

The analysis of the variance breaks down to nine degrees of freedom for treatments (three linear, three quadratic and three interaction), three degrees of freedom for lack of fit, that is, higher-order interactions and three degrees of freedom for true error, if properly randomized.

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Vowel Recognition in Clipped Speech

It would be a great advantage if computers used for translation from one language into another could be provided with voice-operated input equipment. This development, however, depends on the isolation of information-bearing factors in speech, that is, a distinction among different sounds produced by a speaker and an identification of the same sound produced by different speakers.

In the course of work on speech-input devices for a translating machine, clipped speech was examined for the possible extraction of information-bearing factors. Since it is reported to be intelligible¹⁻⁴ while carrying information solely in the temporal pattern of zero-crossings, an apparatus was constructed to analyse the fine structure of the zero-crossings. The apparatus consisted of a magnetic tape player followed by amplifying and clipping circuits. The output was taken through a variable gate to a scaler so that the number of pulses in short intervals of time (of the order of 0.02 sec.) could be counted. The width of the gate was measured by passing generator pulses through it and counting them by means of the scaler. This arrangement, with routine precautions, allowed the number of pulses and time to be determined to an accuracy of about 1 per cent.

The first elementary sounds to be analysed were the vowels, because of their stability⁵⁻⁸ and com-

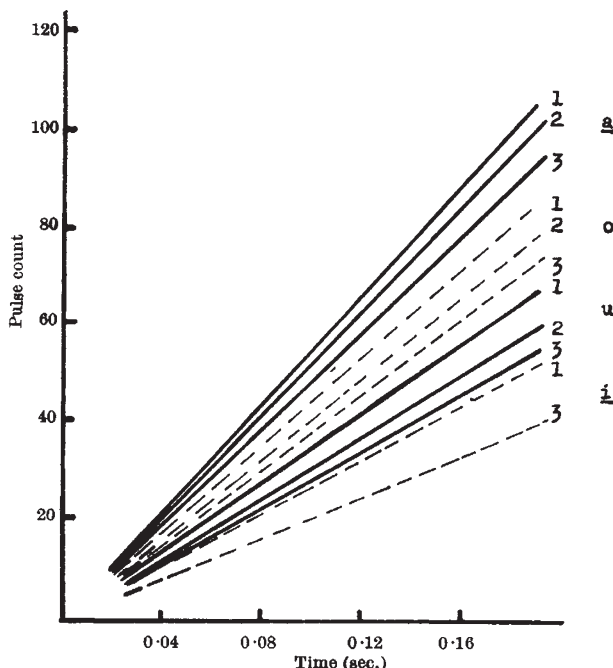


Fig. 1. No. of pulses plotted against time for the vowels *a* (father), *o* (tone), *u* (pool) and *i* (meet), spoken by three persons

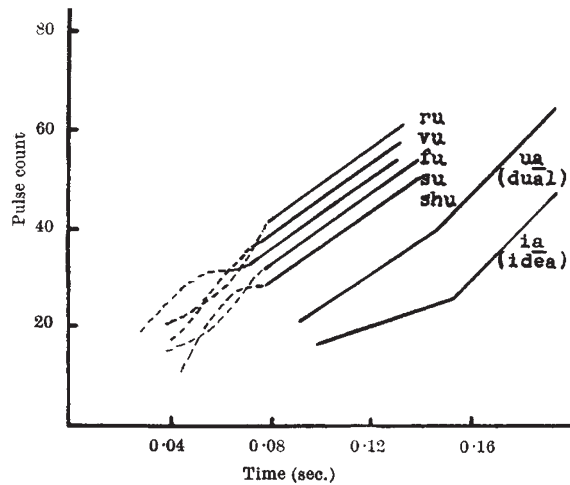


Fig. 2. Characteristic slopes of vowels in combination

paratively easy aural intelligibility. As a result of the experiment it was found that the plots of the number of pulses versus gate-width for the various vowels spoken by different persons were perfect straight lines. The slopes of these lines increased regularly from the vowel *i* (as in 'meet') to the vowel *a* (as in 'father'). Furthermore, the slopes were found to be reproducible within the limits of error of the apparatus. The vowels were thus recognizable singly as well as in combinations. Some of these results are shown in Figs. 1 and 2.

	Counts per sec.			
Voice	<i>a</i>	<i>o</i>	<i>u</i>	<i>i</i>
1	558	450	350	233
2	533	417	317	—
3	491	334	292	218

The constancy of pulse count per second for the various vowels throws some light on the particular feature by which clipped speech conveys information. Since vowels are made up of recurring trains of pulses (and yet they cannot be copied by pulses taken from a generator), it seems obvious that they carry information by: (1) the number of pulses in the interval of fundamental frequency and (2) the width-modulation of these pulses. It is interesting that the number of width-modulated pulses in the fundamental interval may be as small as two to three, as in the case of the vowel *i*.

Further work is being done on width-modulation within the fundamental period, and detailed results of the present study will appear elsewhere.

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