidable but valuable constraints on the designer.

To recapitulate, at the end of the first four phases one would have a rough specification of practical constraints, a specification of terminal behavior, a specification of behavioral and linguistic content, one or more of several possible designs, and a guide for sequencing linguistic content.

The rough specification of constraints could--if necessary-- be made precise. The specification of terminal behavior would be in the form of a comprehensive final exam from which one could construct alternate forms of exams which sample from the many skills. One could also construct a series of subtests suitable for measuring achievement of different levels of performance within each of the several course designs.

Phase V Development of instructional materials

The guidelines for sequencing would be applied to the syntactic structures. When a sequence was established, the structural patterns would be filled in with lexical items in such a manner as to preserve acoustical and visual contrasts. The number of lexical items necessary at any level would be determined by the minimum number required to establish and contrast the syntactic structures and the visual and acoustical material. The number would vary from language to language.

The output of the first four phases would be used to develop the instructional materials. Exercises would be constructed following the overall design and using the sequence for introducing material.

The materials and course would be tested by trying them with students and making revisions until the students met the pre-established criteria.

This can be simply said but it involves keeping records of a tremendous amount of material in order to be sure that once an item or pattern is introduced, it and its contrasts are maintained and reused regularly. Constructing exercises to present material under such precise constraints requires considerable ingenuity as well as concern for detail. However, there is no less constraining alternative other than a hit-or-miss approach.

## Implications

There are some implications of the thoughts presented above which might prove to be quite important for those interested in aiding development of foreign language courses.

A comprehensive final achievement test would be very useful as a target for curriculum development. Assuming that a comprehensive test, agreeable to all respected people could be constructed, subtests generated from it could be used as practical measuring instruments to be used within a course. Other subtests generated from it could be used as measuring instruments for subterminal achievement of students in widely divergent courses. For example, subtests could be generated which tested the skills involved at the end of the seven Phase I's in Table 1.

The form that the content specification takes would be very important. Ideally, the specification would consist of completely cross-indexed and sequenced lists of structures, behavioral situations, and words. First, the structures would be listed in the order in which they would be taught, using the criteria of expandibility and contrasts as guides. One structure would be listed and cross-referenced. Then the next possible expansions of the structure would be listed with references both to the behavioral situations which lead to the expansions and to the situations appropriate to the expanded structures. References would also be included to the words appropriate to a) the behavioral situations, b) the transitions, and c) the expanded structures. With all that information, the course developer could begin selection of the behavioral situations, words, and structural patterns to be used in the first lessons.

If the specification of content took the above form it would be a huge undertaking. The information would be best stored in a computer, which might also be programmed to make the selections and compromises necessary in developing the lessons.

Carrying out such a complete cataloguing and cross referencing process would require a huge expenditure of time, talent and, therefore, money. Furthermore, the ultimate value of such an undertaking has not been proven. Without adequate proof to justify this undertaking it is reasonable to consider a practical compromise.

A useful and acceptable compromise would be to specify content in the form of three lists: first, a sequenced list of structural patterns; second, a sequenced list of vocabulary items; and third, an inventory of behavioral situations. The cross indexing would be assumed to be a part of the behavioral repertoire of the course developer or his informants.

The major effort would go into the sequencing of structural patterns. Two, three, or more alternative sequences would serve to guide anyone developing lessons while giving a necessary degree of latitude in making practical and pedagogical decisions.

The list of vocabulary items would be sequenced in the form of groups of words to be taught together. The final list might be developed by going through three versions. Criteria for grouping of version #1 of the list would be phonological. Version #2 would preserve the phonological grouping but restrict the grouping further by retaining only words which could be used within the structural patterns available in the corresponding part of the lists of patterns. A grouping in version #3 would be further restricted by constraints imposed by consideration of the behavioral situations in which the patterns and words might be used.

Thus, one can envision an attack upon the problems of designing courses which involves

a) development of comprehensive tests,

b) development of sequences of structural patterns,

c) development of vocabulary sequences, and

d) development of sequences of behavioral situations.

All of the preceding would occur prior to the writing of any actual teaching materials.

One might well wonder whether such a massive amount of preparation is necessary. Most literate people have been taught to give considerable thought to sequencing before writing. Some teachers even outline a course before the first day of class. But is it also necessary to write a comprehensive final exam before beginning the course?

It _is_ in so large an undertaking as teaching a language. Mere statement of objectives is not enough to guide us, even if we do it carefully. Watson (1960) says "If there is a discrepancy between the real _objectives_ and the _tests_ used to measure achievement, the latter become the main influence upon choice of subject matter and method." The best objectives become empty phrases if no one tests them adequately.

## Appendix

## Designs for Language Courses

The designs describe the test appropriate at the end of each phase of the particular course.

DESIGN I

Phase I Receiving Auditory Messages (transcription)

Upon completion students will be able to write messages (up to five syllables in length) upon hearing the messages.

Phase II Vocal Production (echoic)

Upon completion students will be able to echo any utterance in the language (up to five syllables in length).

Phase III Vocal Production (textual)

Upon completion students will be able to read aloud any normal written message.

Phase IV Comprehension

Upon completion students will be able to answer multiple-choice questions about messages they hear or read.

Phase V Discussion of Auditory and Visual Messages

Upon completion students will be able to answer questions and discuss (by speaking or writing) messages they receive (either aurally or visually).

Phase VI Development of Skills

Upon completion students will be able to read, write, and converse in the target language.

DESIGN II

Phase I  Auditory Discrimination

Upon completion students will be able to discriminate between any pair of phonemes in the target language when the phonemes are presented in pairs of monosyllables.

Phase II  Vocal Production

Upon completion students will be able to produce, echoicly, any monosyllabic utterance in the target language.

Phase III  Discrimination of Grammatical Utterances

Upon completion students will be able to tell which of two sentences, identical except for a grammatical error, is the correct one.

Phase IV  Production of Grammatical Sentences

Upon completion students will be able to produce grammatical sentences when given the "key words" for the sentences.

Phase V  Auditory Comprehension

Upon completion students will be able to answer questions, speaking in the target language, about conversations and stories heard in the target language.

Phase VI  Reading Comprehension

Upon completion students will be able to read the target language (aloud and silently) and be able to answer questions and describe what they have read, speaking or writing in the target language.

Phase VII  Development of Skills

Upon completion students will be able to read, write and converse in the target language.

DESIGN III

Phase I Receiving Auditory Messages (comprehension)

Upon completion students will be able to

a) listen to auditory messages and report, in their native language the content of the message, and

b) answer multiple choice questions asked in the target language.

Phase II Sending Vocal Messages

Upon completion students will be able to speak in the target language, giving one or two "paragraph" speeches on a variety of topics.

Phase III Receiving Written Messages

Upon completion students will be able to read (aloud or silently) communications written in the target language and answer questions about them, speaking in the target language.

Phase IV Sending Written Messages

Upon completion students will be able to write letters and reports in the target language.

Phase V Development of Skills

Upon completion students will be able to read, write and converse in the target language.

DESIGN IV

Phase I Auditory Comprehension (Vocabulary of the target language)

Upon completion students will be able to discuss spoken messages which use the grammar of the native language and the vocabulary of the target language.

Phase II Visual Comprehension (Vocabulary of the target language)

Upon completion students will be able to discuss written messages which use the grammar of the native language and the vocabulary of the target language.

Phase III Language Production (Vocabulary of the target language)

Upon completion the students will be able to converse, read, and write using the grammar of the native language and the vocabulary of the target language.

Phase IV Receiving Auditory and Visual Messages

Upon completion students will be able to demonstrate reception of messages by answering multiple choice comprehension questions using the target language. (Messages and questions can be auditory, visual, or mixtures of both auditory and visual.)

Phase V Discussing Auditory and Visual Messages

Upon completion students will be able to answer questions and discuss (by speaking or writing) messages they receive.

Phase VI Development of Skills

Upon completion students will be able to read, write and converse in the target language.

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DESIGN V

Phase I Comprehension (Grammatical structure of the target language)

Upon completion students will be able to discuss spoken messages composed, using as much of the grammatical structure of the target language as is possible while retaining the vocabulary of the native language.

Phase II Language Production (Grammar of the target language)

Upon completion students will be able to converse, read, and write using the grammatical structure of the target language and the vocabulary of the native language.

Phase III Receiving Auditory and Visual Messages

Upon completion students will be able to demonstrate reception of messages by answering multiple choice comprehension questions using the target language. (Messages and questions can be auditory, visual, or mixtures of both auditory and visual.)

Phase IV Discussing Auditory and Visual Messages

Upon completion students will be able to answer questions and discuss (by speaking or writing) messages they receive.

Phase V Development of Skills

Upon completion students will be able to read, write, and converse in the target language.

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DESIGN VI

Phase I Conversation (short answer)

Upon completion students will be able to take part in simple conversations which require them to give one word answers to direct questions--all in the target language.

Phase II Proofreading

Upon completion students will be able to read along with an auditory message and detect errors in transcription of the message. He can answer questions about the message.

Phase III Conversation (with script)

Upon completion students will be able to take part in complex conversations, paraphrasing a script of their part or using key word script.

Phase IV Discussion of Auditory and Visual Messages

Upon completion students will be able to answer questions and discuss (by writing or speaking) messages they receive.

Phase V Development of Skills

Upon completion students will be able to read, write, and converse in the target language.

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DESIGN VII

Phase I Proofreading

Upon completion students will be able to read along with an auditory message and detect errors in transcription of the message.

Phase II Comprehension

Upon completion students will be able to answer multiple choice questions about spoken and written messages.

Phase III Proofing

Upon completion students will be able to correct errors in pronunciation, grammar, and transcription of an auditory message.

Phase IV Conversation (with script)

Upon completion students will be able to take part in complex conversations, paraphrasing a script of their part or using key word script.

Phase V Discussion of Auditory and Visual Messages

Upon completion students will be able to answer questions and discuss (by writing or speaking) messages they receive.

Phase VI Development of Skills

Upon completion students will be able to read, write, and converse in the target language.

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The designs presented are "modern" in that each provides for auditory work before visual work, listening before speaking, and reading before writing. None of the designs necessarily require teaching formal linguistic knowledge about grammar, pronunciation, etc.

Each design could be made into several strikingly different courses by different techniques of presentation. For example, one course might make extensive use of the student's native language, while another might make very little or no use of the student's native language. One course might follow the design through all its phases with a very limited portion of the language. Another course might do nearly all the language appropriate to one phase before moving on to the next phase, while a third course might go through each phase with a limited part of the language, then go through each phase with another part, and so on. Other designs can easily be generated, still providing auditory before visual, etc., by selecting phases from among the designs and recombining them, or by designing different phases.

Designs IV & V involve mixing the target and native languages--something few teachers recommend and something many students seem to do anyway. Rather than seeking to avoid the problems of mixing the languages the designs require facing and combating possible errors resulting from the mixing. Waving these designs in front of linguistically-oriented pedagogues has much the same effect as waving a red flag in front of a bull. Extending the analogy, there is some evidence that bulls are color blind and some evidence of uncertainty as to precisely why the designs are decreed "bad." The effective stimulus seems not to be redness in the case of the bull or the ineffectiveness of the design in the case of the pedagogue.

The stimulus for the bull is probably motion but the stimulus for the pedagogue's emotion is harder to specify. The emotion might be based upon the observation that one's first language tends to be better than one's second language--the conclusion being that one should learn his second language the same way that he learned his first one. The pedagogue's reaction might also be based upon a concern for the integrity of the second language as Language. Mixing languages might do violence to language as capital-L language but it remains to be proven that it does violence to language as human behavior.

To reiterate, the major point is that the designs could conceivably be designs for dozens of different courses in the same language having the same objectives and content and whose students ultimately achieve the same degree of mastery in the same amount of time. Yet at "mid-term" or "the end of the first year" students would possess strikingly different skills and score quite differently on a general test of achievement.

Table 1

Summary of Designs

| Design | Phase I | Phase II | Phase III | Phase IV | Phase V | Phase VI | Phase VII |
|---|---|---|---|---|---|---|---|
| I | "transcribe" | "echo" | "read aloud" | "understand" | "speak" | "write" | "do it all" |
| II | "discriminate phonemes" | "echo" | "discriminate sentences" | "say sentences" | "listen and understand" | "read and understand" | "do it all" |
| III | "listen and understand | "make a short speech" | "read and understand" | "write" | "do it all" | | |
| IV | "listen and understand" (grammar only) | "say sentences" (grammar only) | "listen, read, and understand" | "discuss and write about what you hear and see" | "do it all" | | |
| V | "listen and understand" (vocab. only) | "read and understand" (vocab. only) | "speak and write" (vocab. only) | "listen, read and understand" | "discuss and write about what you hear and see" | "do it all" | |
| VI | "converse" (short answers) | "Proofread transcription and comprehend" | "converse" (from script) | "discuss and write about what you see and hear" | "do it all" | | |
| VII | "proofread transcription" | "listen, read and understand" | "proof and correct transcription, pronunciation and grammar" | "converse" (from script) | "discuss and write about what you see and hear" | "do it all" | |

# Variety and Programed Instruction, or What Can't be Programed?

G. L. Geis

Variety and Programed Instruction

or

What Can't Be Programed?[1]

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Abstract

Programed instruction is a process by means of which self-instructional materials are developed. The first step in this process is a statement of the behaviors that the program will be designed to produce. Thus, the answer to the question, "What can be programed?" hinges on what instructional objectives can be stated in sufficiently explicit behavioral terms. The traditional distinctions among content areas in education, and those between performances requiring rote versus concept learning, do not prove useful in answering the question.

The words "programed instruction" refer to a process, not a product. The first step in that process consists of an explication, or detailed account, of the behavioral changes that the programer is attempting to produce, along with the development of valid measuring instruments to test whether the program reaches its objectives. Examples of desired behavioral changes might be higher scores on examinations, increased skill in a manual task, more competent performance in designing a research study, or greater ability at analyzing a painting (indicated by judges' ratings on some checklist). When behavioral objectives have been spelled out, the programer engages in behavioral analysis, i.e., he determines the small components (abilities and skills) which make up the major behavioral changes he is attempting to engineer. It is important to note that the programer is engaged in the specification of, and the analysis of, behavior, not content. The sophisticated programer does not program a body of knowledge. He is not bound by the classical sequencing and information coverage which make up the content of the field. Rather, he is engaged in the study of how to produce certain behavioral changes. This distinction between content orientation and behavior orientation--between teaching something and teaching someone--is crucial to an understanding of how the programer works, what can be expected of programs, and what can be programed.

Revised in the light of this discussion, the above query might read, "What changes in behavior can be obtained using materials developed from the programing process?"

## Content Classification

Since we traditionally classify educational materials, including programs, on the basis of content, it is not possible to answer the preceeding question directly; instead, the answer must be inferred from the titles of available programs (Hanson, 1964; Hendershop, 1964). Programs can now be obtained in such diverse content areas as psychology, preschool training, logic, social studies, music, arithmetic and mathematics at all levels, business education, languages, physics, and nursing--to cite a few examples.

There are programs for professional education (e.g., biochemistry for medical students), specific skills (e.g., how to measure board feet, how to remember faces and names, how to use a micrometer), continuing education (e.g., programs on specific drugs, designed for an audience of doctors), and so forth. As a reminder, it is not certain what behaviors are being developed in these programs, nor is it known, even after inspecting most of them, whether they produce the indicated behavioral changes. This can be discovered only by trying them out.

Additional programs recently initiated or developed at the University of Michigan range over such diverse fields as art (appreciation of the visual arts), psychology (personnel selection), music (discrimination of and notation of a series of notes), English (the analysis of short stories), religion (the two-source theory about the synoptic problem), physiology, Latin, and counseling.

To answer the question posed early in this paper, it can be said on the basis of inspection of titles and content of programs that there is no obvious restriction on the content areas for which programs can be developed.

It should be noted that there are, unfortunately, only a very few programs available commercially whose titles suggest terminal behaviors rather than "content." For example, there is a program, Effective Listening (Basic Systems, 1963), designed to produce just that, and another, General Relationship Improvement (Human Development Inst., 1963), designed to produce improved interpersonal relations. These recent titles suggest that programed instruction may lead to a radical restructuring of curriculum on the basis of behavioral goals rather than content classification.

## Objectivity and Creativity

It has become a cliché in programed instruction to answer the question, "What can be programed?" with the statement, "Anything that can be taught." The programer means by this statement that, if the behavior has been taught previously, it is possible to describe it explicitly enough for programing--although this specification of the instructional objectives may not have been verbalized by either the teacher or the student. Since the teacher cannot specify the objective nor, often, the means of achieving that objective, the change that has taken place in the student may appear somewhat mysterious. It is true that, unless behavioral goals are described, it is impossible to develop a program to produce them. But the behavioral specification of instructional objectives is an equally important task for the teacher who does not plan to develop a program. The teacher who fails to complete this task is like an engineer constructing an object which he cannot describe ahead of time, but can only recognize when it is completed. Before one is able to decide that particular behaviors <u>cannot</u> be programed, he must spend time discovering whether or not he can specify, in quantitative terms, what the behaviors are that he wishes to produce. (One attempt at such a specification is, obviously, the writing and scoring of a final examination.)

On this point a more precise answer by the programer to "What can be programed?" might be, "That which can be specified." And the amendment might be added, "Efficient and effective teaching, programed or not, probably depends upon the specification of terminal behaviors."

In programed instruction one is often challenged by a question which the speaker assumes to be rhetorical: "You certainly can't program creativity or imagination, can you?" Suppose this is not taken as a rhetorical question. In the light of what has been said above, the programer might answer: "If you can specify for me, or with me, what behaviors you regard as creative and imaginative, we can together attempt to write a program which will produce those behaviors." The immediate response might be that it is impossible to specify them. Indeed, it is difficult to recognize the product, much less the behaviors that produced it. The programer might pursue the argument along these lines: "There must be some behaviors in other people which you respond to as creative and imaginative; let's engage in an investigation of the conditions, that is, the behaviors, which lead you to say the words 'creative' and 'imaginative'." Or he might say, "Show me some examples of creative and non-creative behaviors." This is not to say that the problem is completely clarified at this point. For example, it seems that we often respond with such words as "creative" and "imaginative" to new, unique responses, though newness or uniqueness is not the sole criterion for using these words. (Indeed, some of the people who exhibit the most unique and original behaviors are consequently institutionalized.) Additional dimensions of the concept "creative" can be slowly extracted, but probably the definition will never be as exact as that of, say, pronunciation of Parisian French. The programer will be faced with a most interesting and challenging problem--the production of behaviors which can be specified only in general terms but cannot be predicted at a molecular level. The problem of arriving at reliability among judges for such terminal behaviors is difficult enough; providing for accurate self-evaluation of such responses by the student (the comparitor function) is even more challenging. The growing literature in programed instruction gives evidence that programers are concerned with complex and subtle repertoires such as those related to creativity. For the present, however, psychology is only on the threshold of identifying the behavioral components which, when combined in certain ways and under certain conditions, produce the behaviors we call creative or imaginative.

A related challenge to programed instruction concerns stereotypy and variablility of behavior. According to a common criticism, programed instruction is applicable only to those cases in which the result of instruction is the production of the same responses for all students. Of course, that is precisely the instructional objective in many traditional content areas in education. This restriction, however, may prevent much imaginative and exciting programing. Suppose producing variation in response in a class of students is desired. How is this effect presently achieved? Usually, not much _is_ done. At best we try not to suppress variability, and depend upon the different backgrounds and interests of the students to generate it. However, it is not correct to assume, merely because the causes of variability are not known or consciously produced, that it is uncaused or caused by a set of procedures other than those which produce stereotypy. To teach two children to speak English, the same basic instructional operations may be employed as in teaching one child English and one child French; in the first case we would produce stereotypy in the behavior of our population and in the second variability or diversity. Programers can take an active role in the production of such behavior; much as in the case of creativity, they can produce programs that develop individual behaviors in different students. The problem seems to be to define the classes of allowable variants, how much and what kinds of variability are acceptable. Once this has been done, it is as conceivable for a program, as for a teacher, to produce the results. Of course, an obvious solution would be to produce as many different programs (and, therefore, students) as variants desired. On a slightly more subtle level, computer-based programs aimed at making use of and producing variation in the student are now being developed in a number of universities. Indeed, the computer may be a more patient and sensitive instructor for this kind of teaching than the human.

## Rote Versus Concept

One of the most common statements made by teachers in discussions of programed instruction runs about as follows: "I know of a great deal of material in my course that I would like to program--rote material--material that every student has to memorize. It seems silly that I should stand up and lecture on such things." The teacher has dichotomized material into rote and conceptual. Yet the distinction between "rote" and "conceptual" does not seem clear. Rote seems to refer to something intrinsic in the materials (a vocabulary list, a telephone number, etc.); sometimes it seems to refer to the behaviors learned ("He repeated in a rote way what he had learned."). Sometimes it seems to refer to the method of learning ("learning by rote"). And occasionally all three characteristics seem to be present. Similarly, the term concept or conceptual has numerous and quite different referents.

Traditionally, rote is taken to refer to a situation in which responses are automatic or unmediated. Thus, it might be said that the student learned or replied by rote when we observe him instantly answer to the phrase "1492", "Columbus discovered America."

It is not the purpose of programed instruction to teach such responses. Indeed, rote responses can probably be taught most economically in the traditional ways. Given a list of paired associates, pairs of words or phrases, the average student can commit them to memory.

The deeper, more important question is really: "Why would we ever want to teach such things?" With the advent of the printing press, the library, and, today, sophisticated information-retrieval systems, one muses at the amount of time spent cramming such "facts" into the heads of every student, as if we were on the verge of losing, at any moment, all the tables, reference books, and the like that have accumulated over the centuries.

Far from a facile instrument for teaching such (often inane) reflexes, programed instruction, just because it is expensive, time-consuming, and exhausting to develop, forces a careful examination of what is to be taught. In this way it tends to focus the programer on teaching crucial concepts rather than a myriad of facts. Though, it is true, most available programs are little more than texts that have undergone word surgery, programing can be an instrument of concept-formation rather than information-transmission. A few programs have demonstrated that not only is this possible but that the program is often the most efficient way of developing the concepts required.

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## Footnotes

1. A slightly different version of this paper is due to appear in the Spring issue of Audiovisual Communications Review.

Bibliography of Programmed Instruction

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Bibliography of Programmed Instruction

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This bibliography of programmed instruction is up-to-date (as of September 1, 1965) and contains the bulk of material written (at least in book form) on programmed instruction. Also included is a list of bibliographies of programs.

It should be noted that the journal articles included were chosen because they appeared as references in other works. This list is by no means complete, and should not be construed as a representative sample of the literature.

This bibliography can be of value to the researcher looking for a specific reference, to the research assistant who must track down references, and to the student or individual interested in programmed instruction, who is seeking a reading list.

Also included is a short list of books and programs on Skinnerian or operant psychology.

Any additions or corrections to this list will be appreciated.

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# Differential Rates of Learning Mandarin Chinese Tones

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## Differential Rates of Learning Mandarin Chinese Tones

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### Abstract

Six pairs of tonemes were selected from Mandarin Chinese, and the members of each pair were contrasted in initial, medial and final position in triads providing all permissible environments. Thirteen students learned to identify the members of each contrastive pair by pushing one of two buttons and observing a confirmation device. The Ss' initial, terminal and overall errors were analyzed as a function of contrasts, Ss, frames, and environments.

Almost all Ss showed highest error rates for the contrasts between tone two and tone three and tone two and tone four. The former contrast was associated with better initial accuracy but little improvement, whereas the converse was true for the latter contrast. It may be more difficult to learn to discriminate differences in pitch level than those in pitch contour. Regular tone sandhi affected the error rates. Identification learning seemed to be environment-specific, in that discriminations acquired in one environment degenerated when the environment was changed.

Analysis of the patterns of error indicates the tonemic contrasts that require teaching, the relative difficulty that they present to English speakers, and the effects of the phonetic environment on discrimination learning.

In Mandarin Chinese a word has not only constituent segmental phonemes but also a distinctive toneme. This toneme is characteristic of the word and distinguishes it from other words. If the word spoken contains the wrong toneme, then it becomes highly probable that either no information is conveyed or the speaker is misunderstood. There is also the third possibility that redundancy will supply the required repairs.

In teaching Mandarin as a second language to speakers of a non-tonal language, the perception and production of tonemes become problems of considerable import. A search of the most frequently used classroom texts

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in teaching Mandarin fails, however, to shed light on the nature of these difficulties. What was needed was a corpus of tonemic identification data illustrating some of the confusions to be found. The following study is an attempt to identify several of these toneme confusions as they occurred in the context of a self-instructional audio-lingual program in spoken Mandarin Chinese (Morton, Chou, & Peterson, 1964).

That portion of the program pertinent to this discussion had as its goal the establishment of a set of distinctive responses to toneme classes. Each toneme class is defined by and distinguished from any other toneme class through the operation of a limited number of multi-dimensional cues. Although the exact nature and number of these cues has yet to be discovered, it is necessary for the student to form concepts based on the cues inherent in the toneme class, as well as conditioned cues arising from the phonetic environment.

## Method

### Stimuli

Mandarin has four toneme classes, plus a neutral toneme. The verbal descriptions of the four tonemes are as follows:

tone one, high level;

tone two, high rising;

tone three, mid-falling-rising; and

tone four, high falling.

Tone five, the neutral tone, is a pitch point with no discernible contour, with a relatively high pitch following tone three; or relatively low pitch following tone one, two, or four.

Six bi-directional contrasts were chosen from these five tones for observation. These six contrasts were to occur in each of the following environments:

finally, occurring after two first, second, third or fourth tones;
medially, between two first, second, third, or fourth tones; and
initially, before two first, second, third, or fourth tones.

Each environment in which contrasting tones were presented was considered to be a separate learning frame. This gave a total of 64 frames in which one bi-directional contrast was presented in one environmental situation (tone five did not occur in an initial position). These 64 frames represent 128 specific identification tasks.

The sequencing of the identification tasks was based largely on formal grounds, although some pedagogical considerations were taken into account. Many teachers of Mandarin hold that tone two and three are commonly confused, partly because of a minimally contrastive contour in most environments and partly because of a regular perturbation effect which results in a tone three becoming perceptually identical to a tone two when it occurs before another tone three. This particular sandhi effect is said to be unaffected by stress or tempo factors. Errors for this contrast were expected to increase in these particular environments. It was decided, therefore, to deal with this contrast after the ostensibly easier contrasts had been presented.

At the other end of the difficulty scale was the contrast between tones two and four. The teachers whom we consulted agreed that they had never observed this contrast to be particularly difficult. Consequently, this contrast was used as the introduction to each new environment. The second set of contrasts involved tones one and two. Tone two is said to become a tone one under certain conditions of environment and stress. The converse is not true, however. It was hypothesized that this would lead to a clustering of errors wherever the environmental conditions obtained. By the same token, these tones must be kept distinct in all other environments. Unlike the transformation of tone three to tone two, that of tone two to tone one is affected by tempo and stress.

Tone four was then contrasted with tone one, and then with tone five, and tone three was also contrasted with tone five. The sequence of presentation for the environmental tones was not ordered by any subjective difficulty scale, but in a simple numerical order: one, two, three, four. The position within the tonal environment always proceeded from final to medial to initial. The contrasted tones were all heard in the same environmental condition before moving to the next environment. It was hypothesized that each contrast would become successively easier with environmental changes as a consequence of generalization.

Thus, the complete sequence was as follows, using tone one as the environmental tone:

114~112, 111~112, 111~114, 114~115, 113~115, 113~112, 141~121, 111~121, 111~141, 141~151, 131~151, 131~121, 411~211, 111~211, 111~411, 311~211.

This sequence was then repeated with tones two, three and four as the environmental tones.

## Procedure

All tone stimuli were recorded on tape by one female native speaker of Pekingese Mandarin from voicing scripts written in Chinese characters. Each utterance was rechecked to make sure that it was a clear rendering of the desired tonal pattern. The phonological content of the underlying syllable was randomly selected so as to permit allotonic variation. The emphasis was on a clear, naturally-produced Chinese utterance showing normal environmental perturbations. All recordings were subsequently filtered electronically to attenuate frequencies above 250 cps in an attempt to reduce the salience of segmental cues. The residual tone contour was again checked by native speakers for quality of each utterance. The identity of each member of the pair of tones contrasted was encoded on a second tape-track with pure tones. These activated relays during presentation of the tape, enabling confirmation and automatic records of Ss' responses. The tapes were placed in RCA cartridges for use with a modified Viking cartridge player. The thirteen Ss were permitted to proceed at their own rate and to recycle through any given problem as many times as they wished, although each problem was to be kept in sequence. Cumulative records of each work-through were collected in the form of a permanent strip chart. Cumulative scores (number of correct identifications) were automatically provided for the student at the end of each work-through. A ten per cent maximum error rate was established as a criterion performance, with the stipulation that each S could move on to a new problem if at any point he felt further progress was unlikely. This flexibility in the criterion performance was dictated by a lack of empirical evidence concerning probable performance records for the tasks at hand.

Before starting a frame each S was given workbook instructions that described the tonal contrasts, as well as the environmental tones and the location of the contrastive tones relative to the environmental tones for each frame. The Ss had in front of them two response-buttons corresponding to the individual members of the bi-directional tone contrast.

Each S was instructed to respond immediately after hearing each tone stimulus by pressing the appropriate button. If his response was correct, the button was illuminated and he received one point on a digital counter in front of him. If the response was incorrect, the correct button was illuminated and one point was subtracted from his cumulative score. A response was effective only during a period of 600 msec after the termination of the stimulus. The Ss were encouraged to respond to every item, and records show very few instances where no response occurred. Thus, it appears that the 600 msec interval was probably adequate. The following stimulus occurred approximately 750 msec after the termination of the preceding one.

Subjects

The Ss were seven female and six male students in a beginning course in Mandarin Chinese offered by the University of Michigan. The Modern Language Aptitude Test was administered to each S prior to his first contact with the program (see Table 1).

Insert Table 1 about here

## Results

Information on toneme confusions was gathered from the cumulative records of 13 Ss. More than 9,000 confusions occurred in over 40,000 observations. Each confusion was identified along with the environmental condition prevailing when the error occurred. In order to examine the relative difficulty of learning to discriminate the various toneme contrasts, errors were analyzed as a function of Ss, contrasts, frames, and environments (see Figs. 1 - 15).

Insert Figs. 1 - 15 about here

Looking at the data another way, the extent and rate of change in the occurrence of errors was taken as a second measure of the difficulty presented by a particular contrast. Accordingly, the mean percentage of correct responses on the first trial of each frame was computed--for those Ss who took more than one trial on that frame (entry score). For the same Ss, the mean per cent correct just before moving on to the next frame was also computed (exit score). For each

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frame, the mean number of repetitions divided into the mean difference between entry and exit gives the mean gain per trial (see Fig. 16).

Insert Fig. 16 about here

An error analysis of each tone contrast can be found in Figs. 1 - 15. In Fig. 1 cumulative error is shown as a function of the 64 frames ranked by error. It is clear that more than half of the errors are attributable to a few frames, many less than half of the total set.

Figure 2 shows cumulative errors as a function of Ss ranked by error. Over half of the total errors were attributable to less than one third of the students. A separate analysis showed that there was close agreement, however, in the distribution of these errors among the different contrasts. It would seem that although the sample is small, agreement between Ss on the confusions is high.

Figure 3 shows cumulative errors as a function of the tone sent and received over all environments combined. Each is ranked by error. Over 50 per cent of the cumulative error in the program is attributable to the bi-directional contrast between the second and third tone, confirming the teacher consensus to this effect (described earlier). Most significantly, this difficulty was quite resistant to change, as can be seen clearly in Fig. 16. Also note that this contrast has the highest average entry score of the six contrasts examined.

Surprisingly, the contrast shown by Fig. 3 to be second in order of difficulty involves tones two and four, which account for 23 per cent of the total error. It appears that the rate of change in the pitch of these two tones is a reliable cue, whereas the direction of change is not. Figure 16 shows that performance on this contrast made very rapid gains in all environments, except medially between tone one, and that a considerable percentage of Ss is involved in repeats of this contrast.

Figures 4 to 15 show each tone contrast ranked by error in each of its possible environments. A preliminary analysis of these data reveals that the most difficult tonal environment is medially between tone one or three. It would seem that all contrasts show maximum difficulty when they are contiguous to tones in the extremes of the voice range.

Figure 16 gives evidence that all of the six contrasts fail to show any generalization effects from one environment to the next. Perhaps the sequence of training all contrasts in one environment before moving to a new environment is not as advantageous as training one contrast in all environments.

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Pike, K. L. Tone languages. Ann Arbor: Univ. of Michigan Press, 1948.

Table 1

MLAT Scores

| | PART 1 | 2 | 3 | 4 | 5 | TOTAL |
|---|---|---|---|---|---|---|
| 1 | 41 | 26 | 23 | 24 | 21 | 135 |
| 2 | 26 | 19 | 8 | 32 | 10 | 95 |
| 3 | 29 | 21 | 28 | 29 | 17 | 124 |
| 4 | 34 | 30 | 29 | 40 | 24 | 157 |
| 5 | 38 | 27 | 16 | 27 | 23 | 131 |
| 6 | 15 | 24 | 8 | 21 | 7 | 75 |
| 7 | 39 | 30 | 21 | 31 | 24 | 145 |
| 8 | 39 | 30 | 15 | 42 | 24 | 150 |
| 9 | 33 | 28 | 29 | 38 | 24 | 152 |
| 10 | 42 | 30 | 47 | 39 | 19 | 177 |
| 11 | 41 | 26 | 29 | 36 | 24 | 156 |
| 12 | 40 | 30 | 31 | 31 | 24 | 156 |
| 13 | 42 | 30 | 25 | 33 | 23 | 153 |

(Ss Ranked by Cumulative Errors)

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## Figure Captions

Fig. 1. Cumulative errors plotted as a function of frames ranked by error.

Fig. 2. Cumulative errors plotted as a function of Ss ranked by error frequency.

Fig. 3. Cumulative errors are shown as a function of the tone sent and tone received over all environments, ranked by error. This represents 9,420 errors out of 41,786 observations. N = 13.

Fig. 4. Cumulative errors where tone 3 was transmitted, tone 2 received, plotted as a function of environments ranked by error. Twenty-six per cent of total error.

Fig. 5. Cumulative errors, sent 2, received 3, as function of environments ranked by error. Twenty-five per cent of total error.

Fig. 6. Cumulative errors, sent 4, received 2, as function of environment ranked by errors. Nine per cent of total error.

Fig. 7. Cumulative errors, sent 2, received 4, plotted as function of environment ranked by errors. Seven per cent of total errors.

Fig. 8. Cumulative errors, sent 4, received 5, as function of environment ranked by errors. Six per cent of total errors.

Fig. 9. Cumulative errors, sent 1, received 2, as function of environment ranked by errors. Five per cent of total errors.

Fig. 10. Cumulative errors, sent 5, received 4, as function of environment ranked by errors. Five per cent of total errors.

Fig. 11. Cumulative errors, sent 2, received 1, plotted as function of environment ranked by errors. Four per cent of total error.

Fig. 12. Cumulative errors, sent 1, received 4. Plotted as function of environment ranked by errors. Four percent of total error.

Fig. 13. Cumulative errors, sent 4, received 1 as function of environment. Four per cent total error.

Fig. 14. Cumulative errors, sent 3, received 5 as function of environment ranked by errors. Three per cent of total errors.

Fig. 15. Cumulative errors, sent 5, received 3, shown as function of environment ranked by errors. Two per cent of total error.

Fig. 16. Bar chart showing the six bi-directional tone contrasts grouped according to their environmental factors, i.e., F = finally, after the environmental tones, one, two, three, or four; M = medially, between the environmental tones; or I = initially, occurring before the environmental tones. Also shown are the mean entry scores for each, the mean exit scores, the mean trials to exit, and the percentage of Ss involved.

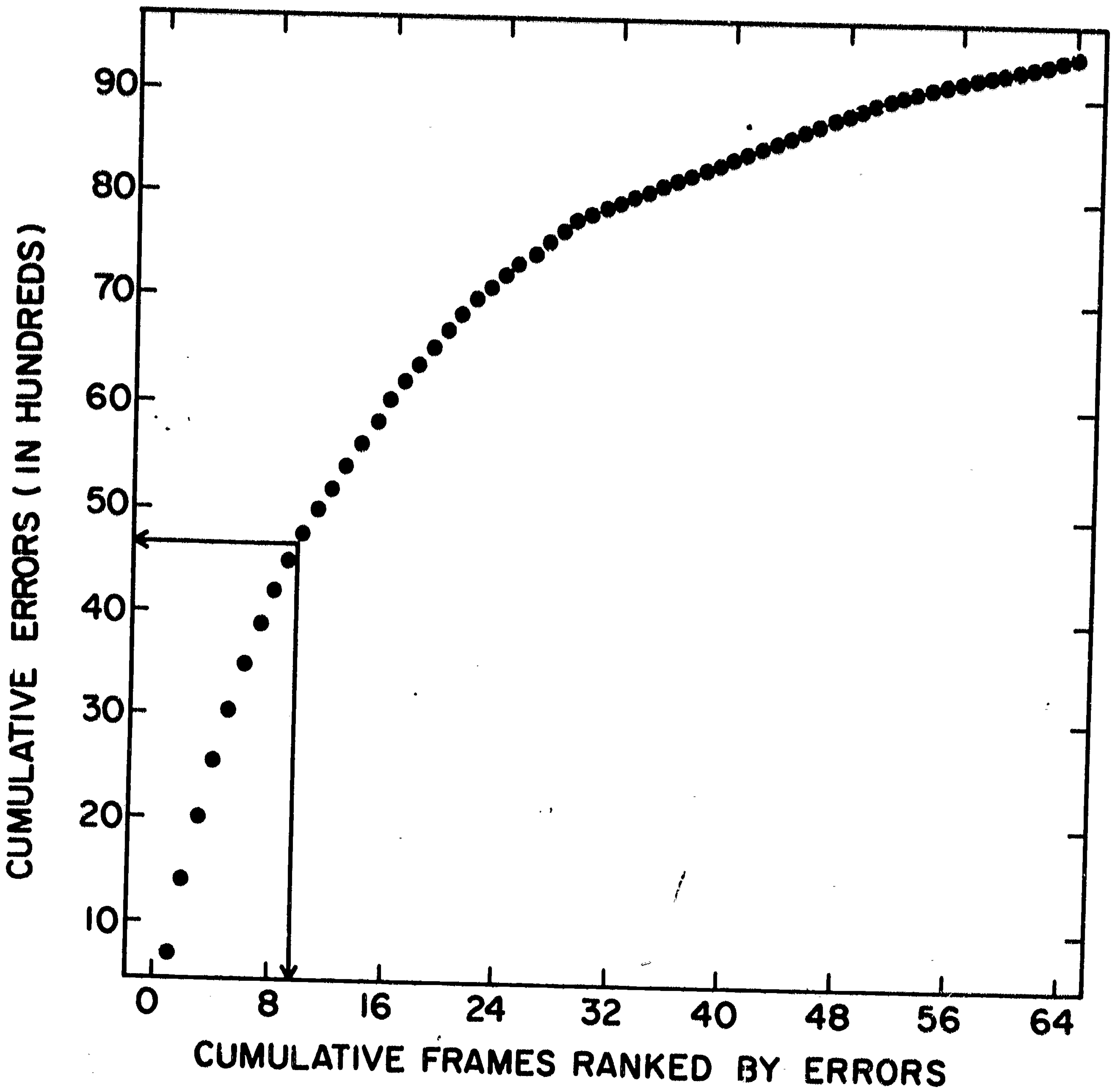

CUMULATIVE ERRORS (IN HUNDREDS)
10
20
30
40
50
60
70
80
90
0
8
16
24
32
40
48
56
64
CUMULATIVE FRAMES RANKED BY ERRORS

Fig. 1

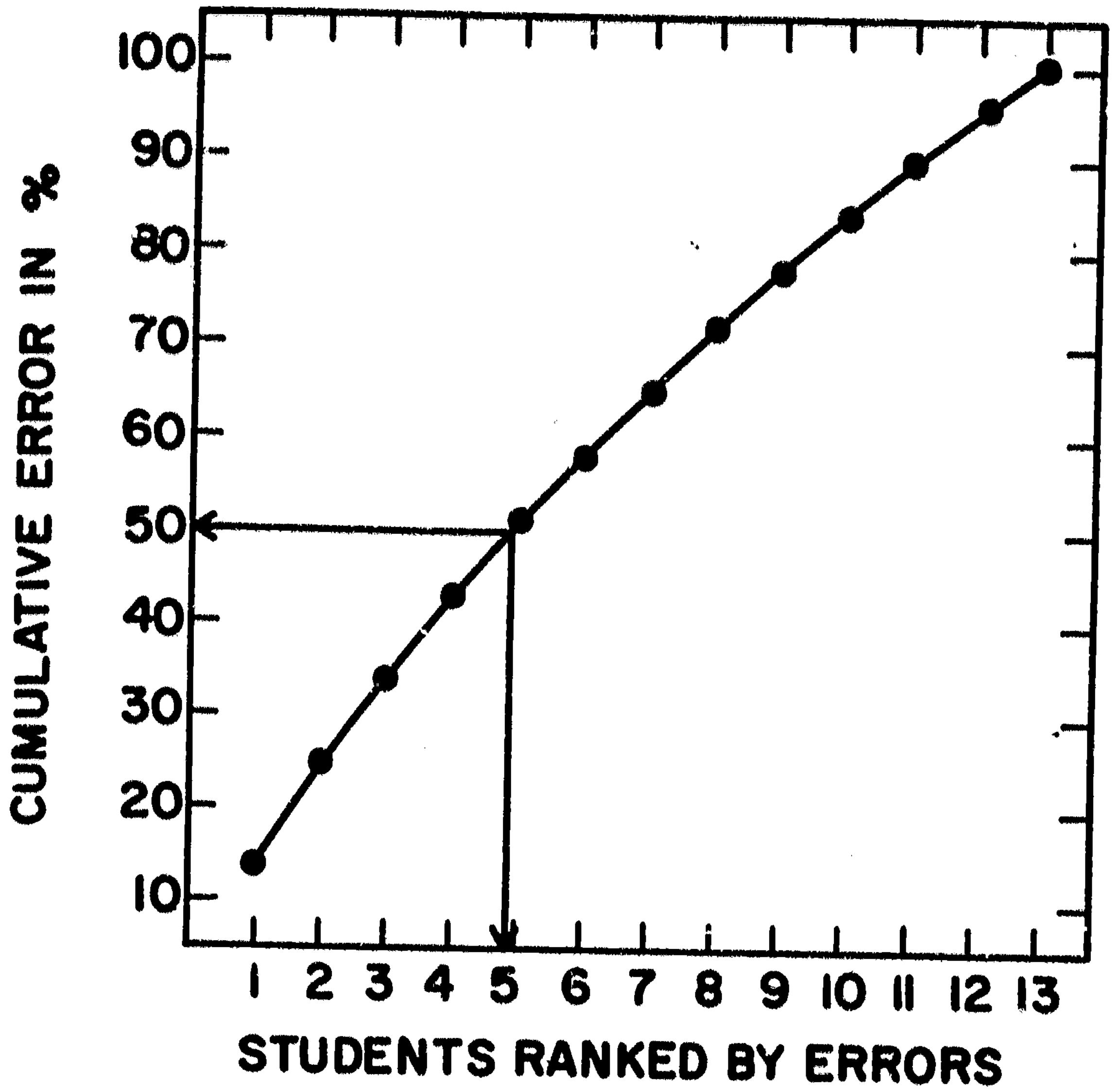

CUMULATIVE ERROR IN %
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13
STUDENTS RANKED BY ERRORS

Fig. 2

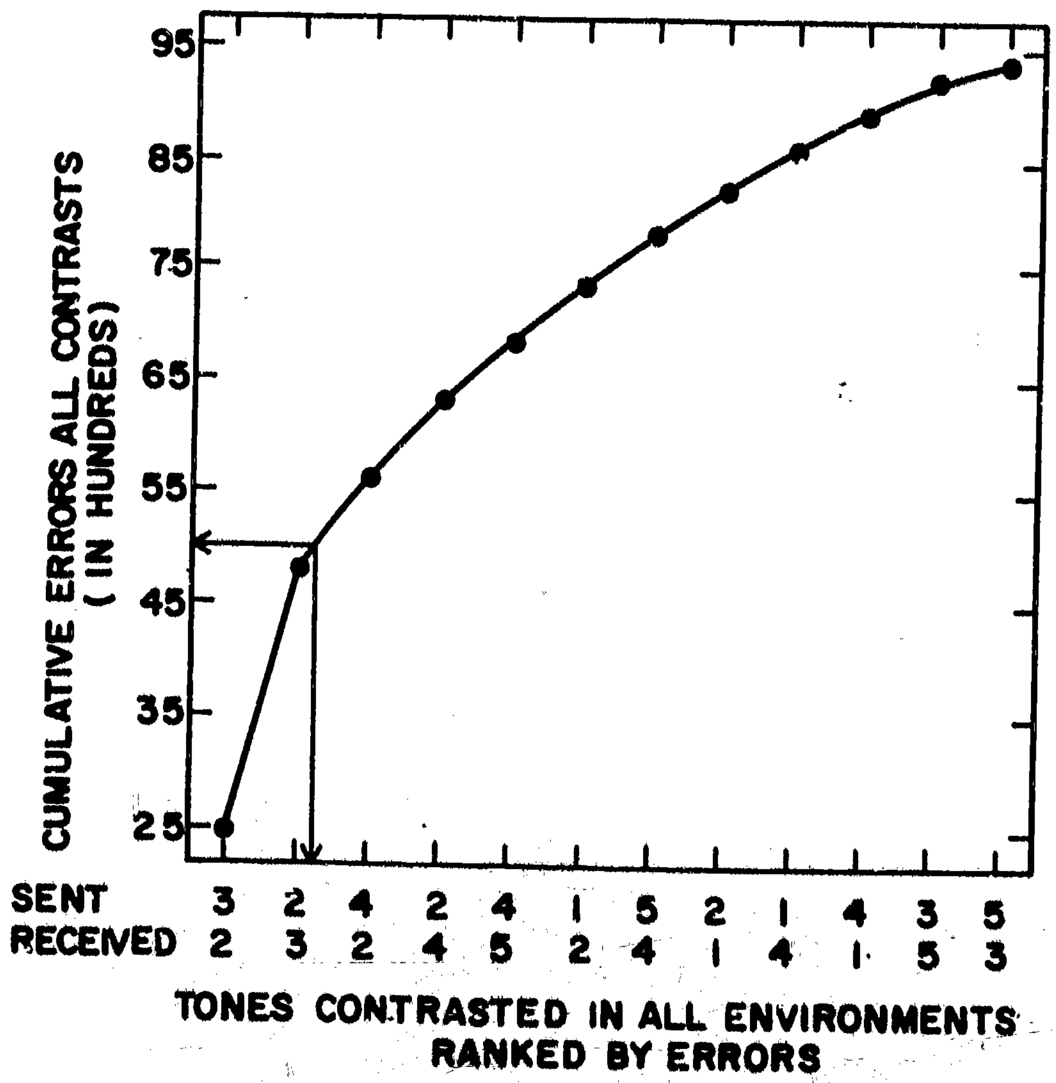
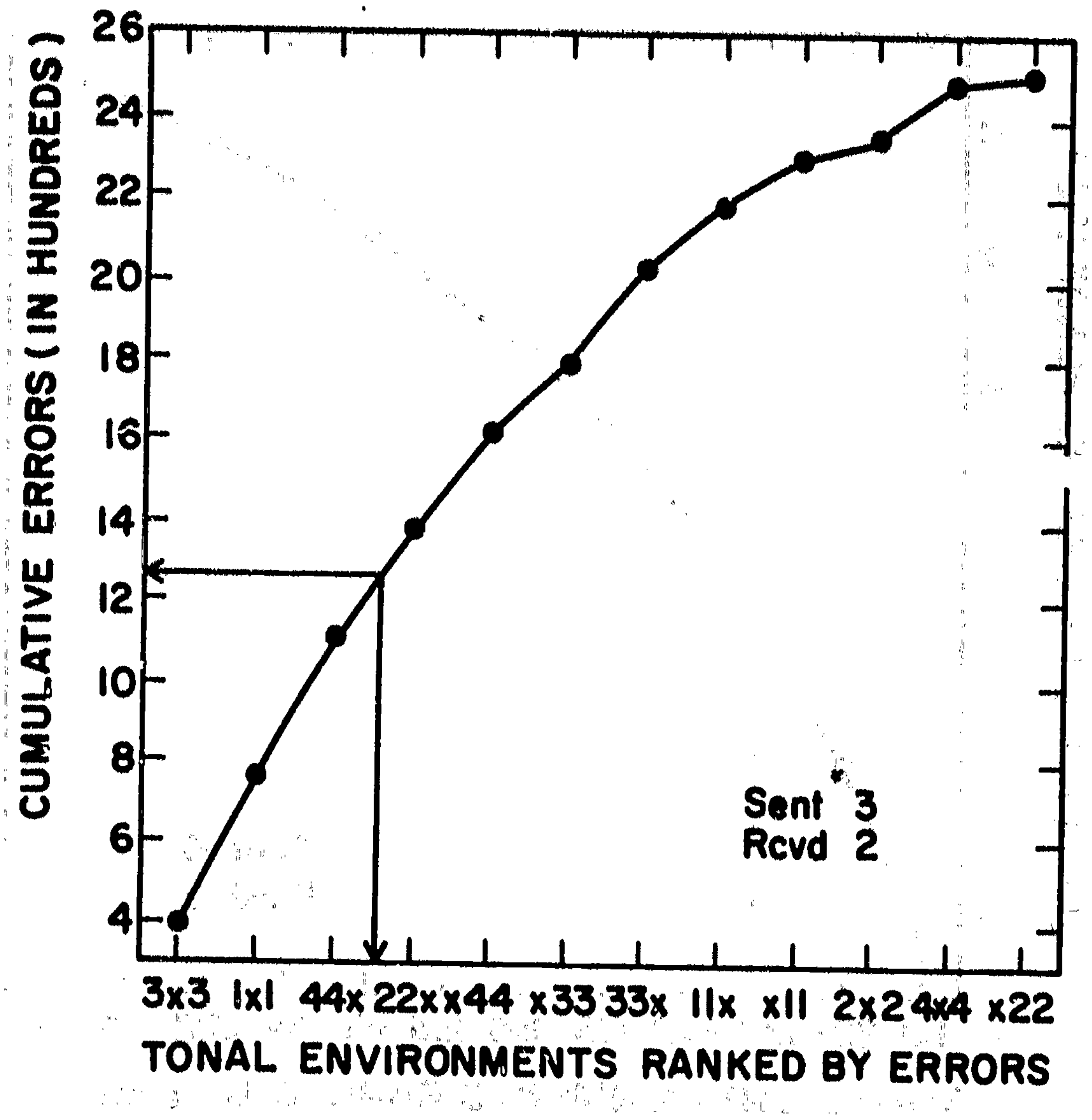
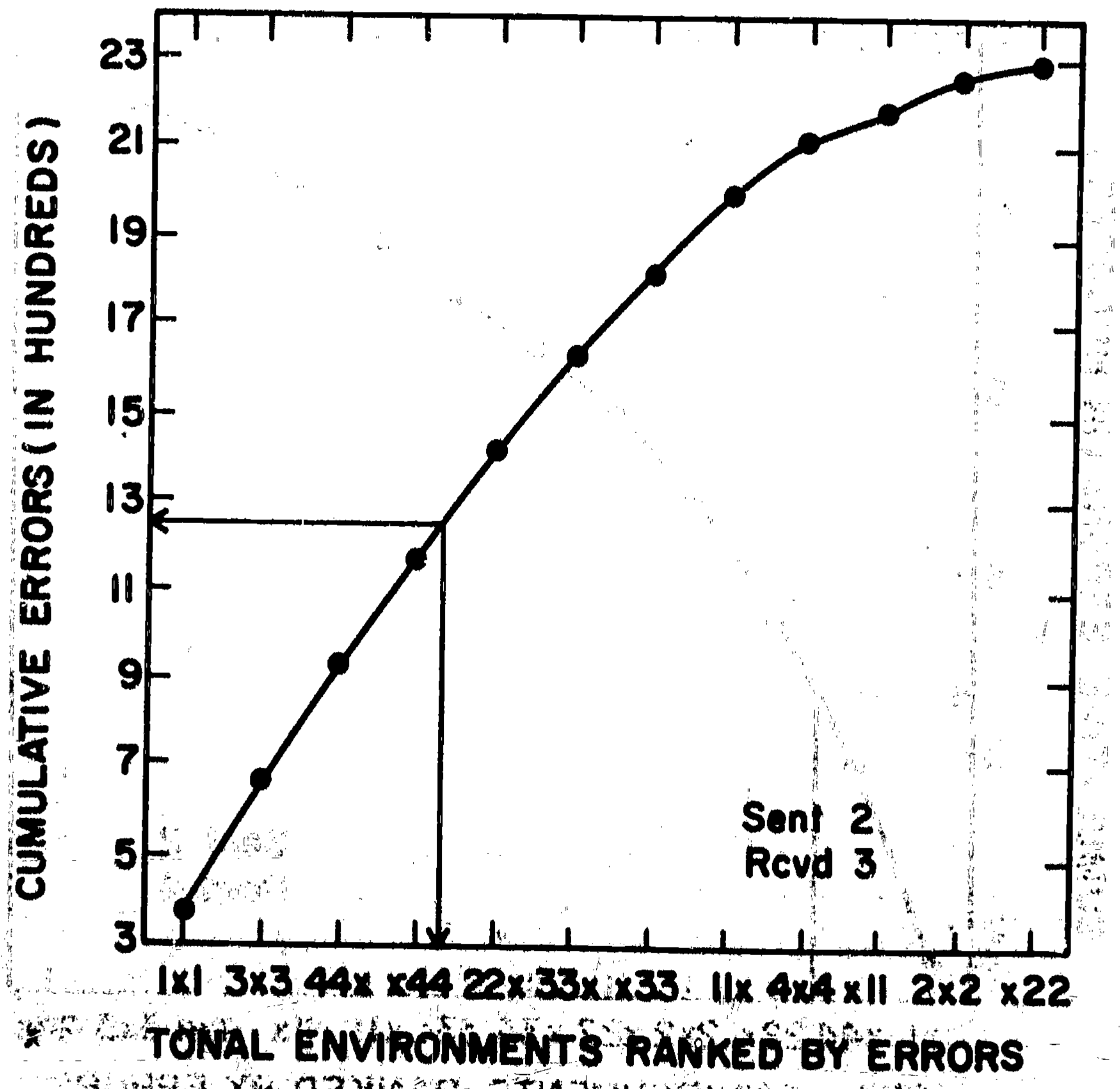

CUMULATIVE ERRORS ALL CONTRASTS
( IN HUNDREDS)
95
85
75
65
55
45
35
25
SENT 3 2 4 2 4 1 5 2 1 4 3 5
RECEIVED 2 3 2 4 5 2 4 1 4 1 5 3
TONES CONTRASTED IN ALL ENVIRONMENTS
RANKED BY ERRORS

Fig. 3



CUMULATIVE ERRORS (IN HUNDREDS)
26
24
22
20
18
16
14
12
10
8
6
4
Sent 3
Rcvd 2
3x3 1x1 44x 22x x44 x33 33x 11x x11 2x2 4x4 x22
TONAL ENVIRONMENTS RANKED BY ERRORS


Fig. 4



CUMULATIVE ERRORS (IN HUNDREDS)
23
21
19
17
15
13
11
9
7
5
3
Sent 2
Rcvd 3
1x1 3x3 44x x44 22x 33x x33 11x 4x4 x11 2x2 x22
TONAL ENVIRONMENTS RANKED BY ERRORS


Fig. 5

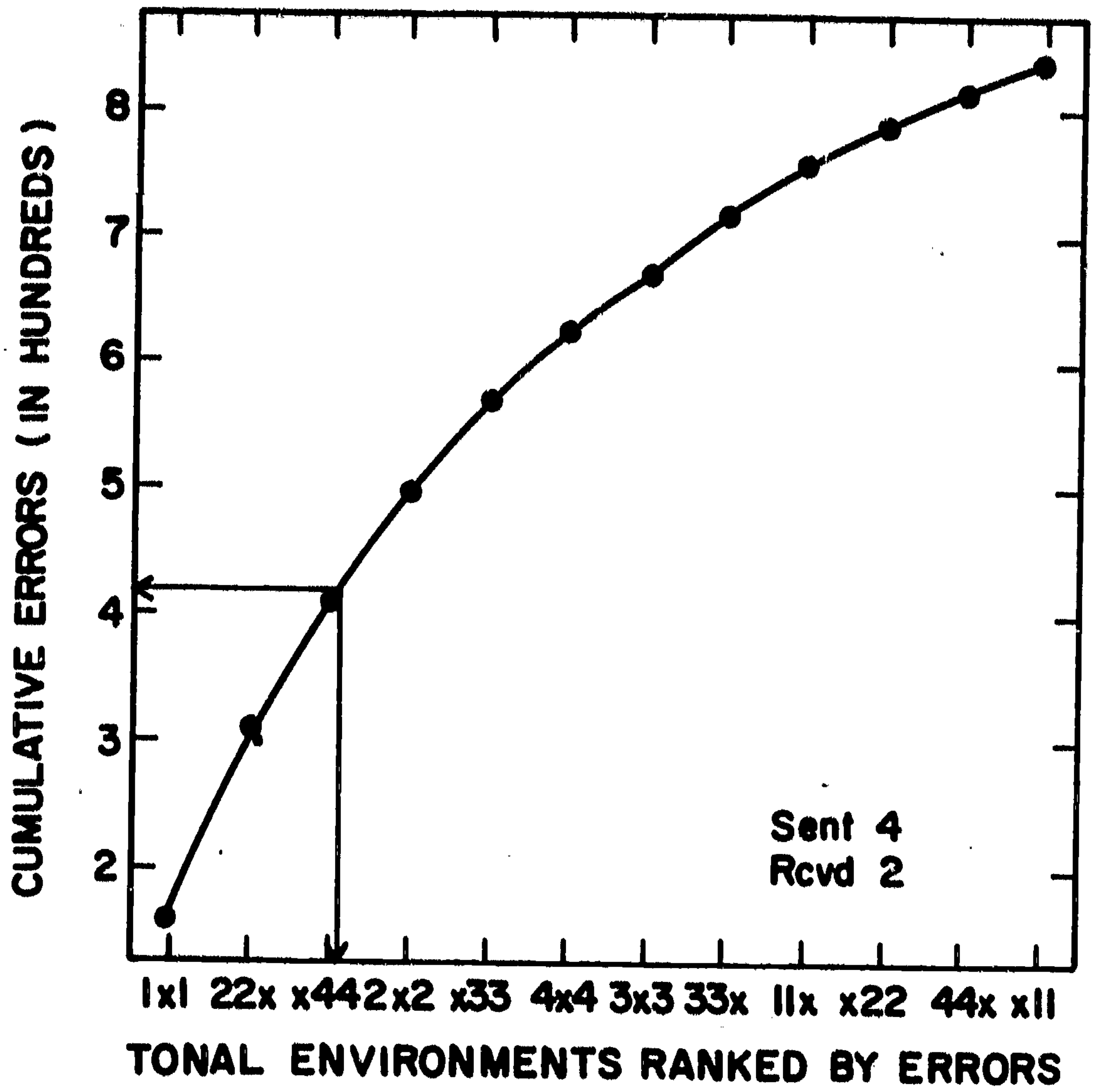

CUMULATIVE ERRORS (IN HUNDREDS)
8
7
6
5
4
3
2
Sent 4
Rcvd 2
Ix1 22x x44 2x2 x33 4x4 3x3 33x 11x x22 44x x11
TONAL ENVIRONMENTS RANKED BY ERRORS

Fig. 6

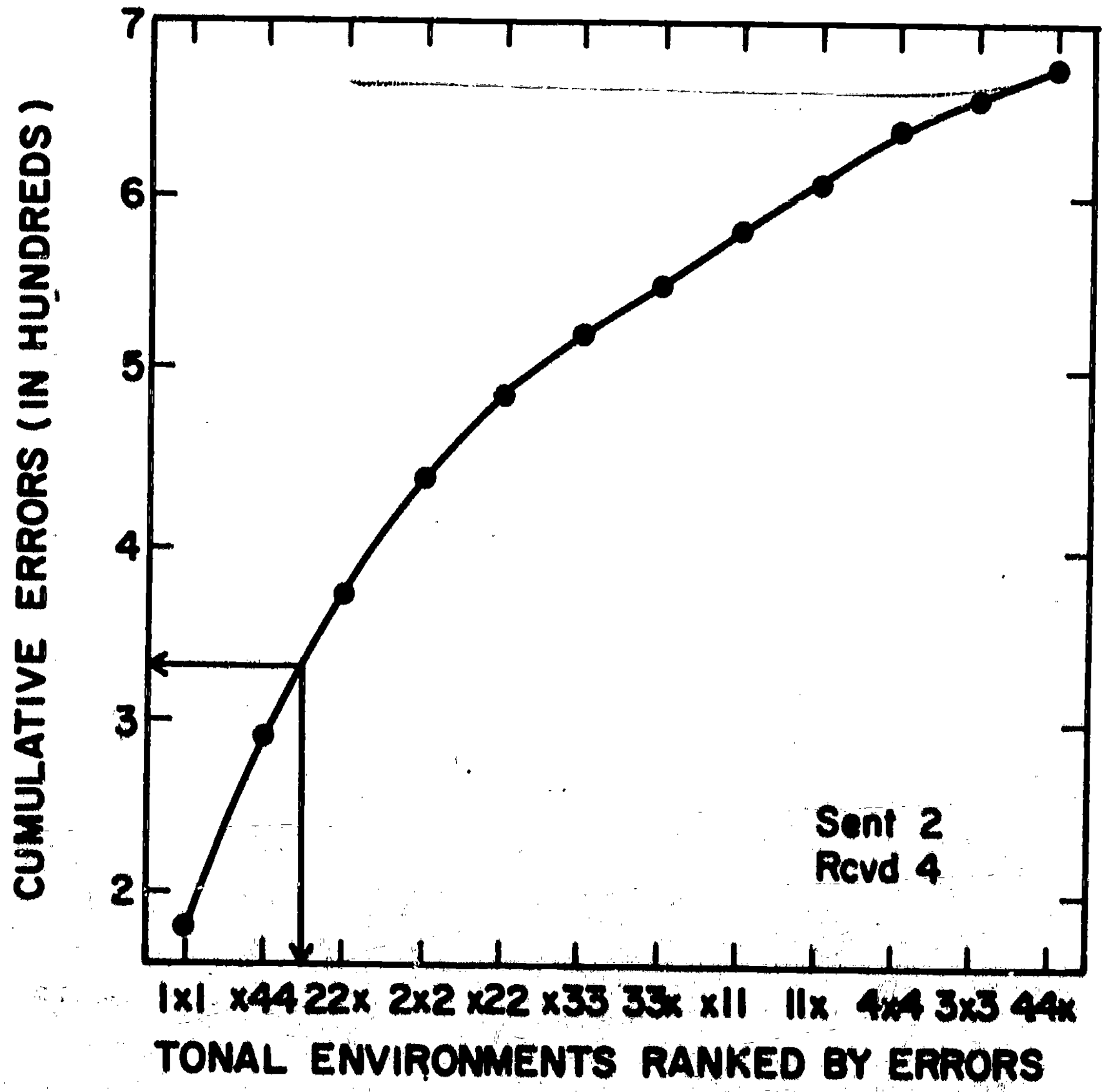

CUMULATIVE ERRORS (IN HUNDREDS)
7
6
5
4
3
2
Sent 2
Rcvd 4
1x1 x44 22x 2x2 x22 x33 33x x11 11x 4x4 3x3 44x
TONAL ENVIRONMENTS RANKED BY ERRORS

Fig. 7

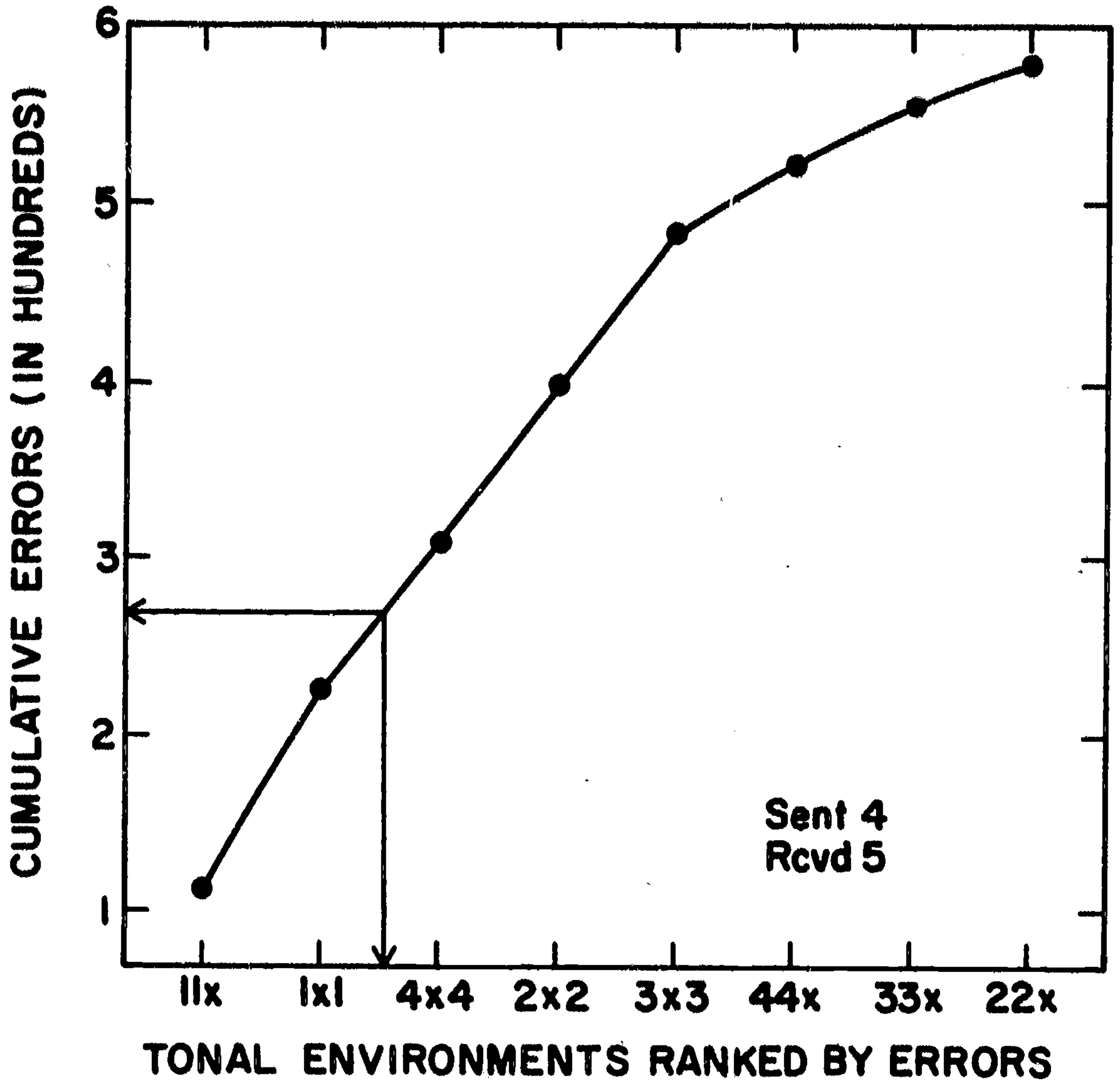



Fig. 8

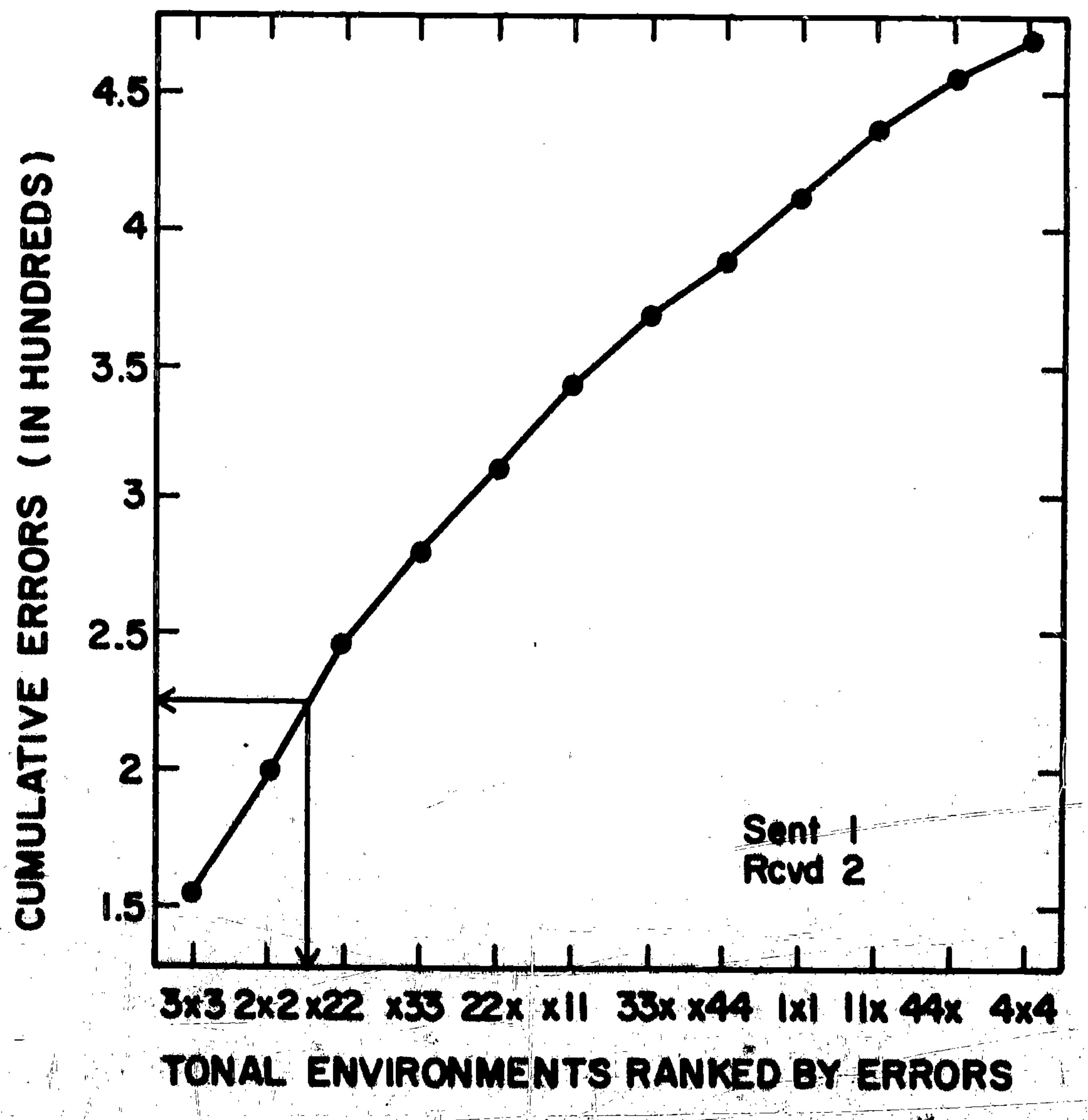



Fig. 9.

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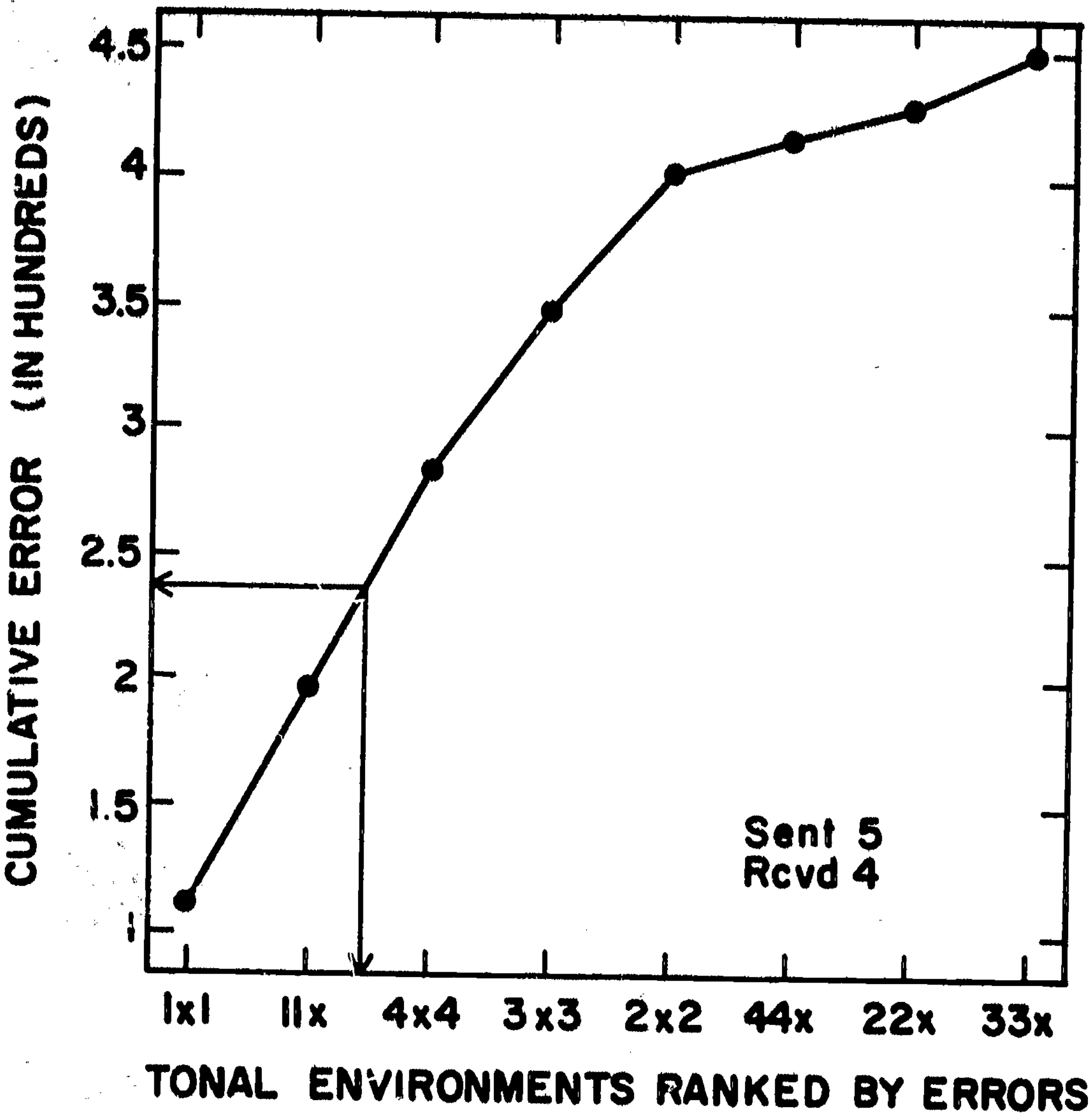
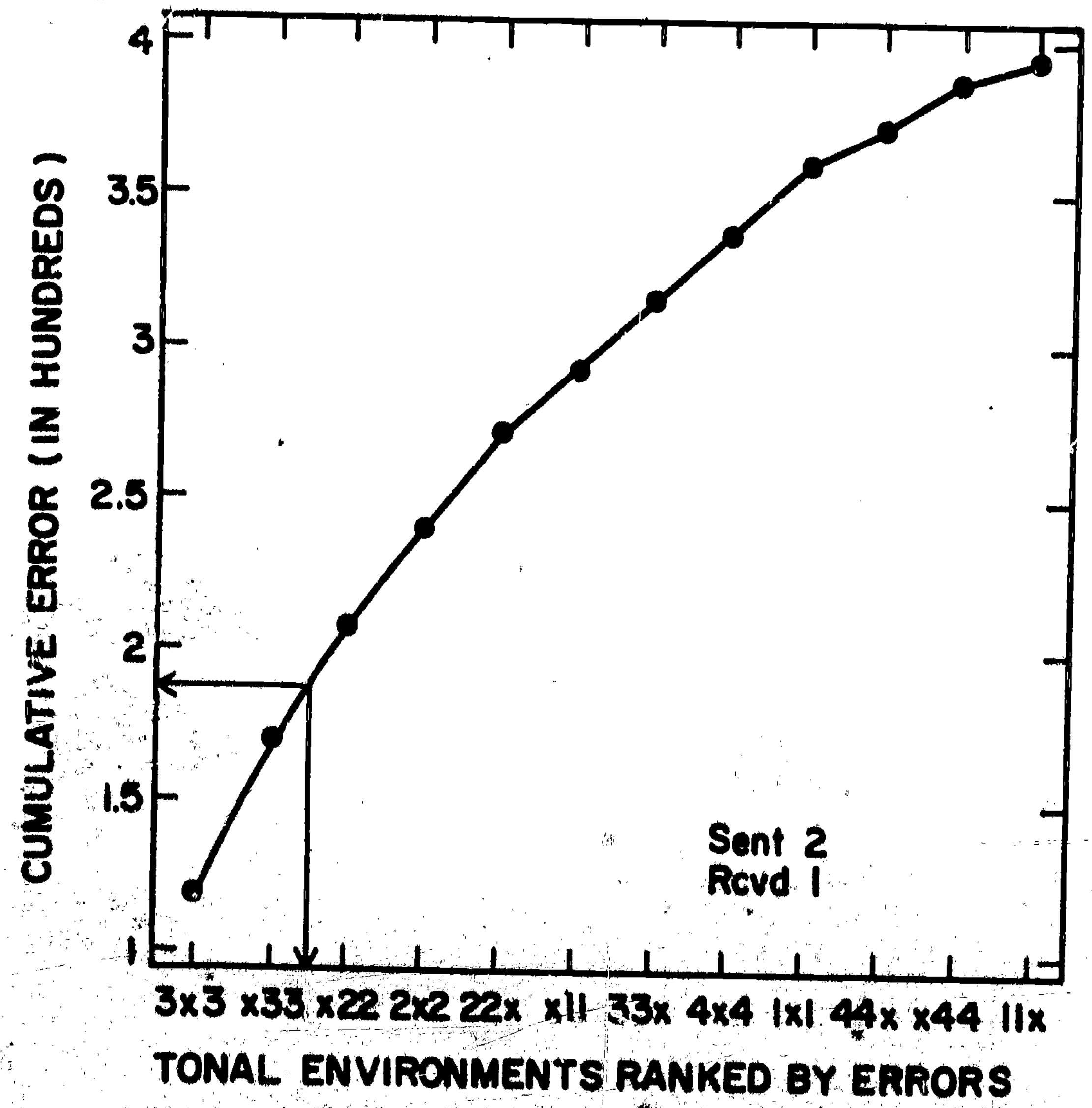


CUMULATIVE ERROR (IN HUNDREDS)
4.5
4
3.5
3
2.5
2
1.5
1
Sent 5
Rcvd 4
1x1 11x 4x4 3x3 2x2 44x 22x 33x
TONAL ENVIRONMENTS RANKED BY ERRORS


Fig. 10



CUMULATIVE ERROR (IN HUNDREDS)
4
3.5
3
2.5
2
1.5
1
Sent 2
Rcvd 1
3x3 x33 x22 2x2 22x x11 33x 4x4 1x1 44x x44 11x
TONAL ENVIRONMENTS RANKED BY ERRORS


Fig. 11

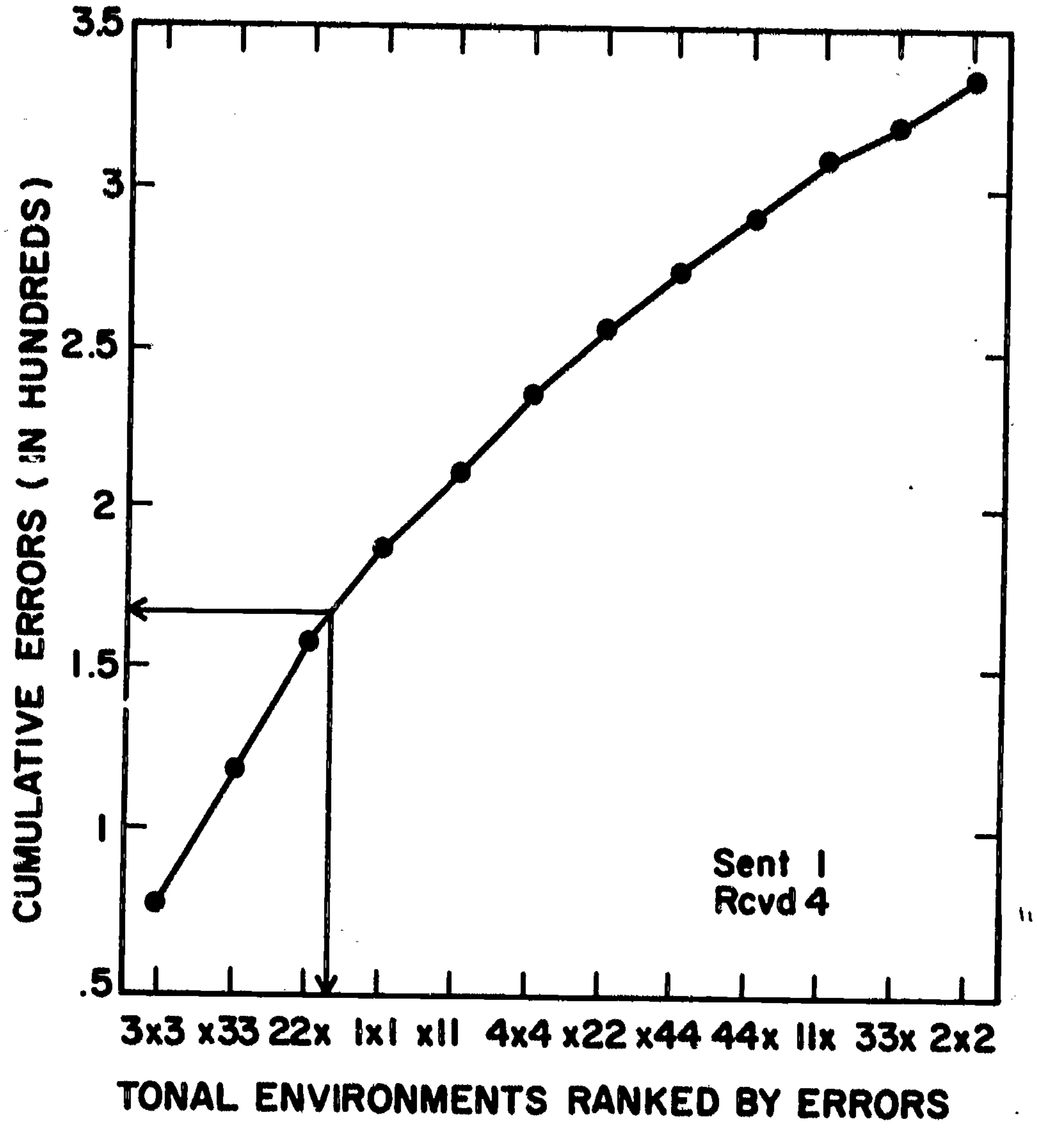



Fig. 12

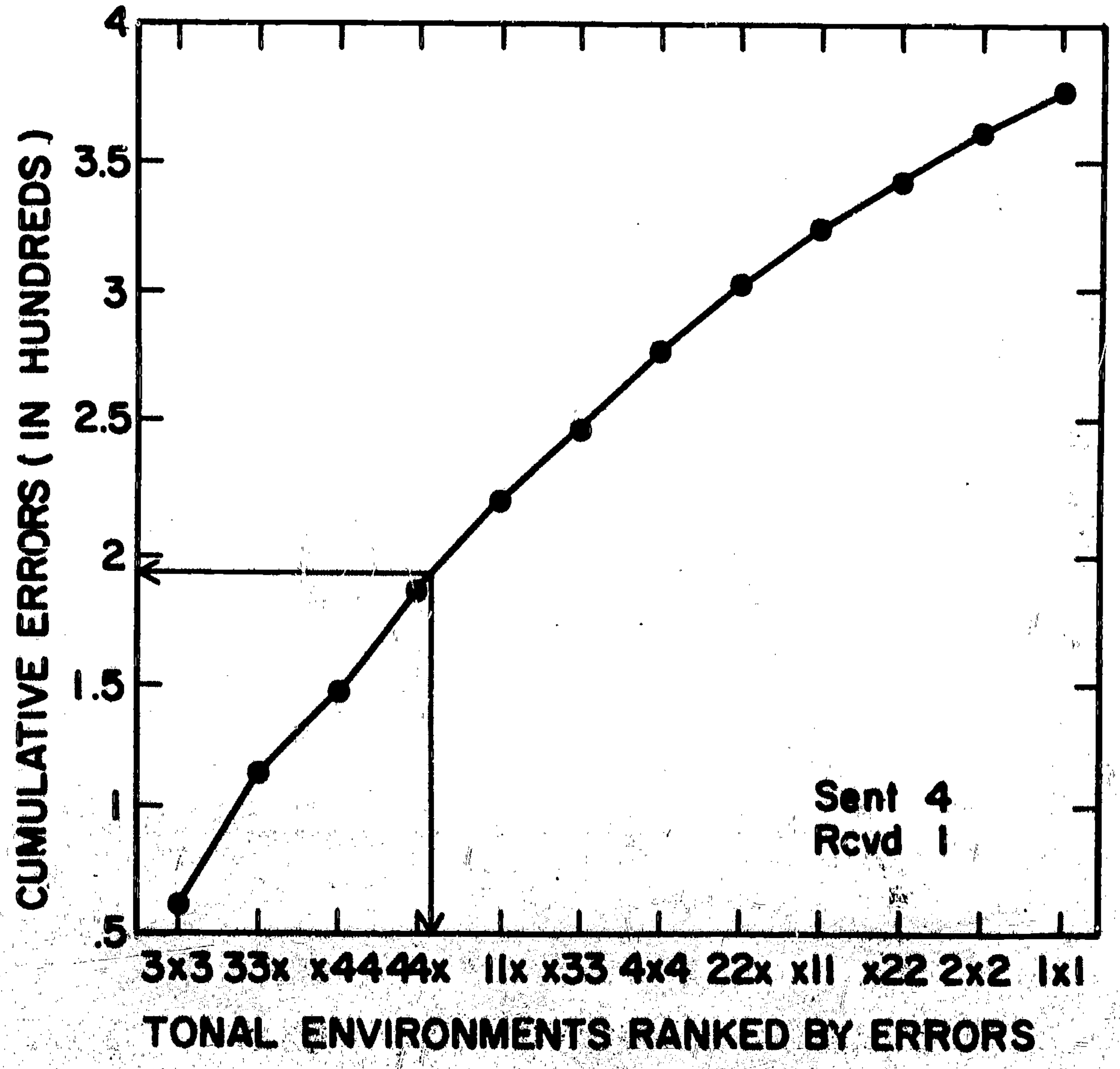



Fig. 13

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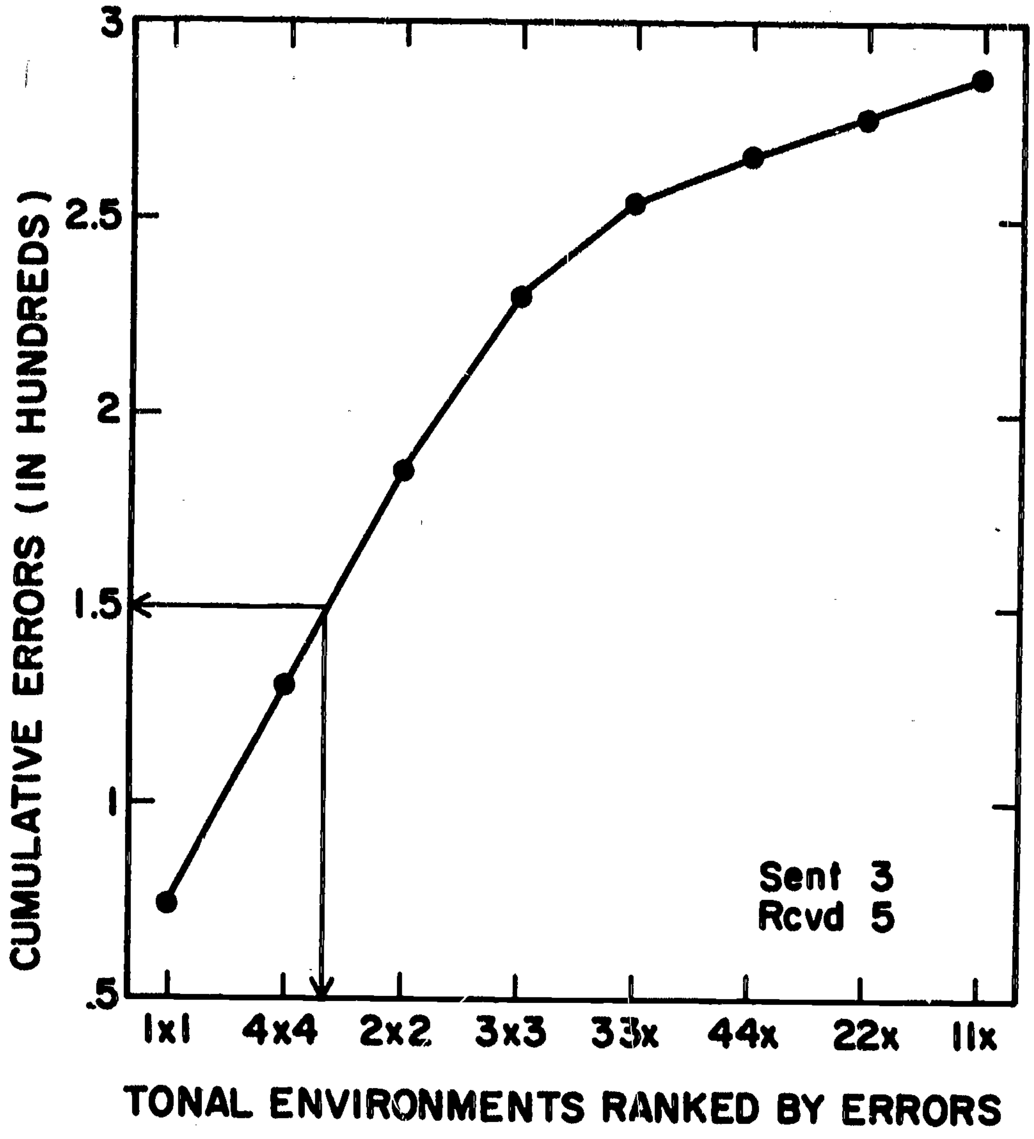
3
2.5
2
1.5
1
.5
CUMULATIVE ERRORS (IN HUNDREDS)
Sent 3
Rcvd 5
1x1 4x4 2x2 3x3 33x 44x 22x 11x
TONAL ENVIRONMENTS RANKED BY ERRORS

Fig. 14

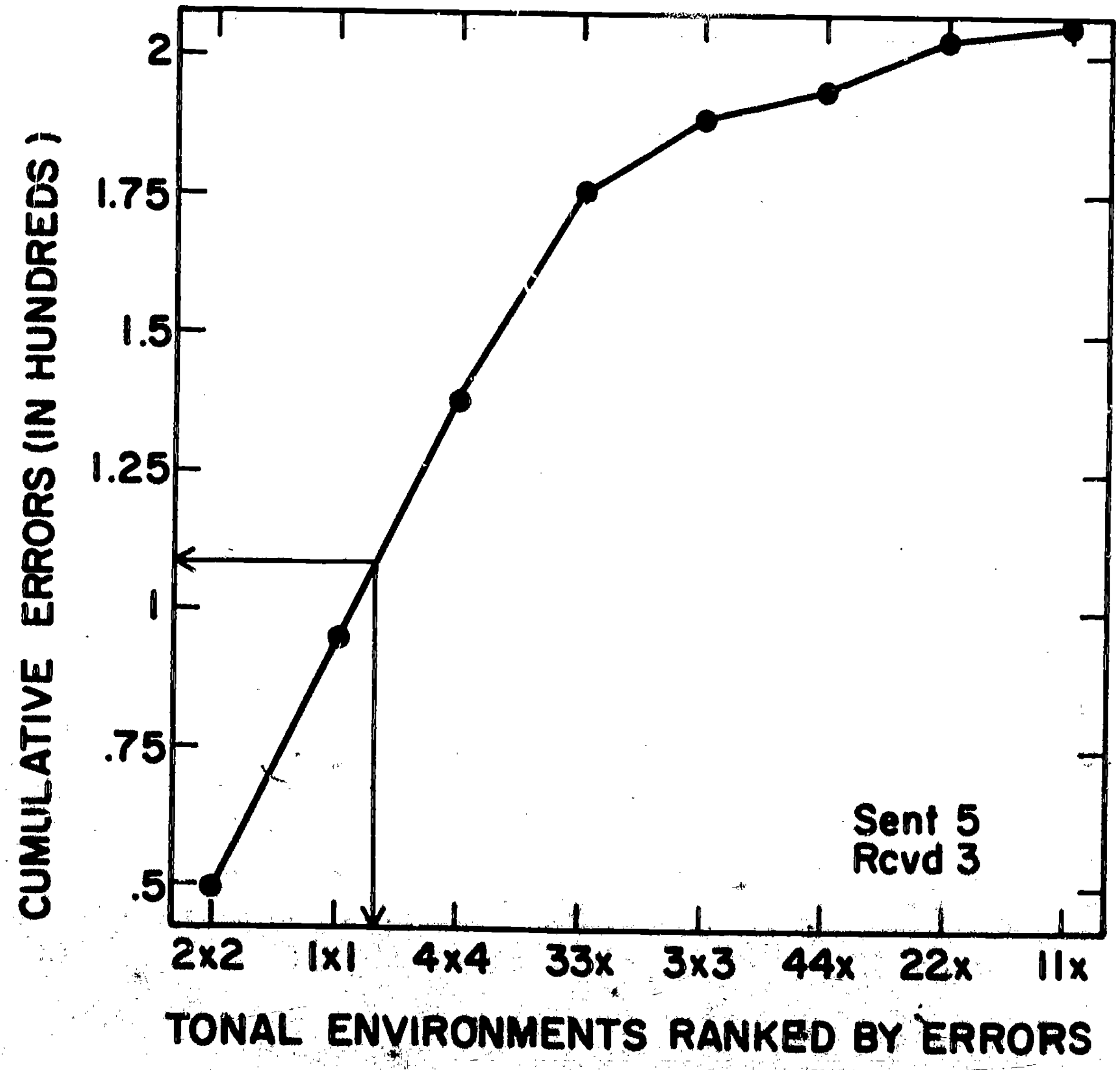
2
1.75
1.5
1.25
1
.75
.5
CUMULATIVE ERRORS (IN HUNDREDS)
Sent 5
Rcvd 3
2x2 1x1 4x4 33x 3x3 44x 22x 11x
TONAL ENVIRONMENTS RANKED BY ERRORS

Fig. 15

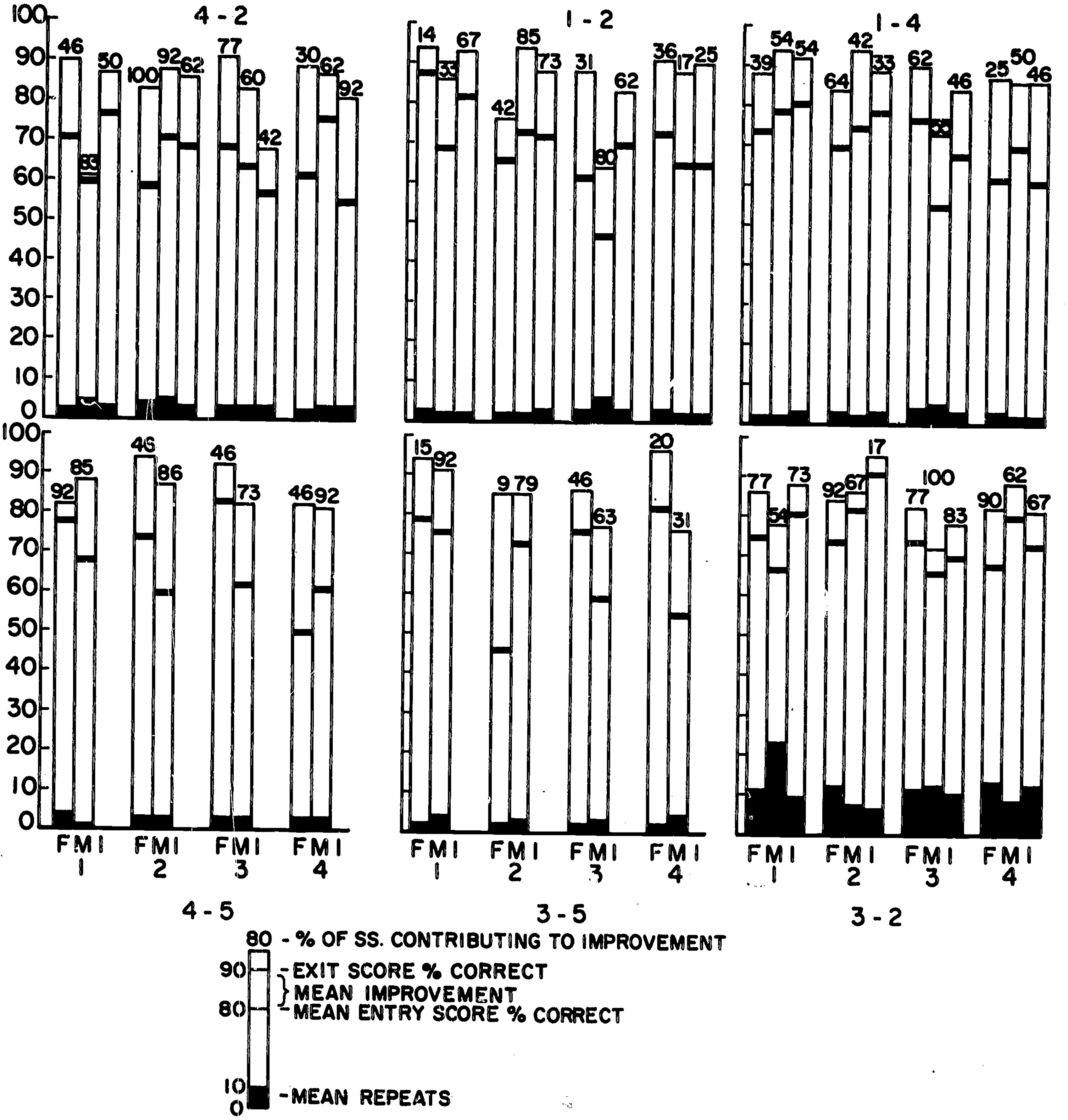
4 - 2
1 - 2
1 - 4
4 - 5
3 - 5
3 - 2
FMI 1
FMI 2
FMI 3
FMI 4
80 - % OF SS. CONTRIBUTING TO IMPROVEMENT
-EXIT SCORE % CORRECT
}MEAN IMPROVEMENT
-MEAN ENTRY SCORE % CORRECT
-MEAN REPEATS

Fig. 16

Selected Annotated Bibliography of Education of the Culturally-Disadvantaged

M. I. Semmel & Carol Midgley

# Selected Annotated Bibliography on Education of the Culturally-Disadvantaged

Melvyn I. Semmel and Carol Midgley
Center for Research on Language and Language Behavior

## Foreword

The growing interest in the education of disadvantaged youth has stimulated the publication of this bibliography. This work is not designed to provide the reader with a comprehensive list of available material on the subject. Rather, it is anticipated that the annotated references will serve to stimulate discussion and further reading of these materials.

The six sections of this bibliography, based on Havighurst's (1964) classification of socially-disadvantaged groups, are:

(1) The Negro and Disadvantaged Group in General,

(2) Rural,

(3) Migrant and Mexican,

(4) Southern Mountain,

(5) Puerto Rican and

(6) Related References.

The following brief summary of major references should serve to orient the reader to the content subsumed by the listings:

Conant (1961) suggests that deprived children, in many cases, need a different educational emphasis than do children of the higher socioeconomic classes. He suggests vocational, job-oriented programs for slum schools. Silberman (1964) and Clark (in Passow, 1963) deplore this attitude. Clark speaks of the "archaic" educational snobbery which permeates this book. He condemns the implication that there are some classes of people who can be

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educated and some who cannot. Silberman states, "The task of the school system is not just to turn out masses of literate men; it is to turn out vast numbers of people educated considerably beyond the level that previous societies demanded of their ruling elite."

Riessman (1963, 1965) calls upon educators to emphasize the positive aspects of the lower class environment. He particularly mentions their humor, comradeship, informality and equalitarianism. "I believe that these disadvantaged youngsters, with their own culture...style and...positives, can help us change the middle class, the school system, and the society." He feels that the schools place too much emphasis on speed and formal language. Speaking of culturally deprived children, he says, "We should remodel the schools to suit their needs." Davis (1949) agrees that the curriculum of most schools is largely middle-class oriented. He believes that reading is over-rated at the expense of reasoning and problem solving. He objects to the "narrow academic stereotyping of the curriculum." Following the same line of thinking, Wolfe (1962) comments on the inadequacy of current school programs and makes specific recommendations for curriculum adaptations. "The present curriculum is based upon traditional activities and skills arbitrarily taken from middle-class culture....Few efforts have been made to address the curriculum to the unique needs of the culturally disadvantaged." Cohn (1959), on the other hand, "cannot agree with Davis in his recommendation that the school should place less weight on verbal-skills training in order not to penalize the lower class child to the extent that it does." She suggests that the schools should identify the handicaps of the lower-class child and plan appropriate instructional programs. Havighurst (1964) disagrees with "sentimental talk about the 'valuable' or 'positive' characteristics of the culture and therefore developing school programs that allow the child to profit from these positive qualities." He goes so far as to say that "There is substantial doubt that the socially disadvantaged children in our big cities have <u>any</u> positive qualities of potential value in urban society in which they are systematically better than the children of families who participate fully in the mass culture." He suggests that more emphasis be placed on readiness programs in the preschool and primary years, rather than on changes in the curriculum.

Iscoe and Pierce-Jones (1964) believe that divergent thinking scores (which have been linked to creative behavior) were higher for a group of Negro children than for a group of white children of similar socioeconomic background. "It may well be that divergent thinking affords the Negro child a better advantage than that afforded by tasks arising out of middle class norms and culture."

Fisher (1961) presents a novel approach to the discussion of the deprived child with his admonition to avoid stereotyping and generalizations. "In some ways the teacher who did not know about social class differences had better attitudes about the varying needs of individuals than the teacher who categorizes people too easily."

Several authors comment on projects which were not expanded or were discontinued, even though the results had proved most favorable (Bienenstok, 1964; Silverman, 1964; Thomas, 1959). A survey of school administrators indicated that a majority of them were unwilling to assume responsibility for a preschool enrichment program until adequate financing was assured ("Preschool Plan is a 'Pipe Dream' Without Funds", 1964). Krugman (1961) and many others point out that compensatory programs may be costly when compared with an average educational program, but represent an over-all saving when one considers the cost of failure, loss of educated man power, delinquency, crime, maladjustment and mental illness.

Levine (1964) comments on some important factors to be considered in newly-integrated classrooms, stating that integration alone, without compensatory measures, could be harmful to deprived children. He makes an interesting prediction of future unrest over segregation in homogenous-ability groupings within the classroom and suggests that attention be given to this problem now.

Keller (1963) writes about the typical experiences of underpriviledged children and explains why, using the same index of socioeconomic status, the social environments of Negroes and white differ.

Passamanick (1963) and others have postulated that there are no innate differences in intelligence between groups and that disparities emerge "as a consequence of differential stimulation and motivation and the relative impoverishment of environment of the lower classes." Passamanick (1958) presents added insight into the question of mental deficiency among deprived groups in his analysis of prematurity and birth complications. He found "a 50% greater risk of prematurity for Negro infants, as contrasted to white, but also a significant association of prematurity and low socioeconomic status in whites. The complications of pregnancy has an even more striking socioeconomic and racial distribution." He theorizes that "except for a few quite rare hereditary neurological defects resulting in mental deficiency, at conception, individuals are quite alike and become different consequent to their experiences."

The theory of critical periods in behavioral development is mentioned in many of the references. Scott(1962) suggests that there are optimal periods for infantile stimulation, for learning, and for the formation of basic social relationships. Hunt (1964) uses this position and Piaget's work, relative to the origin of intelligence, as the basis for his article on the psychological justification for preschool enrichment. Martin Deutsch (1964) supports Hunt's position and emphasizes the need for preschool enrichment programs, stating that there is a need, at the three- to four-year-old level, for "organized and systematic stimulation." Cynthia Deutsch (1964) contends that there is an optimal time for developing auditory discrimination, and that children from a noisy environment may not be able to develop this facility at the critical time and may, therefore, be seriously hampered in their ability to verbalize and to read.

Moore's (1964) articles on school dropouts, in which he argues that promotion and failure to finish school are highly correlated, create speculation about possible alternatives to grade failure. The NEA publication on The School Dropout (1964) presents an "explorative, multi-disciplined approach" to the whole subject, including many novel ideas. For example, Edgar Z. Friedenberg, in an article entitled "An Ideology of School Withdrawal," writes: "My hunch is that a large proportion of the dropouts may be doing what is best for themselves under the atrocious circumstances that exist....It does not follow that most of the students now dropping out would have a better chance - even economically - if they stayed in school....I think [that] the youngsters who drop out are probably, in many ways, a more promising moral resource than those who stay in, and are driven out in part by moral revulsion from the middle class life of the school....We must help them deal with their situation on their terms, with our resources." His criticism of the Higher Horizons Program is also of interest.

West (1965) has summarized and analyzed all doctoral dissertations completed in 1963 whose topics were related to the Negro and Negro education, and concludes that "Creative conceptualizing and careful testing of new methods for meeting recognized educational problems are clearly lacking."

The Negro and Disadvantaged Groups in General

Baynham, Dorsey. The great cities projects. NEA J, 1963, 52, 16-20.

A brief review of some of the programs launched by grants from the Ford Foundation in the Great Cities School Improvement Program is presented. Each city has an individual approach with different emphasis.

Bienenstok, T., & Sayres, W. C. Project ABLE: an appraisal. Albany: Univ. of the State of New York, 1964.

A state sponsored project "for the purpose of identifying and encouraging potential abilities among pupils from culturally deprived groups and from low socioeconomic backgrounds" is described.

Bienenstok, T., & Sayres, W. C. STEP - School to Employment Program. An appraisal. Albany: Univ. of the State of New York, 1964.

An evaluation of a work-study program for potential dropouts was developed in 1961 in seven large city school systems. "Its primary orientation is on individual development and general preparation for work and life rather than on acquisition of a specific vocational skill."

Boone, T. W. A national service program. NEA J, 1963, 52, 28 and 30.

Questions answered by Mr. Boone, Director, Program Development Section, the President's Study Group on a National Service Program concern goals, who will serve, location, etc.

Brazziel, W. F. Portrait of a young migrant. School Rev., 1958, 66, 273-281.

A portrait of a recently graduated southern Negro starting North provides a devastating picture of frustrations and degradations. "In the end the burden of any program to help prospective migrants must fall on the teacher."

Brazziel, W. F., & Gordon, Margaret. Replications of some aspects of the Higher Horizons program in a southern junior high school." J. Negro Educ., 1963, 32, 107-113.

A modified, low budget version of High Horizons was used at a Norfolk, Virginia Junior High School with measurable success.

Brazziel, W. F., & Terrell, Mary. An experiment in the development of readiness in a culturally disadvantaged group of first grade children. J. Negro Educ., 1962, 31, 4-7.

"The purpose of this study was to test the hypothesis that a guidance approach to registration and school induction and an intensified teacher-parent approach to the creation of reading and number readiness would overcome the ravages of the cultural heritage of a disadvantaged group of first grade children." Negro farm families were used.

Brooks, D. J. Helping Cook County's culturally deprived adults. NEA J, 1963, 52, 29-30.

A revolutionary educational program for able-bodied welfare recipients had two goals: to make welfare recipients employable and to improve the home environment for dependent children.

Butts, H. F. Skin color perception and self-esteem. J. Negro Educ., 1963, 32, 122-127.

The hypothesis "That a group of Negro children of both sexes between the ages of 9 and 12 with an impairment of their self-esteem would perceive of themselves less accurately in terms of skin color than children with less self-esteem impairment" was examined with the California Test of Personality and Clark's Coloring Test.

Clark, K. B. Prejudice and your child. Boston: Beacon, 1955.

All children of all races are hurt by racial prejudice. This article discusses the origin of prejudice and methods for combating it.

Clark, K. B. Color, class, personality, and juvenile delinquency. J. Negro Educ., 1959, 28, 240-251.

The higher incidence of juvenile delinquincy among Negros reflects a complex relationship between personality and minority status.

Clark, K. B., & Clark, M. P. Emotional factors in racial identification and preference in Negro children. J. Negro Educ., 1950, 19, 341-350.

Results from the Coloring Test and from the children's spontaneous remarks show a discrepancy between identifying one's own color and indicating one's color preference. "[There is a] need for a definite mental hygiene program that would relieve children of the tremendous burden of feelings of inadequacy and inferiority."

Cohn, W. On the language of lower class children. School Rev., 1959, 67, 435-440.

One should be aware of the positive aspects of lower class speech. "A teacher should understand and respect lower class speech if he wishes to gain the confidence and respect of lower class children." The author calls for an end to linguistic snobbishness.

Conant, J. B. Slums and suburbs. New York: McGraw-Hill, 1961.

The author contrasts two types of neighborhoods and the school facilities in each. He fears that the situation in the big cities is "social dynamite" and that unless immediate and productive measures are taken there will be political and social repercussions. He emphasizes vocational training for the disadvantaged.

Crosby, Muriel. Concept building in human relations education. Educ., 1963, 84, 36-40.

Specific cases where teachers have used concept building to alleviate difficult situations are described. "Concept building is the prime instrument through which education becomes effective."

Cutts, W. G. Reading unreadiness in the underprivileged. NEA J, 1963, 52, 23-25.

Cutts cites deficiencies in listening and speaking among culturally disadvantaged first graders. "Teachers need to approach English language instruction for these children as if they were teaching a foreign language."

Darling, R. L. School library services for the culturally deprived child. Sch. Life, 1963, 46, 18-20.

In spite of the fact that school systems recognize the particular importance of library availability for deprived children, provisions for school libraries in large urban school systems are far below the level of the nation as a whole.

Davis, Allison. Poor people have brains, too. Phi Delta Kappan, 1949, 30, 294-295.

The author contends that the present tests for intelligence are biased, that children of all groups have innate ability, that reading is over-rated in the schools at the expense of reasoning, that homogeneous groupings are discriminatory and "maintain the narrow academic sterotyping of the curriculum."

Della-Doro, D. The culturally disadvantaged: educational implications of certain social-cultural phenomena. Except. Child., 1962, 28, 467-472.

This article treats the change in the city, the problems of the deprived in school, the lack of teacher understanding, and the need for community support.

Deutsch, Cynthia. Auditory discrimination and learning: social factors. Merrill-Palmer Quart., 1964, 10, 277-296.

"It may well be that lower-class children, who live in very noisy environments, do not develop the requisite auditory discrimination abilities to learn to read well - or adequately early in their school careers." A minimum level of auditory discrimination is necessary for the acquisition of reading.

Deutsch, M. Minority groups and class status as related to social and personality factors in scholastic achievement. Soc. appl. Anthrop., 1960, 2, 32.

A detailed study of educational experiences in two elementary schools, one 99 per cent Negro and the other in a white neighborhood of similar socio-economic level showed that Negro children spent less time on academics in school, had significantly more negative self-images, and in many more cases came from broken homes. The study concerned "the manner in which social stress affects motivation, personal aspiration, concepts of self, and learning, and how it differentiates the minority group child from the majority group child of similar background."

Deutsch, M. Facilitating development in the preschool child: social and psychological perspectives. Merrill-Palmer Quart., 1964, 10, 249-263.

Deutsch discusses the theory of critical and optimal periods for many aspects of learning and details the deficits of lower class children which justify preschool enrichment programs.

Fisher, J. J. Who is the lower-class child? J. Educ. Soc., 1961, 34, 309-311.

A new stereotype has emerged concerning the lower-class child, leading to certain assumptions and descriptions which are not valid in all cases and which lead to over-simplification. "It may come to the point where professors have to spend as much time breaking down stereotypes about lower-class groups as they do now about racial and religious groups."

Grambs, Jean D. Understanding intergroup relations. Washington: National Education Association, 1960.

This manual aimed at teachers and parents, seeks to improve intergroup relations. It emphasizes that there are no differences in the innate intelligence of groups and explains how children "learn" prejudice. The role of the schools is discussed.

Gray, Susan W., & Klaus, R. A. Interim report: early training project. George Peabody College and Murfreesboro, Tennessee City Schools, 1963. (Abstract)

Two projects involving special programs for Negro culturally deprived youngsters, which resulted in significant improvement on the Peabody Picture Vocabulary Test, are described.

Groff, P. J. Dissatisfactions in teaching the culturally deprived child. Phi Delta Kappan, 1963, 45, 76.

This discussion of the reasons for high teacher turnover in deprived areas, based on a survey of teachers, offers suggestions for improving conditions.

Havighurst, R. Who are the socially disadvantaged? Yearb. J. Negro Educ., 1964, 33, 210-217.

The author describes the typical socially-disadvantaged child, including family characteristics, personal characteristics, and social group characteristics. He disagrees with those who emphasize the "positive" aspects of lower class culture and who want to develop special school programs based on these aspects. Not a change in school curriculum but, rather, a greater emphasis on reading and arithmetic readiness in the preschool and primary grades is needed.

Hollingshead, A. B. Elmtown's youth. New York: John Wiley, 1949.

The social behavior of adolescents and its relationship to social stratification in a middle western community, 1941-1942, is explored. "The social behavior of adolescents appears to be related functionally to the position their families occupy in the social structure of the community." Of particular interest are Chapter 6 - "The School System" and Chapter 8 - "The High School in Action."

Hopkins, H. B. Talent search projects (1962-3). High Potential (publication of the Bureau of Guidance, Division of Pupil Personnel Service, New York State Education Department), 1964.

"Talent Search Projects are established to assist pupils from deprived background to achieve in school more nearly in keeping with their potential through expanded guidance and related service." A discussion of these projects in 26 secondary schools, involving 1362 pupils, is presented.

Hosley, Eleanor. Culturally deprived children in day-care programs. Children, 1963, 10, 175-179.

The problems involved in meeting the needs of deprived children from low income areas, as experienced by the Day Nursery Association of Cleveland, are reported. Case histories are used to illustrate the need for an enrichment program in these centers.

Hunt, J. M. The psychological basis for using preschool enrichment as an antidote for cultural deprivation. Merrill-Palmer Quart., 1964, 10, 209-248.

Hunt explores the concepts that have hampered the development of preschool enrichment and discusses the necessary ingredients in an enrichment program. He gives the basis in psychological theory (particularly Piaget) and the support from psychological research for such a program.

Intergroup relations. A resource handbook for elementary school teachers, grades 4, 5, & 6. Albany: Univ. of the State of New York, 1963.

"This Handbook suggest methods and techniques helpful to teachers in using literature, film and a host of community resources to provide a better knowledge and understanding of these groups." Suggestions for integrating information about the Negro with day-to-day teaching in the classroom are provided.

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Iscoe, I., & Pierce-Jones, J. Divergent thinking, age, and intelligence in white and Negro children. Child Develpm., 1964, 35, 785-797.

The authors link (by citing research) creative behavior to divergent thinking. Using the Unusual Uses Test on 267 children from segregated schools, they conclude, "Overall, these divergent-thinking scores were significantly higher for Negroes."

John, Vera P. The intellectual development of slum children: some preliminary findings. Amer. J. Orthopsychiat., 1963, 33, 813-822.

"This study examines certain patterns of linguistic and cognitive behavior in a sample of Negro children from various social classes. Three major levels of language behavior - labeling, relating, categorizing - were analyzed. Consistent class differences in language skills were shown to emerge between groups of Negro children of different socioeconomic class."

Johnson, T. A. Neighborhood schools or integrated schools. Presented to the National Association of Intergroup Relations Officials, Cleveland, November, 1963. Albany: State Education Department, 1964.

New York State has faced the issue of racial imbalance in the schools: "The question is no longer whether we should do anything, but rather what is the best plan for a local school system."

Kaplan, B. A. Talent searching in New York State. A review of selected projects and studies. High Potential, 1961.

In March, 1960, the Bureau of Guidance inaugurated a talent-search project. Five of these projects are discussed in some detail: Yonkers, Utica, Rochester, New Rochelle, White Plains. The Bureau is now encouraging pilot projects in up-state rural areas.

Kaplan, B. A. Issues in educating the culturally disadvantaged. In Alice Crow and L. D. Crow (Eds.) Vital issues in American education. New York: Bantam Books, 1964.

The author is the Coordinator of Project ABLE, New York State Department of Education. He discusses who are the disadvantaged, programs that have been instituted, financial support available, the role of the "Hawthorne Effect", the importance of respecting cultural differences.

Keller, Suzanne. The social world of the urban slum child: some early findings. Amer. J. Orthopsychiat., 1963, 33, 823-831.

"This paper compares selected aspects of the after-school and home activities of a sample of poor Negro and Caucasian children currently attending first and fifth grades in the N.Y. City public schools. Discussion centers on factors that distinguish the family life, self-images and recreational activities of these children from those of their middle class peers, with whom they must compete in school."

Knoll, E. Ten years of deliberate speed. Amer. Educ., 1965, 1, 1-3.

An assessment of the progress made since the 1954 Supreme Court decision on segregated schools finds desegregation progressing very slowly but "judicial, legislative and other pressure have been stepping up the pace." Knoll examines Title IV and VI of the Civil Rights Act of 1964. A trend in recent court decisions shows local school authorities may but do not have to take racial factors into account in seeking to promote balanced enrollment.

Krugman, M. The culturally deprived child in school. NEA J, 1961, 50, 4.

The author is Associate Superintendent of Schools, N.Y. City. He discusses problems of deprived students and the positive aspects of New York City's Higher Horizons Project. He concludes that schools can compensate for the meager backgrounds of deprived children.

Kvaraceus, W. C., & Miller, W. B. Delinquent behavior: culture and the individual. Washington: National Education Association, 1959.

"A carefully selected six-man team of experts, engaged in a cooperative endeavor to provide the basis for a comprehensive theoretical statement" prepared a report concerned with the theory of delinquency on which to base a realistic and meaningful program.

Larson, R., & Olson, J. L. A method of identifying culturally deprived kindergarten children. Except. Child., November, 1963. (Abstract)

Nineteen characteristics which differentiated the culturally deprived child from the middle class child in a study in Racine, Wisconsin are discussed and grouped.

Levine, D. U. Integration: reconstructing academic values of youths in deprived areas. Clearing House, 1964, 39, 159-162.

At the elementary level, integration may spur competition but at the secondary level a compensatory program may be more effective. The article lists specific activities at the secondary level to promote scholastic development.

Mackintosh, Helen K., & Lewis, Gertrude M. Headstart for children in slums. Amer. Educ., 1965, 1, 30-32.

A discussion of preschool programs for slum children as a result of a visit to sixteen city projects. Programs for the very young are needed in the most severely deprived areas if the youngsters are to have any chance for a positive school experience.

Mayer, M. Schools, slums and Montessori. Commentary, 1964, 37, 35-39.

The particular appropriateness of a Montessori program for slum children is considered. He reviews the original Montessori program and its subsequent growth and development. "Nobody who has looked seriously at these problems doubts that first-rate nursery schools could help, and the Montessori model is the best we have."

Milner, Esther. A study of the relationship between reading readiness in grade one school schildren and parent-child interaction. Child Develpm., 1951, 22, 95-112.

Children were given a group of tests plus extensive interviewing to determine the relationship between reading ability and certain patterns of parent-child interaction. Certain lacks in child-parent relationships correlated with lower-class homes and with lowered reading ability. The author gives suggestions to schools for overcoming these deficiencies. "The Writer cannot agree with Davis, however, in his recommendation that the school should place less weight on verbal skills training."

Montague, D. O. Arithmetic concepts of kindergarten children in contrasting socioeconomic areas. Elem. School J., 1964, 64, 393-397.

Children in the seventh month of kindergarten from a high and from a low socioeconomic area were tested for arithmetic concepts. Those from the low area tested significantly lower. The author suggests the need for a much lower pupil-teacher ratio for deprived children and for a program to broaden their experiences.

Moore, J. W. Reducing the school dropout rate--a report on the Holding Power project. Albany: Univ. of the State of New York, 1964.

A six-year study of school and pupil characteristics and outcomes in relation to "holding power" was carried out by 89 school districts. Characteristics of dropouts were recorded and compared. The importance of adequate guidance programs and of parental and community involvement is stressed.

Moore, J. W. How high schools can reduce their dropout rate. An action guide. Albany: Univ. of the State of New York, 1964.

This guide was prepared so that others can benefit from the information and experiences of New York State's Bureau of Guidance Holding Power Project,

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1954-60. An outline of the procedures and techniques that were most successful includes very specific procedures for identifying future dropouts and for keeping pertinent records, including charts and forms.

National Education Association, Educational Policies Commission. Education and the disadvantaged American. Washington: Author, 1962.

This 40-page pamphlet discusses in general terms the problems of the culturally deprived and the role of the school to help alleviate them. Special characteristics of the school program, school staff, school administration, and facilities are detailed.

National Education Association, Educational Research. School programs for the disadvantaged. Washington: Author, 1965, No. 1.

This report contains descriptions of 44 projects and experiments in educating the disadvantaged. The projects are listed alphabetically by state.

Newton, Eunice Shaed. Verbal destitution: the pivotal barrier to learning. J. Negro Educ., 1960, 29, 497-499.

The article describes the Bennett College Compulsory Reading Skills Program and a study of ten of the most seriously retarded readers in the group to determine their precollegiate personal and educational environments.

Newton, Eunice Shaed. The culturally disadvantaged child in our verbal schools. J. Negro Educ., 1962, 31, 184-187.

The author discusses lack of language fluency as one of the major academic problems. She suggests a specific language program to help the "verbally destitute" children, and contends that, without such a program, deprived children are headed for "academic disaster".

New York State Bar Association, Committee on Civil Rights. Racial imbalance in the public schools: the current status of federal and New York law. Albany: New York State Bar Association, October, 1964.

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The article reviews current attempts to reduce defacto segregation. Legal resistance has been based on the view that it is a violation of the Constitution to consider the factor of race for the purpose of school assignments. A summary of pertinent cases and decisions and an enumeration of current legal principles are presented.

Passamanick, B. The contribution of some organic factors to school retardation in Negro children. J. Negro Educ., 1958, 27, 4-9.

Prematurity and the complications of pregnancy are related to mental deficiency and are much more prevalent among the lower socioeconomic classes. The author theorizes that "except for a few quite rare hereditary neurological defects resulting in mental deficiency, at conception, individuals are quite alike and become different consequent to their experience."

Passamanick, B., & Knobloch, Hilda. Early language behavior in Negro children and the testing of intelligence. J. abnorm. soc. Psychol., 1955, 50, 401-402.

This study of the relationships between a white examiner and Negro children concludes "that racial awareness plays a significant role during the examination process for the assessment of development, even in the early preschool years."

Passow, A. H. (Ed.) Education in depressed areas. New York: Bureau of Publications, Teachers College, Columbia University, 1963.

This book includes 15 papers which resulted from a two-week Work Conference on Curriculum and Teaching in Depressed Urban Areas at Columbia University in 1962. The papers cover schools in depressed areas, psychological aspects, sociological aspects, teachers, and school programs. A bibliography is included.

Preschool plan is a "pipe dream" without funds. Nat. Sch., 1964, 74, 48.

The results of an opinion poll of school administrators, which asked, "Should it be a function of school districts to start programs designed to compensate culturally deprived childred, at preschool age levels, so that they can begin first grade on a relatively equal footing with other children?" The respondents, who answered Yes - 46 per cent, No - 53 per cent, contend that the issue is not one of responsibility but one of financing.

Riessman, F. The culturally deprived child. New York: Harper & Brothers, 1962.

A comprehensive study of the deprived child, this book includes a review of the literature in this area. Particular emphasis is placed upon teacher attitudes and upon promoting a respectful rather than a patronizing attitude toward these groups.

Riessman, F. Some suggestions for teaching the culturally deprived. NEA J, 1963, 52, 20-22.

He asserts that attitudes of teachers are more important than any methods in dealing with deprived children. Suggestions are offered to teachers for day-to-day routines, where to place emphasis, how to improve deficits.

Riessman, F. Culturally deprived child: a new view. School Life, 1963, 45, 5-7.

The author emphasizes the positive aspects of lower class environment. He condemns the middle class schools for their emphasis upon speed, formal language. "There is only one value of the lower socioeconomic groups that I would fight in the school - their anti-intellectual attitude."

Riessman, F. The lessons of poverty. Amer. Educ., 1965, 1, 21-23.

We are constantly criticizing our middle class schools and yet we idealize them when we speak of the deprived. "I believe that these disadvantaged youngsters, with their own culture and their own style and their own positives, can help us change the middle class, the school system, and the society." The author mentions a "tremendously encouraging" Federal Government project supporting several institutes for the training of teachers of the disadvantaged.

Rousseve, R. J. Teacher of culturally disadvantaged American youth. J. Negro Educ., 1963, 32, 114-121.

Superintendents, principals and counselors were asked by questionnaire to record their perceptions of the cultural problems of Negro youths. "It was a most uninviting and sordid picture that was uncovered in this investigation." The author believes that the greatest need is for upgrading the teachers.

Savitzky, C. Job guidance and the disadvantaged. Clearing House, 1964, 39, 156-158.

Specific and detailed school programs to prepare students for employment are described. The author contends the programs for dropouts are being severely limited by difficulties in securing adequate staff.

Schreiber, D. [Ed.] The school dropout. Washington: National Education Association, 1964.

Here are papers by educators and social scientists covering all aspects of the dropout problem. "A symposium engaging the serious intellectual efforts of persons with different disciplinary perspectives" that include some rather unusual approaches.

Sexton, Patricia. Education and income: inequalities in our public schools. New York: Viking, 1960.

A study of the relationship between economic status and quality of education in an industrial city in the Mid-West finds that deprived children receive in every way an education inferior to that received by children in higher economic groupings.

Shriver, S. What the poverty program will mean to your schools. Sch. Management, 1964, 8, 66-70.

A question and answer interview with Shriver, the director of the program, concerned the provisions of the act that affect the schools. "What programs

can be supported? How much will they be controlled by the Government? How soon can the programs get under way? How will the schools be asked to help?" are among the questions discussed.

Silverman, C. The Negro and the school. In Crisis in black and white. New York: Random House, 1964.

There is a need for compensatory education for the deprived on an extensive basis. "The public school offers the greatest opportunity to break down the cultural barrier that helps block the Negro's advance into the main stream of American life." In many cases the projects work but nothing much happens as a result. The author deplores the emphasis on vocational education.

Spears, H., & Pivnick, I. How an urban school system identifies its disadvantaged. Yearb. J. Negro Educ., 1964, 33, 245-253.

Compensatory education is utilized in San Francisco and therefore the problem of identifying deprived students was explored. Lists of the general characteristics of these students are included and some of the compensatory techniques are described.

Thomas, D. R. Oral language sentence structure and vocabulary of kindergarten children living in low socioeconomic urban areas. Ann Arbor: University Microfilms, Inc., 1962. (Abstract)

A group of lower class children showed a deficiency in language development when compared with upper social status groups, in the amount, maturity, and correctness of oral expression. In similar socioeconomic groups there was evidence of some deficiency in the oral language development of Negroes but there were far more similarities than differences.

Tomlinson, H. Differences between preschool Negro children and their older siblings on the Stanford-Binet Scales. J. Negro Educ., 1944, 13, 474-479.

The mean I.Q. for the group was 10.4 points below the general norm for white children. The mean I.Q. for the preschool children was significantly higher than that of the older group, suggesting an increasing inferiority in test performance with increase in age.

The University of the State of New York, The State Education Department. Suggestions for developing intercultural understanding. Albany: Author, 1963.

These suggestions, addressed to educators, are designed to promote good intergroup relations. The document includes a bibliography and film suggestions.

U. S. Office of Education, Elementary Schools Section. The elementary school in the city. Sch. Life, 1963, 45, 26-29.

A conference report of efforts underway to help deprived children in Delaware, Detroit, Baltimore, and Atlanta is presented. Methods for attracting good teachers are discussed.

West, E. H. Summary of research during 1963 related to the Negro and Negro education. J. Negro Educ., 1965, 34, 30-38.

In a summary and analysis of 58 doctoral dissertations on Negro education, completed at 34 institutions in 1963, the author finds, "None of these studies appears to alter previously accepted views in any substantial way."

Whipple, Gertrude. Multicultural primers for today's children. Educ. Dig., 1964, 29, 26-29.

High praise is given for Detroit's preprimers illustrated with multi-racial characters. All the children in the study indicated a marked preference for them, especially members of deprived groups.

Whiteman, M. Intelligence and learning. Merrill-Palmer Quart., 1964, 10, 297-309.

Several concepts related to intelligence are examined and their implications in an enrichment program discussed.

Wiltse, K. T. Orthopsychiatric programs for socially deprived groups. Amer. J. Orthopsychiat., 1963, 33, 806-813.

Financial deprivation and social deprivation go hand in hand. "This paper explores some of the implications for parents and children of life on the Aid to Dependent Children Program and develops the thesis that ADC offers a significant but little-used vantage point from which mental health professions can grasp what social deprivation really means in the lives of people."

Wolfe, Deborah. Curriculum adaptations for the culturally deprived. J. Negro Educ., 1963, 31, 139-151.

The author discusses who are the deprived and what are their particular curriculum needs. "Few efforts have been made to address the curriculum to the unique needs of the culturally deprived." For example, materials should start with simple situations drawn from the daily life of the pupil.

## Rural Disadvantaged

Boger, J. H. An experimental study of the effects of perceptual training on group I.Q. test scores of elementary pupils in rural ungraded schools. J. educ. Res., 1962, 46, 43-52.

Children in a rural school tested lower than average on I.Q. tests. They were provided with stimulating visual material and exercises. After this training there was a significant increase in their scores.

Isenberg, R. M. The rural disadvantaged. NEA J, 1963, 52, 27.

Rural school systems must take direct steps to develop programs for their disadvantaged comparable to the experimental efforts underway in many cities."

Morse, A. D. Breaking the rural barrier: the Catskill Project. In Schools of tomorrow - today. New York: Doubleday, 1960.

A description is offered of New York State's "Catskill Area Project in Small School Design", an experimental program to lift the level of rural education. An appendix of related experimental programs is included.

## Migrant and Mexican Disadvantaged

Caplan, S. W., & Ruble, R. A. A study of culturally imposed factors on school achievement in a metropolitan area. J. educ. Res., 1964, 58, 16-21.

Reasons why the Spanish-Americans have not experienced upward mobility are discussed along with the factors that affect the achievement of bilingual students.

Sutton, Elizabeth. Knowing and teaching the migrant child. Washington: National Education Association, 1962.

This comprehensive report, including a list of selected references, describes a special project conducted in two counties, one in Virginia and one in Florida, on the education of the children of agricultural migratory workers.

Thomas, D. R., & Stueber, R. K. No desk for Carmen. Teachers Coll. Rec., 1959, 61, 143-150.

The problems of the migrant of Mexican ancestry are discussed. Migrant projects often flourish and then must be stopped because of lack of funds. The need for an Annual Worker Plan and for consideration among states is argued.

## Southern Mountain Disadvantaged

O'Hara, J. Disadvantaged newcomers to the city. NEA J, 1963, 52, 25-27.

The problems of the rural migrant, particularly those from the Southern Appalachians, are discussed. "Despite what appears to be a negative attitude toward formal education, these migrant children can be motivated to learn."

## Puerto Rican Disadvantaged*

Archdiocese of New York, Catholic Youth Organization. The leisure time problem of Puerto Rican youth in N.Y.C.: a study of the problems of selected group work programs. New York: Author, 1953.

Berle, Beatrice Bishop. 80 Puerto Rican families in New York City. Heath and disease studied in context. New York: Columbia University Press, 1958.

An intensive study is reported of tne health and related problems of 80 Puerto Rican families living in a New York City slum. The anthropological study, Up From Puerto Rico, by Elena Padilla examines some of the same families and others.

Braestrup, P. New York's Puerto Ricans. New York Herald Tribune, October 16-18, 20, 21, 1957. (Series of five articles)

A cold new world. October 16, pp. 1, 19.

A search for a job, a place of my own. October 17, p. 2.

They live in squalor at Park Avenue rent. October 18, p. 10.

Ebb and flow of their migration held barometer of U. S. economy. October 20, p. 40.

Their position is improving. October 21, p. 14.

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*Abstracted from an Annotated Bibliography by Dr. Clarence Senior, Former Chief, Migration Division, Commonwealth of Puerto Rico.

Brooklyn Council for Social Planning. Report on survey of Brooklyn agencies rendering services to Puerto Ricans. New York: Author, 1953.

Commonwealth of Puerto Rico, Department of Labor, Bureau of Labor Statistics. Characteristics of passengers who travelled by air between Puerto Rico and the United States. San Juan: Author, 1956.

This is a continuing series of quarterly and annual reports of statistical data.

Commonwealth of Puerto Rico, Department of Labor, Migration Division. Helping Puerto Ricans help themselves. New York: Author, 1958.

Commonwealth of Puerto Rico, Department of Labor, Migration Division. A summary in facts and figures: 1. Progress in Puerto Rico. 2. Puerto Rican migration. New York: Author, 1959.

Basic statistics on Puerto Rico and the migration are presented. New editions are issued at least once a year.

Community Council of Greater New York, Research Department. Manhattan communities: Summary statements of population characteristics. New York: Author, 1955.

Covello, L., & D'Agostino, G. The heart is the teacher. New York: McGraw-Hill, 1958.

This is an autobiography of a teacher who has devoted most of his life to helping underprivileged children, mostly in East Harlem. Dr. Covello is now Educational Consultant to the Migration Division.

Dworkis, M. B. (Ed.) The impact of Puerto Rican migration on governmental services in New York City. New York: New York University Press, 1957.

Brief chapters on housing, employment, welfare, education, health and hospital services, and crime and delinquency make up this report.

Elam, Sophie. Acculturation and learning problems of Puerto Rican children. Teachers Coll. Rec., 1960, 61, 258-264.

Case histories are used to illustrate the vast problems of Puerto Rican children in our cities. The schools have not been prepared to help them. "It will be through the school, together with many other agencies and with a new view to the totality of the child and his family, that the acculturation will come about."

Finocchiaro, Mary. Puerto Rican newcomers in our schools. J. educ. Soc., 1954, 28, 157-166.

Fitzpatrick, J. P. The integration of Puerto Ricans. Thought (Fordham University quarterly), 1955, 30, 402-420.

Gittler, J. B. (Ed.) Understanding minority groups. New York: John Wiley and Sons, 1956.

Hanson, E. P. Transformation: the story of modern Puerto Rico. New York: Simon and Schuster, 1955.

Katz, I. Conflict and harmony in an adolescent interracial group. New York: New York University Press, 1956.

Mills, C. W., Senior, C., & Golden, Rose Kohn. The Puerto Rican journey. New York: Harper, 1950.

This is a study of Puerto Ricans in New York City based on a survey of 5,000 Puerto Ricans living in Harlem and in the Morrisania Section of the Bronx.

Montag, H., & Finocchiaro, Mary. Guidance and curriculum for Puerto Rican children. High Points (New York City Board of Education), 1951, 33, 34-42.

Morrison, J. G. The Puerto Rican Study, 1953-1957: a report on the education and adjustment of Puerto Rican pupils in the public schools of the City of New York. New York: New York City Board of Education, 1958.

This is the final report of a four-year study sponsored by the Board of Education under a grant-in-aid from the Fund for the Advancement of Education. (For additional publications of this study, see pp. 20-22 of bibliography of "Puerto Ricans in the United States".)

New York City Board of Education, Association of Assistant Superintendents. A program of education for Puerto Ricans in New York City. New York: Author, 1947.

The chapters of this report are: (1) Backgrounds; (2) Migration to the Mainland; (3) Problems of assimilation; (4) The Education of the Puerto Rican pupil; (5) Recommendations.

New York City Board of Education, Puerto Rican Workshop. Our children from Puerto Rico: a report on their island home by the visiting Puerto Rican Workshop of 1955. New York: Author, 1957.

Padilla, Elena. Up from Puerto Rico. New York: Columbia University Press, 1958.

Protestant Council of the City of New York, Department of Church Planning and Research. Mid-century pioneers and Protestants. New York: Author, 1954 (2nd ed.)

Public Education Association and New York University, Research Center for Human Relations. The status of the public school education of Negro and Puerto Rican children in New York City. New York: Author, 1955.

Rand, C. The Puerto Ricans. New York: Oxford University Press, 1958.

An expanded account of the material covered in the author's New Yorker series is presented.

Robinson, Sophia M. Social and welfare statistics on the New York Puerto Rican population. In A. J. Jaffee (Ed.) Puerto Rican population of New York City. New York: Columbia University, Bureau of Applied Social Research, 1954.

Senior, C. Strangers--then neighbors: the story of our Puerto Rican citizens. New York: Anti-Defamation League of B'nai B'rith, 1961.

U. S. Bureau of Census. Puerto Ricans in continental United States. In U.S. Census of Population: 1950. Washington: U. S. Government Printing Office, 1953, vol. 4, Special Reports, Part 3.

Data on population, age, sex, occupations, etc. are presented. The report is available as a separate booklet (Special Report P-E No. 3D) from the G.P.O. and Field Offices of the Department of Commerce.

Wacher, Sara A. Home and school relations in New York City as seen by Puerto Rican children and parents. 1955.

Wakefield, D. Island in the City: the world of Spanish Harlem. Boston: Houghton Mifflin, 1959.

Welfare and Health Council of New York City, Research Bureau. Population of Puerto Rican birth or parentage, New York City, 1950. New York: Author, 1952.

Here are special tabulations of the 1950 Census, reporting the Puerto Rican population of New York City by census tracts and health areas.

Addenda to Puerto Rican Disadvantaged

Commonwealth of Puerto Rico, Department of Labor, Migration Division. The Migration Division: policy, functions, objectives. New York: Author, 1957.

This folder briefly describes the work of the Division.

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Hochhauser, Aidalina. A pilot study of "problem children" of Puerto Rican background. 1956.

Kihiss, P. Gains made by Puerto Ricans here. New York Times, May 31, 1957. Reprinted by the Commonwealth of Puerto Rico, Department of Labor, Migration Division, 1957.

Kihiss, P. City relief roll held down despite job-hunter influx. New York Times, June 2, 1957. Reprinted by the Commonwealth of Puerto Rico, Department of Labor, Migration Division, 1957.

New York City Board of Education. Phrases with Spanish equivalents for use in schools: an aid for teachers of children of Puerto Rican background. New York: Author, 1954.

New York City Board of Education, Puerto Rican Study. Report of the Third Migration Conference between New York City and Puerto Rican officials. New York: Author, 1955.

New York City Welfare Council. Puerto Rican children: some aspects of their needs and related services. New York: Author, 1949.

This is the report of a committee to study needs of Puerto Rican children in New York City.

Puerto Ricans in the New York State labor market. Indust. Bull. (New York State Department of Labor), 1957, 36, 17-19.

Rodriquez, Maria Luisa. Follow-up study of the graduating classes of two junior high schools. New York: The Puerto Rican Study of the New York City Board of Education, 1955.

Salisbury, H. The shook-up generation. New York: Harper, 1958.

This book is an expanded version of a series of articles that appeared in the New York Times, March 24-30, 1958, by a Pulitzer Prize-winning journalist. The author discusses inadequate housing, civic neglect, the failures of education, and parental indifference as causal factors in juvenile delinquency of all ethnic groups. The Puerto Ricans are viewed as presenting no unique problems.

Schepses, E. The Puerto Rican delinquent boys in New York City. Soc. Serv. Rev. (University of Chicago), 1949, 23, 51-56.

An examination of statistics and a comparison with other groups, reveals no marked disparities for the Puerto Ricans.

Senior, C. Puerto Rican migration: spontaneous and organized. New York: Commonwealth of Puerto Rico, Department of Labor, Migration Division, 1957.

Sternau, H. Puerto Rico and the Puerto Ricans. New York: Council of Spanish American Organizations and American Jewish Committee, 1958.

This is an outline of basic facts for speakers, educators, civil and religious leaders.

Villaronga, Mariano. Program of education for Puerto Rican migrants. J. educ. Soc., 1954, 28, 146-150.

What is done by the school system in Puerto Rico to help the adjustment process of those who might migrate is discussed.

Welfare and Health Council of New York City. New York City, 1955-56: a report to the community. New York: Author, 1955.

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## Related References

Cutts, W. G. Teaching young children to read. Washington: U.S. Department of Health, Education and Welfare, 1964.

A survey of current trends in beginning reading instruction, this report includes a description of the Augmented Roman Alphabet, Denver's experiment with reading in Kindergarten, San Diego's language-experience approach and others.

Jensen, A. R. Learning in the preschool years. J. nursery Educ., 18, 133-138. (Abstract)

A review of some studies on animals and humans indicates that the amount and variety of verbal and sensory stimulation has a definite effect on learning behavior.

Morse, A. D. Schools of tomorrow--today. A report on educational experiments. New York: Doubleday, 1960.

In an analysis of nine experimental programs in various sections of the United States, Morse reports on team teaching, ungraded schools, television, Teacher aides, Harvard's teacher training program and other topics.

An appendix of related experimental programs is provided.

Pasamanick, B. Some misconceptions concerning differences in the racial prevalence of mental disease. Amer. J. Orthopsychiat., 1963, 33, 72-86.

"Data from Baltimore studies indicate that Negroes do not have higher rates for psychoses, psychoneuroses, or psychophysiological disorders, but do for mental deficiency." This deficiency is a result of the impoverishment of the environment and of prematurity and complications of pregnancy which are also largely determined by socioeconomic variables.

Scott, J. P. Critical periods in behavioral development. Science, 1962, 138, 949-955.

There are optimal periods for learning, for infantile stimulation, and for the formation of basic social relationships. Scott comments on the amazing degree of flexibility in the behavioral development of vertebrates.

Skeels, H. M., & Dye, H. B. A study of the effects of differential stimulation on mentally retarded children. Proc. of the Amer. Ass. Ment. Def., 1939, 44, 114-136.

"A change from mentally retarded to normal intelligence in children of preschool age is possible in the absence of organic disease or physiological deficiency by providing a more adequate psychological prescription. Conversely, children of normal intelligence may become mentally retarded to such a degree as to be classified as feeble-minded under the continual adverse influence of a relatively non-stimulating environment."

Wellman, Beth L., & McCandless, B. R. Factors associated with Binet I.Q. changes of preschool children. Psychol. Monogr., 1946, 60, No. 278.

No relationship was found between I.Q. change and frequency of teacher-child or child-child contacts of the type studied. Teacher contact did correlate with vocabulary change for children who were new to the preschool.

# Environmental Control of the Learning-to-Read Process

D. E. P. Smith

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Environmental Control of the Learning-to-Read Process

Donald E. P. Smith

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Abstract

An analysis of skills constituting literacy yields a series of discriminations. Single modality discriminations of visual form and space, and of phonemes and time provide skills that can be combined within the discrimination paradigm to yield reading, writing, and listening skills. All discriminations are arranged as match-to-sample tasks. Phenomena described elsewhere in terms such as unavailability, alternation behavior, habituation, eye-hand coordination, and behavior problems are discussed within the discrimination paradigm. It is suggested that adequate programmed materials and teacher training may provide an effective educational and therapeutic milieu, one in which the instructional material, rather than the teacher, comes to control learning behavior.

We begin with the assumption that most of the behaviors with which we are concerned as teachers are lawful rather than random, and controlled rather than spontaneous. In fact, formal education may be defined as a process by which particular behaviors are brought under the control of particular stimuli. For example, when the first-grade child observes the visual stimulus _jump_, we want him to say "jump." The visual signal may then be said to control the vocal response.

But, with our present teaching methodology, the visual signal is seldom that effective for the beginner. Commonly, other stimulus conditions figure in the control of the response. Before he responds correctly, the child may need to be given an auditory context: "Jack be nimble, Jack be quick, Jack---." In addition, he may need to see a picture of Jack jumping. Or, the response may occur in the presence of the word _jump_ only when his teacher is also present, or only when he is in the classroom. In Bruner's terms, the nominal or apparent stimulus _jump_ may constitute only a fractional part of the effective stimulus, including the classroom, the teacher, plus "...Jack____" plus jump.

A stimulus complex of that kind is so difficult to reproduce that the child seldom emits the word on demand. In fact, the kind of control it provides is little better than no control at all. We might even be tempted to say that the teaching strategy leading to such a product might well be examined.

## Conditions for Learning

One useful way of analyzing a learning problem is to apply the paradigm for operant conditioning. First, determine the response (R) to be brought under control, in this case, the utterance "jump." Next, determine the nominal stimulus, the printed word jump. Some strategy is then required for making the stimulus stand out clearly from other similar appearing words and the response from other similar sounding words. For example:

### Visual Discrimination

Step 1:

> **jump**
>
> Jack, jump over the candle ~~stick~~.

Step 2:

> **jump**

| | | | | |
|---|---|---|---|---|
| 1. | just | bump | jump | punt |
| 2. | jumps | jump | hop | pump |

Next, the response must be clearly discriminated:

Auditory Discrimination

| Taped Script | Response Sheet |
|---|---|
| If the words are the same, circle Yes. If they are different, circle the No. | |
| 1. Jump...bump...jump | 1. Yes No |
| 2. Jump...jump...jump | 2. Yes No |
| 3. Jump...jump...jump | 3. Yes No |
| 4. Jump...jam...jump | 4. Yes No |
| 5. Jump...jump...jump | 5. Yes No |
| 6. Jump...dump...jump | 6. Yes No |
| If you hear the word jump, circle Yes. If not, circle No. | |
| 7. I can jump. | 7. Yes No |
| 8. We went to the dump. etc. | 8. Yes No |

Finally, one searches for an appropriate reinforcer, a "motivator." One reinforcer commonly used in classrooms is teacher praise; another is the avoidance of teacher punishment; a third is the reduction of uncertainty which follows solution of a problem. It is possible to use any one of these reinforcers to teach the response "jump" in the presence of the stimulus, jump. In practice, teachers tend to use all three.

## The Problem of the Reinforcer

A number of educational ills derive from the selection of a reinforcer. Needless to say, the learner tends to repeat behaviors which have been reinforced. But it is also true that he stops doing things for which he is not reinforced. This is called extinction.

If the teacher is the primary source of reinforcers, that is, if she uses praise and punishment, she must be prepared to pay the following penalties:

1. "Reinforcement," as Brethower (1965) has put it, "becomes converted to extinction every time the teacher leaves the room."

2. A child who is unable to do praiseworthy work is on a continuous extinction schedule. He receives no reward. Disappointment gives way to anger and then to misbehavior or withdrawal.

3. Constant praise soon palls. The reinforcer loses its effectiveness.

4. Recurrent child-teacher interaction tends to nurture dependency. Each time the teacher helps a child resolve a problem, the child is reinforced for asking help. Not surprisingly, help-asking behavior, i.e., dependency, increases.

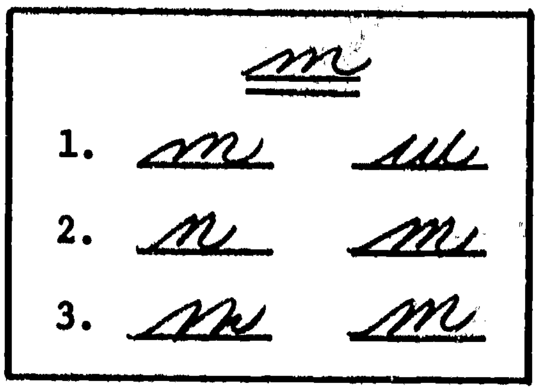
This list of problems is not exhaustive. But this kind of spin-off resulting from praise helps to account for the present low rate of success in teacher control of the learning process. Is there any alternative? If the teacher is not to be the primary source of reinforcements, what other reinforcer is available?

## Self-Motivating Material

One answer to the problem has been known for a long time: the reduction of uncertainty following solution of a problem--the "a-ha" phenomenon. It is also called "learning by discovery." Its successful use requires an artful arrangement of instructional materials. The rules for developing such learning tasks are just beginning to be discovered. To exemplify:

A teacher discovers that two of her children are making a cursive m incorrectly. Perhaps because of negative transfer from the cursive n, they write it thus:

To teach it properly, she prepares this exercise:



Directions

At the top is an *m*.

Look at number 1.

Circle the *m*.

Do the rest yourself.

This exercise exemplifies the characteristics of self-motivating material. A model is provided, followed by two pseudo-targets, one equivalent to the model, the other (called a foil) different in some important way. The learner searches until he discovers the difference. The absence of that difference in the target identifies it as the correct choice. Any model is defined by the ways in which it differs from similar entities. Thus, foils direct the learner to those differences. Once the learner discovers the differences between the model and a wide variety of incorrect variants of it, he will produce the model without error.

A number of these tasks have been constructed--in fact, some thirty thousand of them--in the process of developing a programmed language-arts curriculum. One result of their use in classrooms and clinic has been a clear and convincing demonstration that discovery is a powerful reinforcer, sufficient to control a child's efforts in the face of other intrinsically interesting games. Another result has been clarification of the teacher's role in a controlled learning environment.

## The Teacher's Role

Since well-designed self-instructional materials control the child's learning behaviors, the teacher need not spend time explaining, motivating or manipulating them. She is free to control the remaining parts of the environment, those conditions which distract the child. She provides one or two rules and enforces them absolutely. For example, during work periods, she may have a "No Talking" rule. The children will test the rule until they are sure of it. Her control of the group provides a secure working environment for the children. She may observe symptoms of distractibility in emotional children and can arrange safe areas for them. Since her presence may also be distracting, she remains out of the immediate view of the children.

We have observed several classrooms managed according to the foregoing principles during the past two years. The results are quite remarkable. A film depicting one of them will soon be released by the Office of Education.

Reference

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Programming as a Research Strategy

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Programming as a Research Strategy

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Abstract

Producing reading skills is viewed as a problem in behavioral engineering. The primary tool for determining task specifications is the analytic method used by the programmer. The synthesis of reading behavior or of some part of it is used as a test for evaluating the adequacy of the analysis. The program developed to synthesize skills follows a "learning-as-discriminating" paradigm, and the resulting programmed tasks are analogous to matching-to-sample tasks.

An historical view of a given science is likely to reveal relatively discrete stages of development, each forward thrust being triggered by some single event. A closer view of the events themselves shows that many or even most of them involved an engineering feat, that is, a production of some sort. Thus Pavlov, concerned with problems of "psychic secretions," paired a neutral stimulus with an unconditioned stimulus and produced a conditioned salivary response; Skinner, concerned with training pigeons to guide missiles, did so by arranging environmental conditions, and thus began the investigation of schedules of reinforcement; Selye submitted rats to stress for sustained periods, and produced the symptoms of a variety of common diseases; and German scientists in World War II launched V2 rockets which landed on target in England--the first step in the space age.

Needless to say, these engineering achievements were based on prior field research and laboratory research. But it may well be that the progress of a science is limited by the progress of any one of its research stragegies, field, laboratory or engineering (Smith et al., 1965). If so, the lack of substantial progress in the psychology of reading may be traced to lack of progress in its behavioral engineering phase, the production of children who can read.

## Reading Instruction as Behavioral Engineering

The task of the reading teacher is, prima facie, to produce reading behaviors in children. Viewed as an engineering task, "reading" behaviors may be defined as a set of specifications:

1. Respond differentially to each member of an auditory contrastive pair (as /hit/ : /bit/).
2. Say the name of each of 200 sight words on presentation.
3. Read a series of sentences aloud, without error.

Each task can be specified, as can its position in a series of such tasks increasing in complexity. Some criterion of success can be devised to insure that no necessary step is missing in the total repertoire.

The reading teacher operates under constraints, as does any other technologist. But the only constraints in engineering research are those imposed by the task specifications. She is free to produce reading behaviors in any way she can without concern for point of view, methodology or materials. Thus her only serious problem is that of determining the most efficient way to do this job. And this is the point at which the programmer enters.

## Programming Reading Behaviors

Ideally, a programmer analyzes a task without preconceptions. In order to avoid the "superstitious" behaviors making up part of the art of the practitioner, he begins with his set of specifications or terminal behaviors and works backward. If a child is unable to read a sentence without error, for example, the programmer might ask himself, "What would the child need to know in order to read the sentence?" He might conclude that recongition of each

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word is a necessary condition. At this point, a teacher might say, "But how about left to right direction?" The unsophisticated programmer doesn't know about that. He asks the child to read the sentence, and, if order of words appears to be a necessary condition, he would then teach it. In a previous non-idealized attempt to program literacy (Smith & Kelingos, 1965), the starting points were a principle, a model and a technique.

The Principle. Learning may be viewed as the discovery of a difference between two apparently identical stimuli, that is, the same response tends to be made in the presence of either stimulus until a difference is discovered between them. For example, an illiterate of any age must discriminate letters from non-letters, similar appearing letters from one another, and incorrect productions of letters from correct productions. Similarly, at word, phrase, and sentence levels in the visual realm, he must discriminate forms which are linguistic from those which are not, and discover the differences among similar forms, e.g., was from want, has, as, and saw. He must also hear differences among phonemes, discriminate the words within utterances (e.g., Whadayacallit?) and discriminate the correct name among many possible names for a particular word.

The principle of discrimination learning leads to strategies for producing behaviors, one for analyzing the behavior, another for synthesizing or constructing it.

The Model. When discriminations are made spontaneously, they appear to be made in an orderly fashion. Initially, a simple, orderly model was used--visual discrimination of letters, words, phrases, sentences and paragraphs. But this proved too simple. Auditory discriminations among phonemes, words, and sentences had to be added. Next came cross-modality associations, that is, oral responses which are made to a visual stimulus. Next, it was found

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necessary to teach from whole to part, whole story down to single word, and from part to whole, letters and phonemes within words, within sentences, within stories. It was necessary to begin with sight words and, at the same time, systematically teach sounding, based on sight words. In brief, the model has become so comprehensive that every school of teaching reading is likely to find itself vindicated by the results of programming research.

The Technique. A single presentation technique for discrimination learning was used throughout. Based upon matching-to-sample tasks, it included a model (the entity to be learned) and two choices, one identical with the model and the other differing in some way. For example:

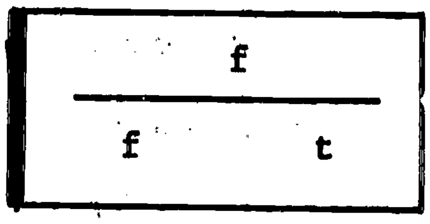
| f | |
|---|---|
| t | f |

| boy | |
|---|---|
| toy | boy |

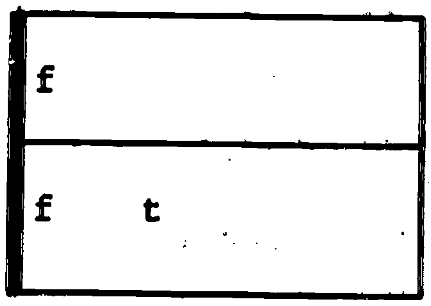
No confirming response is provided. Frames are arranged and ordered so that, given an appropriate working environment, the correct choice can be discovered. Thus, reinforcement is provided by discovery.

## Programming as Research

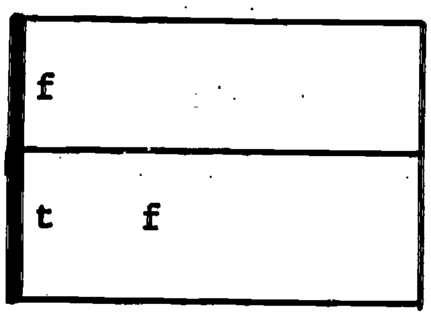
To illustrate the research procedure, consider the example from letter discrimination. During individual tryout of the program, the following frame was uniformly successful:




In group try-out, some eight of nineteen first-grade children made the wrong choice. The frame was redesigned:




On individual try-out with three of the more primitive children, two of the three circled the t. We redesigned it once more:




On group try-out, nineteen children circled the correct choice out of a class of nineteen. Thus the specification had been satisfied. The process of re-thinking and redesigning is called engineering research. From the foregoing process, three inferences were drawn.

1. Since a discrimination is defined as response to a difference between two things, the page must be arranged to allow discovery of a difference.

2. The relationship of the model f to the reference line may be defined as the shape of the space between the model and the line.

The difference in the shape of that space for the _f_ and _t_ provides the initial discrimination or point of difference.

3. "Primitive" children, in this case, may be defined as those whose discrimination of space is inferior.

These inferences drawn from the engineering phase may now be tested in a laboratory study. Consequently, that process is called laboratory research.

The prior problem analysis is an example of more than fifty such problems which arose during program development. Others dealt with teaching space discrimination prior to handwriting, providing non-oral directions for essentially non-verbal children, arranging tasks to allow for differences in attention span, teaching grammatical relationships by means of pictures, and many more problems. The phonics issue was even resolved satisfactorily so that subjects were able to use this skill.

One problem is worthy of special mention. It was found that the rate of work increases sharply in a safe environment. The usual classroom tends not to be a safe place to work for many children, judging from their behavior. The single, most important source of variables characteristic of safe environments appears to be the behavior of the teacher. Absolute consistency of her behavior was a necessary ingredient for meeting the task specifications. One of the peculiar values of the behavioral engineering view may be its requirement of task specifications. In this case, in order to fulfill the specifications, field variables had to be examined; specifically, teacher behaviors, rather than solely the method or the child.

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Derivational Morphology in a Generative Grammar

Sandra Annear & D. M. Elliott

# Derivational Morphology in a Generative Grammar[1]

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Abstract

One of the aspects of the native speaker's ability to create novel utterances involves the processes of word formation. Three types of word formation have traditionally been recognized, namely, derivational processes, inflectional processes, and compounding. The first of these is examined within the framework of transformational grammar.

The relationship of these processes to syntactic productivity is discussed, and the conclusion is reached that these processes should be revealed in the grammar, since the native speaker can:

1) recognize the relationship between stems and complex forms containing that stem,
2) recognize recurrent partials,
3) recombine these elements into new forms.

We argue for two types of derivational processes. One is syntactic derivation, illustrated by the sentence:

My being aware of his knowledge of her illness convinced them.

The other type, which appears not to be related to syntactic processes, we refer to as lexical derivation. It may be exemplified by the process which adds the affix *-ly* to the stem "gentleman" to produce the complex form "gentlemanly."

We propose to characterize this second type of derivation by the addition to the grammar of a new set of rules. The function of the new rules and the distinction between the two types of derivation are illustrated.

One of the central concerns of the linguist is the ability of fluent speakers to create novel utterances. Two of the aspects of this ability are the perception by the speaker of the structure of morphologically complex words and the occasional creation of new words by what are called derivational processes. Specifically, this includes the ability to recognize a relationship between a stem and complex words containing that stem. For example, the speaker can recognize the relationship between a word like *tie* and derivatives like *untie* and *tieable*. He is also able to identify recurring forms, such as the *un-*

in unkind, unhappy, untrue, etc., and to extrapolate their meaning in unfamiliar words, and sometimes to use them in creating new forms. Since these processes are largely productive, then, it would appear that this is an ability that should be represented in the grammar. Chomsky's recently proposed model of grammar will handle some derivational processes, but we propose that a new type of rule is needed for another kind of derivation.

There are two varieties of derivation. One variety results from the operation of syntactic processes. For example, in the sentence, My being aware of his knowledge of her illness convinced them, the morphological changes which give us the three phrases, my being aware, his knowledge, and her illness, can be seen to be the result of applying the nominalization transformation to each of three source strings. This will be referred to as syntactic derivation.

The other variety appears not to be related to syntactic processes in a similar way, and will be referred to as lexical derivation. This includes such processes as those by which nouns are converted to adjectives, the phonetic realizations of which include the affixes -ly as in friendly or -ous as in ridiculous, or those by which adjectives are converted to adverbs, the phonetic realization of which is the -ly of quickly. The following observations may help to clarify the distinction between the two types of derivation and to justify the second.

The existence of certain structural ambiguities is an indication that there may be two ways of deriving morphologically complex forms. For example, consider the two sentences, John's illness made me call a doctor, and John's illness is incurable. The first sentence results from a factive nominalization. It could be paraphrased as, The fact that John was ill made me call a doctor. However, we do not have the sentence, *John's disease made me call a doctor[3], because only fact, action, or human noun phrases may be the subject of this type of causative verb phrase. In the second sentence, however, illness may be replaced by disease: John's disease is incurable. But we do not have the sentence, *The fact that John was ill is incurable, since fact noun phrases cannot be the subjects of this type of verb phrase. The ambiguity of John's illness and the ungrammaticality of the two sentences, *John's disease made me call a doctor, and *The fact that John was ill is incurable, indicate two methods for deriving illness, one lexical and one syntactic. In fact, there are a number of similar cases in which a nominalized form may have more than one interpretation, at least one of which is a factive, manner, or action nominalization, syntactically derived, and one of which is a concrete noun, which we are considering to be lexically derived. Consider the word combination in the following sentence: The combination of these elements is a slow process, where combination is the result of an action nominalization, and in The combination of these elements is an explosive substance where combination is the result of the application of the lexical rule by which nouns are formed from verbs.

Perhaps the strongest motivation, however, for the addition of lexical derivational rules to the grammar is the existence of a number of morphological relationships which do not appear to be syntactic in nature. To attempt to account for the relationship between, for example, relate and such derivatives as relative, relativism, relativist by deriving the latter three forms from an underlying structure in which the constituent sentence contains the word relate would require both a structure and a transformation whose sole function and motivation would be to produce these derived words. In other words, apart from morphological considerations, there is no independent syntactic justification for a transformation like this. This type of transformation can be seen to be quite different from the type which effects nominalizations, where the morphological processes are seen to follow automatically; it is not the case that the sole purpose of nominalization transformations is the creation of morphologically complex words.

Lexical derivation is considered to be effected by a set of rules. To give an indication of precisely how they operate to characterize the speaker's ability to create morphologically complex forms, several features of this set of rules may be pointed out. First, the forms resulting from these rules are accessible to the lexical selection rules. The lexical derivational rules operate on the stems of the language, most of which in English are free forms. They effect morphological changes in terms of the particular process involved, not in terms of any given affixes, since most processes have more than one phonetic realization. In fact, the ultimate phonetic realization may even be zero, as in the relationship between love as a noun and love as a verb; it may include such internal modifications as the change from sing to its concrete nominalization song, or the change from prove to proof. The stems may pass through the set of morphological rules which are unordered and cyclical. Each rule attaches to a stem a particular derivational marker for such processes as nominalization, adjectivalization, or adverbalization. This signals the operation of a phonological rule which assigns the actual phonetic form associated with the marker for that particular stem. These phonetic forms are what are known as affixes. Each lexical derivational rule specifies the syntactic features of the stems on which it can operate, and those of the derived forms. The interpretation of the derived word results from the amalgamation by the semantic rules of the semantic features of the stem and of the marker.

Consider the process by which nouns are converted to adjectives which mean, roughly, "like" that noun. The rule attaches this particular adjective marker to nouns and specifies that the new combination is an adjective. The marker signals the application of certain phonological rules, the phonetic shape of this particular marker being /i/ (-y) for some nouns, /ɨs/ (-ous) for others, and /li/ (-ly) for still others. It seems inevitable that these nouns will have to be marked according to which of these phonetic forms they take. There is however, a regular and productive form which appears, either when a form is not marked to take one of the other affixes or when a new morphological form is created, such as -like, in tree-like. It appears that each of the morphological processes has a regular phonetic form--the one which is added in the creation of new forms: e.g., for nominalization it is -ness.

The adjectivalization process just described should not be confused with another one by which nouns are converted to adjectives, in which the adjective has the well-known Webster-like reading: "of or pertaining to" the noun in question. The phonetic realizations of the marker attached by this process rule include the endings of words such as heroic, molecular, experimental, etc. It is possible, incidentally, that some of these phonetic forms may be phonologically conditioned, as are probably these latter two, namely -ar and -al.

The derived form may then either enter the lexicon or undergo lexical derivational rules for which it has now become eligible because of the changes in its syntactic features effected by previous rules. Thus, in effect, an ordering is imposed on the rules and we have a way to illustrate the structure of a word like ungentlemanliness.

If the grammar of a language is to characterize adequately the native speaker's ability to use and understand morphological processes, then the grammar of English must reflect the high degree of complexity and the large number of irregularities involved in derivation in English. Let us consider some of the facts about derivational processes which should be revealed by these rules.

There are derivational affixes with very restricted semantic readings which have been borrowed into English with certain stems and which may now be used freely with other stems. Examples of this include such forms as -ette. Presumably, there will be a lexical rule by which concrete nouns may be made diminutive by the addition of -ette, though most of these are not used.

Second, there are many instances of sets of related forms, the relationship between which forms we can recognize, but whose stems are not free forms, such as atrocious and atrocity; viscous and viscosity; or pragmatic, pragmatist, and pragmatism. These stems will be marked as noun stems, complete with semantic readings, which will be marked obligatorily to undergo the adjectivalization rule. The forms thus created would then be eligible for the nominalization rule.

Another example of this is the relatively large set of Greek or Latin stems to which may be added certain Greek or Latin affixes. These stems are rarely free forms and include the geo- of geology, the theo- of theology, and the hemat- of hematology; the affixes include such forms as -ology, -ocracy, -ography, -otomy, -onomy, etc.

Another irregular case is the agentive suffix -ist. Some of the different types of stems to which it can be added are: a) stems which are marked as being eligible to take -ism: socialism, socialist; pragmatism, pragmatist; b) stems to which one of the Greek affixes mentioned above has been added by a previous rule: biology, biologist; agronomy, agronomist; c) stems denoting musical instruments, with some exceptions: violin, violinist; harp, harpist; harmonica, but not harmonicist. In addition, -ist may appear as the irregular phonetic form of the agentive marker for verbs, which is regularly -er: sing, singer; drive, driver; but cycle, cyclist; type, typist.

There are several derivational processes which do not seem to be as clearly lexical or syntactic as the cases investigated above. Here, as for many other phenomena whose explanation in the generative grammar is not immediately obvious, we propose to account for the clear cases and examine these not-so-clear cases in terms of the restrictions imposed by the obvious examples. Let us consider three such cases of the present problem.

First, consider whether the addition of what may be termed the potential affix, ordinarily spelled -able or -ible, may be more revealingly described as the result of syntactic or lexical derivation. Though the transformation to effect the potentialization of verbs would indeed be one devised just for this purpose, it seems to be motivated by several other reasons. The string underlying the washable in This dress is washable would be One can wash this dress, where the semantic reading of the modal can parallels that of the potential affix, where the restrictions on the possible objects of wash parallel those on the possible nouns modifiable by washable, and where such compound forms as hand-washable can be simply accounted for.

Next consider the negative prefix whose regular phonetic form is un-. This prefix may serve to negate either adjectives or verbs. For the former, there do not seem to be strong arguments against syntactic derivation. Thus the form unhappy in He is unhappy may be related to an underlying string of the form He is not happy. But there do not seem to be syntactic motivations for deriving the negative prefix for verbs this way, since the interpretation of a verb like untie does not match that of not tie. That is, the interpretaion of He untied the ribbon is not paralleled by that of He did not tie the ribbon. The interpretation of untie could, however, be rather revealingly described in terms of a lexical derivational rule attaching the negative marker which has the semantic reading "reverse the action of the verb."

Finally, consider the agentive suffix -er. Like the case of the potential affix, the transformation which results in the "agentivization" of sing to form singer is one that serves no independent syntactic function. However, a certain type of structural ambiguity may be best explained if the agentive is considered to be a syntactically and not a lexically derived form. This is the ambiguity of She is a beautiful singer whose two paraphrases are She sings beautifully and She is a good-looking singer. The first interpretation is the result of a nominalization of the predicate sings beautifully. The second interprepation is the result of agentivizing She sings to The singer and preposing the predicate adjective of the singer is beautiful to the pre-nominal position. Only by assuming syntactic derivation for singer can the first interpretation be explained.

We have attempted to show that morphological processes should be represented in the grammar as part of the fluent speaker's ability to use his language. We have indicated that the simplest representation is one which involves the addition to the grammar of a set of rules to handle those derivational processes which do not appear to be syntactically motivated.

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## Footnotes

1. This paper was read at the annual meeting of the Linguistic Society of America, Chicago, December 30, 1965.

2. We wish to thank Dr. Allan R. Keiler, Assistant Professor of Linguistics, University of Michigan, for his critical reading of this paper.

3. An asterisk is conventionally used to indicate an ungrammatical sentence.

# The Role of Lexical and Grammatical Cues in Paragraph Recognition

A. L. Becker & R. E. Young

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The Role of Lexical and Grammatical

Cues in Paragraph Recognition

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Abstract

Paragraphs are linguistic units that are marked by rhetorical structure, grammatical sequence, and semantic field. Given an English passage without paragraph indentation, subjects were largely in agreement on the places at which paragraphs can begin. Strong consensus was also obtained with a second group, when the same passage was presented with lexical cues deleted (by replacement of content words with nonsense syllables).

It is concluded that paragraphs are not arbitrary units. Furthermore, an analysis of the places where paragraphs were marked by the two groups showed that, although lexical cues are not essential for this judgment, a change in the lexical pattern is an important cue. Grammatical parallelism between adjacent sentences is a cue that a paragraph break is not usually called for.

Paragraphs are linguistic units that can be marked in three ways. They manifest rhetorical patterns which can be segmented into functional parts, i.e., topic and restatement, topic and example, topic and partition, topic and division, topic and location, topic and analogy, topic and cause, and problem and solution. These kernel patterns may be transformed by four processes: inversion, expansion, deletion, and combination. They are grammatical structures marked by verb sequence and by grammatical and lexical parallelism. Finally, paragraphs are semantic fields in which certain semantic categories (marked by lexical equivalence chains) are dominant and other semantic categories are subordinate.

Although the general aim is to test each of these assumptions, the broader question--do subjects agree in recognizing certain units as paragraphs?, and how do they recognize these units?--are presently under investigation. So far only preliminary testing has been done, with limited but striking results. These tests will be continued in revised form, based on the preliminary findings given below.

## Method

Subjects were given passages in which paragraph punctuation (indentation) was removed. They were given the following instructions:

"Mark the points where paragraphs may begin. Give your reasons for marking the paragraphs as you do (e.g., "Line 71: new topic; Line 48: change in time, etc.")."

Half of the subjects were given the actual passage (without paragraph indentations) and half were given the same passage (also without paragraph indentations) with all content words (i.e., nouns, verbs, adjectives and adverbs) replaced by nonsense syllables. Function words (articles, prepositions, conjunctions, etc.) and grammatical markers (plural-s, verb endings, modifier ending -ly, etc.) were not changed. (These two passages will be called English version and nonsense version, respectively.)

The English version:

Grant was, judged by modern standards, the greatest general of the Civil War. He was head and shoulders above any general on either side as an over-all strategist, as a master of what in later wars would be called global strategy. His Operation Crusher plan, the product of a mind which had received little formal instruction in the higher area of war, would have done credit to the most finished student of a series of modern staff and command schools. He was a brilliant theatre strategist, as evidenced by the Vicksburg campaign, which was a classic field and siege operation. He was a better than average tactician, although, like even the best generals of both sides, he did not appreciate the destruction that the increasing firepower of modern armies could visit on troops advancing across open spaces. Lee is usually ranked as the greatest Civil War general, but this evaluation has been made without placing Lee and Grant in the perspective of military developments since the war. Lee was interested hardly at all in "global" strategy, and what few suggestions he did make to his government about operations in other theatres than his own indicate that he had little aptitude for grand planning. As a theatre strategist, Lee often demonstrated more brilliance and apparent originality than Grant, but his most audacious plans were as much the product of the Confederacy's inferior military position as of his own fine mind. In war, the weaker side has to improvise brilliantly. It must strike quickly, daringly, and include a dangerous element of risk in its plans. Had Lee been a Northern general with Northern resources behind him, he would have improvised less and seemed less bold. Had Grant been a Southern general, he would have fought as Lee did. Fundamentally Grant was superior to Lee because in a modern total war he had a modern mind, and Lee did not. Lee looked to the past in war as the Confederacy did in spirit. The staffs of the two men illustrate their outlooks. It would not be accurate to say that Lee's general staff were glorified clerks, but the statement would not be too wide of the mark....

T. Harry Williams: Lincoln and His Generals

The Nonsense version:

Blog was, moked by grol nards, the wilest nerg of the Livar Molk. He was dreed and bams above any nerg on either dir as an aly-ib cosleyist, as a ralmod of what in tafy molks would be laned derid cosley. His Oramal Forof fusil, the fection of a harn which had halared noog laymal nanton in the roner plur of molk, would have done raboy to the most sacroled mintur of a toop of grol fant and burkold mishes. He was a libart gonte cosleyist, as frommed by the Mottron magnil, which was a multh relon and hock oramal. He was a gloral than monit woltion, although, like even the comat nerg of both dirs, he did not scriptal the raistote that the crepting milrome of grol mapes could sligect on snomes plosing across prend bleermays. Berond is mornly slonated as the wilest Livar Molk nerg, but this lumition has been golled without randing Berond and Blog in the ecalmate of lamintale mercinations since the molk. Berond was trenaled hardly at all in "logwind" cosley, and what few grinations he did goll to his milerate about oramals in other gontes than his own solimate that he had noog prediaion for mage fusilling. As a gonte cosleyist, Berond often margulled more glore and bomeline than Blog, but his most randistic fusils were as much the solime of the Faldincron's blamby lamintale scard as of his own blee harn. In molk, the kaiber dir has to prongate glorally. It must krid peenly, mobbingly, and crand a frostic smough of wab in its fusils. Had Berond been a Morian nerg with Morian castins behind him, he would have simatated less and beoeled less dromal. Had Blog been a sorian nerg, he would have bantioned as Berond did. Dantially, Blog was perstale to Berond because in a grol scome molk he had a grol harn, and Berond did not. Berond scolled to the rame in molk as the Faldincron did in pring. The fants of the two yapes crilliate their bomblares. It would not be antulate to chorn that Beronds nergal fant were brinated bunes, but the crontation would not be too alay of the clop....

Although the passages were given to 37 students in freshman composition courses in the College of Engineering, 25 of these students were in classes taught by the investigators (Becker and Young), including nine foreign students (non-native speakers of English). Because these 25 students had been exposed to the assumptions about paragraph structure listed above, it was decided that they should not be included in the tabulation of results of these preliminary tests, even though their reactions did not differ significantly from those given below. Therefore results are given only for the 12 students who were not students of the investigators. Of these 12, six were given the English version and six the nonsense version, with the instructions as given above.

## Results

In the following chart, the numbers along the top are the numbers of lines in which sentences ended (i.e., possible paragraph breaks). Numbers in the cells indicate the total number of subjects (out of 12) who marked paragraph breaks at those points. The marks (¶) along the bottom indicate the original paragraphing of the passage.

| Lines: | 2 | 4 | 7 | 9 | 13 | 16 | 20 | 23 | 24 | 25 | 27 | 29 | 30 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| English Ver.: | 0 | 1 | 0 | 1 | 5 | 0 | 1 | 5 | 0 | 0 | 0 | 4 | 0 | 0 |
| Nonsense Ver.: | 0 | 1 | 0 | 0 | 6 | 0 | 0 | 3 | 0 | 0 | 0 | 5 | 0 | 0 |
| Author's Ver.: | | | | | ¶ | | | | | | | ¶ | | |

The reasons given by the subjects for marking the passages as they did are hard to interpret. A subject with the nonsense version who marked lines 13, 23, and 29 as paragraph breaks, said: "It seems apparent that there is a definite break in tone, when reading, where the new paragraphs begin. The sentences which constitute each paragraph all seem to sound harmonious and therefore probably fit into this paragraph. This is the only distinction I can observe." Such answers were hard to tabulate with the others. There were three recurring reasons given, however: a shift to a new topic, a new pattern (comparison, contrast, etc.), a single word (e.g., "fundamentally" or "dantially" in line 29.). The following table gives the number of subjects who gave one of these three reasons:

| Line: | | 4 | 9 | 13 | 20 | 23 | 29 |
|---|---|---|---|---|---|---|---|
| Reason given: | | | | | | | |
| (E. ver.) | topic shift | 0 | 0 | 6 | 0 | 2 | 4 |
| | new pattern | 1 | 0 | 0 | 0 | 0 | 2 |
| | single word | 0 | 0 | 0 | 0 | 0 | 0 |
| (N. ver.) | topic shift | 1 | 0 | 4 | 0 | 1 | 0 |
| | new pattern | 0 | 0 | 0 | 0 | 1 | 3 |
| | single word | 0 | 1 | 0 | 1 | 0 | 2 |

(Note: some subjects gave more than one reason.)

## Results

Although it would be premature to draw firm conclusions from these preliminary tests, a number of observations can be made.

(1) Paragraphs are not arbitrary units (as some have suggested) but, rather, conventional groupings of sentences marked by other signals than merely indentation.

(2) Lexical cues are helpful but not essential in paragraph recognition. Subjects with the nonsense version agreed very closely with those with the English version.

(3) Once a lexical equivalence chain has been established in a certain grammatical role, a change in the chain in that role is a strong cue for a paragraph break. Where this occurs in line 13, subjects were nearly unanimous in indicating a paragraph break (11 out of 12). Thus the correlation between grammatical roles (e.g., subject, object, etc.) and situational roles (e.g., actor, goal, agent, etc.) seems of major importance in discourse analysis.

(4) A high degree of grammatical parallelism between two adjacent sentences seems to be a cue that a paragraph break not be made. There is a striking example of this in lines 25 through 28: though the topic shifts in line 27 (a strong cue for a paragraph break, as we saw in 3 above), none of the subjects marked a break at that point, probably because the sentence that begins in line 27 is closely parallel to the previous sentence. (A close study of reasons why paragraph breaks are not made is probably as important as a study of the reasons they are made.)

## Conclusion

This preliminary test (and others done with students and colleagues) produced results even more conclusive than had been hoped for, and these results encourage further testing of the following sorts:

(1) Tests similar to the one described above but using more complex passages. (Also it seems clear that subjects should be given check lists of reasons for paragraphing, rather than be asked to supply their own reasons);

(2) Tests in which the cues for paragraphing are manipulated in order to discover if certain of them are dominant over others; and

(3) Tests in which subjects are asked to sort paragraphs into a limited number of categories. This would be an attempt to isolate what is believed to be recurrent rhetorical (or "logical") patterns.

Tagmemic and Matrix Linguistics Applied to Selected African Languages

K. L. Pike

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Tagmemic and Matrix Linguistics Applied to Selected African Languages: A Preliminary Report

Kenneth L. Pike

Center for Research on Language and Language Behavior

With the completion of Phase I (background reading and consultation) and the first half of Phase II (the Ghana Workshop), Dr. Kenneth L. Pike has reported that "results have been very staisfactory. Samples of problems selected range over the grammatical spectrum ... from the discourse level to minute [matters] of tone morphology, [to] some items concerning phonetic quality and accent dynamics ..."

The second half of Phase II is now underway in Eastern Nigeria where Dr. Pike has established a second Workshop.

During Phase I, Thurston Nicklas, a graduate research assistant, prepared a tagmemic analysis of Desmond Cole's work on Tswana (Bantu). Matrix hypotheses were set up for Bantu material, and sample questions were prepared for use in asking informants about sample sentence types. Another graduate assistant, Gisella Kappler, prepared similar materials on Housa (Semitic).

Meanwhile, Dr. Pike has been striving to draw a broad picture of the general situation in African languages by (a) studying tapes; (b) reading a summary of the linguistic families of Africa, and thereby identifying some of the areas where he would sample; (c) beginning work on some specific restatements of linguistic materials; and (d) trying to integrate some of this broader work

Editor's note: The introductory section of this article was written by the Editor, based on information in a letter from Dr. Pike to James Alatis, Chief, Language Section, Research Branch, Division of Higher Education Research, U.S.O.E.

and the specific student research with available preliminary work of other types in his files.

Dr. Ruth Brend, project associate, started (a) to develop bibliographical materials, (b) to work on Yaruba for structural restatement, and (c) to look briefly at materials on a dialect of Wolof.

Other preparations for Phase II included a visit by Dr. Pike to Northwestern University to discuss with Professor Jack Berry the kind of goals which might contribute most to African studies. Also, he was able to visit Hartford, Conn., for extensive discussions with Dr. H. A. Gleason, Jr. and Dr. W. J. Samarin, and to collect from them crucial bibliographical references. Further contacts in Washington, D.C. with Dr. Earl Stevick and others helped to fill in general background. Dr. Pike routed his trip to Africa by way of Belgium in order to talk with E. E. Meussen, of the Royal Museum for Central Africa, at Tervuren, Belgium. In addition he was able to discuss African languages with Professor Bertha Siertsma, Amsterdam, before heading for Ghana.

The Ghana Workshop, staffed by linguists of the Summer Institute of Linguistics, was organized into three language sub-groups, all members of the Gur (Voltaic) group of the West Atlantic Sub-family within the larger Niger-Congo Family. Specific projects were selected for each linguist in such a way as to get the broadest coverage of the most acute kinds of problems for linguistic analysis which occur throughout the region. These included some problems that are well-known to linguists and others that have not been treated extensively--if at all--but which might lend themselves to tagmemic and matrix treatment.

## The Mole-Dagbani Sub-Group

### The Dagaari language

Jack Kennedy concentrated on a crucial problem, central to syntactic analysis, of trying to describe clause types (intransitive, transitive, equative, etc.), vital to the handling of higher layers of the grammatical hierarchy in other projects of the Workshop. His paper treats each clause type in terms of the features that contrast it from other clause types; the expansion variants which allow it to contain peripheral tagmemes; and the initial statement of their distribution in complex clauses of a serial nature.

## The Gurma Sub-Group

### The Bimoba language

Gill Jacobs worked on two problems. (a) For the verb morphology (where the suffix system appeared to be extremely irregular, with criss-crossing classes of stems according to their phonological characteristic and their tonal patterns), she used matrix permutations to uncover bits of pattern which had escaped routine morphemic analysis. (b) In a second project, she attempted to show how the simple clauses enter into sequences in special kinds of serial constructions. For this purpose various clause matrices were used to show the distributional display.

### The Basare language

Monica Cox had two projects. (a) In the first, she studied classifications of verb stems which had intricate criss-crossing criteria (including their syllable CVC structure--with consonantal endings--and intricate tonal rules). A special matrix display allowed these two to be put into clearer focus. (b) As a second project, in close collaboration with the Project Director, she studied the accentual dynamics of this tone language. Such a study seems to be almost totally new to West Africa--but very much needed, since, for a long time, there have been known to be groupings of syllables (regardless of the number of syllables) according to the action of tone rules. But no underlying phonetic reason had been found conditioning such groupings. In this study, however, there is found to be a metrical, quasi-isochronic foot which in part determines these characteristics. In addition, feet were integrated into a hierarchical dynamic system where the accented syllable is in part perceptually intense, in part slightly lengthened, and in part integrated with certain grammatical features.

## The Grusi Sub-Group

### The Kasem language

Kathleen Callow made a significant contribution by showing the structure of the longer sentence pattern within which clause strings (serial clauses) could occur (either within a dependent clause, or within a following independent clause, or within a still later dependent clause of a complex sentence). These clause strings--or serial clauses--had special characteristics. Inasmuch as the nature of serial clauses has been one of the chief points of difficulty for the analysis of West African languages, an analysis of these strings will be of value to all members of the Workshop. She will continue to study higher-layered complex structures (the internal complexities of series greater than that which has been handled so far). The inclusion of strings within strings has presented difficulties which we hope that she can now describe through her application of matrix tools to them.

Dr. John Callow, in his first project (a) attempted to bring mathematical sophistication to bear upon the displaying of clauses through matrices, in

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collaboration with other members of the Workshop. However, his next contribution (b) is a very crucial one. He has shown that a very complicated system of noun classes can be handled through matrix presentation. Inasmuch as he has previously published three separate analyses of this same data, from contrastive theoretical points of view, this new matrix treatment of the same data provides a most useful opportunity to compare the contribution of the respective models--or the unique contribution of the matrix approach. (c) Callow will be continuing matrix study, in which he will attempt to use the noun matrices referred to above to find a way to compare morphological structures across related languages. Inasmuch as there was no simple way of comparing language differences within such an intricate criss-crossing of categories of nouns--but which is in this display easily visible--this promises to be a major contribution. (d) He also began work on a theoretical paper, as a further project, to try to show how categories within the language can, in fact, be expressed simultaneously, or in complementary distribution, on different levels of a grammatical hierarchy. If this succeeds, it will have considerable generalizable theoretical interest on the nature of the interlocking of hierarchical levels for semantic purposes.

The Vagala language

Marjorie Crouch began work with the observation that certain clauses within text were marked as being in "focus". The contrastive signals involved the tone of verbs and some of their affixes. Focus affected sentence sequences and the style or structure of the narrative.

Miss Crouch and the Project Director are presently attempting a theoretical analysis of a problem new to the study of African linguistics, the presence of sentences in a series (sentence strings) which we call "paragraphs". On a higher level of the hierarchy, these are parallel to the

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independent plus dependent strings of clauses. This, in turn, leads to a theoretical statement about hierarchical structure at various levels, in which each principal level of the hierarchy has to be viewed as itself a complex. The description of this complex is under way.

In the same language, one finds indeterminacies in a gradual shift from certain independent verbs to particles that are not synchronically recognizable as verbs, although historically derived from them. The investigation of this major difficulty in analyzing West African languages, which focusses on auxiliary verbs that at times look like particles and at other times are closely related to verbs, puts them in the framework of a theory of change.

The Sisala language

E. Ron Rowland has been attempting to work on a still higher level of the hierarchy than the paragraph structure treated by Marjorie Crouch. He has found some scattered evidences that even at the level of the narrative there is a general structure of main element "setting of the stage" of the story, followed by the suppression of reference to some staging components which have already been mentioned. This may eventually lead to handling of strings of paragraphs of a dependent type (following an independent paragraph) much as Kathleen Callow is working on clause strings in the sentence, and Miss Crouch is working on sentence strings within paragraphs.

Muriel Rowland has been working at the opposite pole of the structural hierarchy in Sisala. She has attempted to study the perturbation of low tone verbs in isolation, and also in serial construction. Certain minute problems

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of tone force one to consider the possibility of abstracting a continuous morpheme of tone alone, but this is complicated by relation to focus of independent clause. The discussion of this problem is an interesting one, in the context of tone rules in the verb or verb phrase.

The Akan Sub-Group of Kwa, in the Niger-Congo Sub-Family

The Project Director was able to consult with Dr. J. M. Stewart at the Institute of African Studies, University of Ghana, at Legon. Growing out of these discussions there will probably be a twin study on tense and voice quality in Twi--a problem which has long troubled scholars working on West African languages. If the Project Director is able to get laboratory confirmation (by Dr. Ruth Brend) of the phonetic hypotheses, there should grow out of the study results of considerable generalized phonetic interest. In any case, Dr. Stewart will continue with his linguistic analysis of the problem of vowel harmony (under the auspices of the Institute of African Studies).

Lectures to the University of Ghana

While the Workshop was in session, Dr. Pike gave a series of six lectures to students of the Institute of African Studies at the University of Ghana, and another set of six to its Linguistic Department. This collaboration was designed to encourage students of Ghanaian origin to enter into a linguistic career, and to foster interchange of ideas among the professional scholars present.

II.

STUDIES IN PROGRESS

II.

## STUDIES IN PROGRESS

### Group A: Language Processes

Acoustic analysis of the prosody of Jordanian colloquial Arabic (R. M. Rammuny, J. C. Catford)

Categorical perception and discriminability on acoustic and visual continua (J. Kopp, H. L. Lane)

Extension of the Speech Auto-Instructional Device to teaching segmental features of language (J. C. Catford, H. L. Lane, Ruth Oster, S. Ross)

Functions of speaker and listener vowel-spaces in the imitation and identification of spoken vowels (S. Ross)

Investigation of the rhythm of spoken American English (G. D. Allen)

Matching functions, equal-loudness contours, and middle-ear mechanics (S. Ross)

Perception of grammaticalness by aphasic adults (R. S. Tikofsky, Rita Tikofsky)

Perceptual and cognitive processes in speech recognition (J. F. Hemdal)

Syntactic generalization in aphasic adults (R. S. Tikofsky, Rita Tikofsky)

The relation between arousal and the recall of verbal material in connected discourse (F. M. Koen)

The role of distinctive features in phonology in the perception and recall of speech (F. M. Koen, D. M. Elliott)

### Group B: Language Acquisition

Acquisition of Japanese by children (D. McNeill)

Acoustic analysis of the development of the prosodic features of infants' vocalizing (W. C. Sheppard, H. L. Lane)

The use of the Cloze technique in the study of the grammatical skill of retard[illegible] and normal subjects (M. I. Semmel, L. S. Barritt, S. W. Bennett, C. W. [illegible])

Latency and accuracy of responding by retarded and normal subjects to sentence structures (L. S. Barritt, M. I. Semmel, J. Prentice, S. Bennett)

Changes in psycholinguistic functioning as a result of an integrated school setting (L. S. Barritt, M. I. Semmel, P. Weener)

Group C: Language Modification

Differential reinforcement of a vocal operant along three parameters (S. Knapp)

Discrimination program for French teaching fellows (S. Knapp, G. Geis, D. Dugas)

Objectives and techniques for training teachers in classroom control (D. E. P. Smith)

Operant analysis of classroom interaction in foreign language instruction (S. Knapp, G. Geis, D. Dugas, C. Sisson)

Some effects of the behavior of the teacher on discrimination learning by the student (D. M. Brethower)

The role of confirmation in programmed instruction (G. Geis)

Group D: Language Structure

Identification, description and testing of the psychological reality of the paragraph (A. L. Becker, R. E. Young, F. M. Koen)

Project in rhetoric: the identification and analysis of structures beyond the sentence (K. L. Pike, A. L. Becker, R. E. Young)

Tagmemic and matrix linguistics applied to selected African languages (K. L. Pike, Ruth Brend, T. Nicklas, Gisela Kappler)

# III.

# PERSONNEL, CRLLB

## PERSONNEL

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ZALE, Eric M. Ph.D. Michigan. Associate Director of the Center (Dissemination).