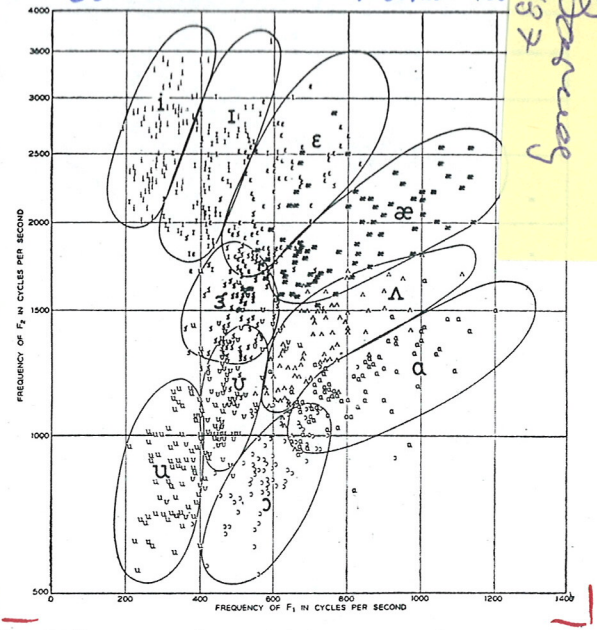

FIG. 8. Frequency of second formant *versus* frequency of first formant for ten vowels by 76 speakers.

steady state period of the vowel. When corrected, these 88 points were within the $\pm 3\ \sigma$ limits. Of the remaining 30 points which were still outside the limits, 20 were the result of the individuals' having produced pairs of sounds which were unlike phonetically, as shown by the results of the listening tests.

The duplicate measurements may also be used to show that the difference between successive utterances of the same sound by the same individual is much less significant statistically than the difference between utterances of the same sound by different individuals. An analysis of variance of the data in Fig. 7 shows that the differences between callings of pairs are not significant. However, the value for the variance ratio when comparing speakers is much larger than that corresponding to a 0.1 percent probability. In other words, if the measurements shown in Fig. 7 for all callings by all speakers were assumed to constitute a body of statistically random data, the probability of having a variance ratio as high as that found when comparing speakers would be less than one in a thousand. There-

fore it is assumed that the dat
random, but that there are s
differences between speakers. Si
for pairs of callings were so near
with the measurements on the sa
speakers, this indicated that the
ments with the sound spectrogr
resolve satisfactorily the differenc
individuals' pronunciations of th

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In Fig. 3, as discussed previou
in the plane of the second form
formant F_1. These areas enclo
repetitions of the sustained v
writers. It is clear that here the vo
readily, simply by plotting F_2 a
the F_2-F_1 plane, points for eac
areas, with no overlapping of
though there exists the variation
which we have discussed above.

The variation of the measure
speakers is much larger than the
in repetitions with the same spea
be shown by the data for F_1 and
In Fig. 8 are plotted the points fo
each speaker, with the points ide
speaker's word list. The closed
have been drawn arbitrarily to
points; the more extreme and isc
regarded so that in general thes
90 percent of the values. The fr
and Fig. 9 are spaced according
to an aural scale described by Ko
1000 cps and logarithmic above.[1]

Considerable overlapping of a
ticularly between [ɜ] and [ɛ], [
[u], and [ɑ] and [ɔ]. In the cas
may be easily distinguished fro
third formant frequency is used,
third formant is very close in fre
second.

The data of Fig. 8 show tha
points in the F_1-F_2 plane is co
sound to sound; these distributio

TABLE I. Classifications of vowels by speakers and by listeners. Vowels as classified by li

	i	ɪ	ɛ	æ	ɑ	ɔ	ʊ