FEIGENBAUM, E. A., & SIMON, H. A. A theory of the serial position effect. *British Journal of Psychology*, 1962, 53, 307-320.

GLANZER, M., & DOLINSKY, R. The anchor for the serial position curve. *Journal of Verbal Learning & Verbal Behavior*, 1965, 4, 267-273.

REYNOLDS, J. H., & HOUSTON, J. P. Rehearsal

strategies and the primacy effect in serial learning. *Psychonomic Science*, 1964, 1, 279-280.

WISHNER, J., SHIPLEY, T. E., & HURVICH, M. S. The serial-position curve as a function of organization. *American Journal of Psychology*, 1957, 70, 258-262.

given monologue and m is the range of sequential constraint (in number of sample units⁴) for the criterion value of chi square with $df = 1$. This formula has been applied at .05 and .01 significance levels to each of 50 monologues described in our previous report,⁵ with results shown in Fig. 1. Independent of criterion stringency, it is observed that no Ss have converged by 0.6 sec and that all have converged by 4.5 sec. Within that range, most converge between 1.5 and 2.7 sec, the median S converging at 1.8 or 2.1 sec, depending on criterion. If we take these values as our best average estimate, we arrive at the satisfying conclusion that speech samples about 2.0 sec apart are statistically independent of each other. This corrected figure approximates the duration of an average breath group in acoustic phonetic research (Lieberman, 1967).

Range of sequential constraint in monologue rhythms¹

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Using an ad hoc model, previous research has found the presence or absence of speech samples taken 4 to 5 sec apart to be statistically independent. The present paper applied a chi-square test to the 5-min monologues of 50 Ss, and found the range of sequential constraint to be 2 to 3 sec. The equivalence of this result to the average breath group in acoustic phonetic research was noted.

In a previous paper from this laboratory (Jaffe, Cassotta, & Feldstein, 1964) it was established that the time pattern of normal speech is adequately described as a two-state Markov process when presence or absence of sound is sampled at appropriate rates.³ Thus, two parameters, q_0 , the conditional probability of speaking given silence in the previous sample, and q_1 , the conditional probability of speaking given speech in the previous sample, together specify the entire distribution of pause and vocalization durations. As the time between samples is increased, the estimates of these parameters converge upon the independent probability of vocalization so that sequential constraint is no longer detectable.

In our earlier report, we suggested that samples taken 4-5 sec apart were

independent of each other, but have subsequently rejected that conclusion for two reasons: (1) The original criterion was based on an ad hoc model, and (2) the resulting estimate was not referable to the duration of any linguistic event.

Since q_0 and q_1 specify the transition matrix of a Markov process, convergence can be redefined as the first nonsignificant difference (chi-square test) between a higher power of this matrix and the matrix predicted by the independent probabilities. In addition, we have found the following direct relation between our two parameters and chi square: $\chi^2 = N (q_1 - q_0)^2 m$, where N is the total number of samples in a

REFERENCES

- JAFFE, J., CASSOTTA, L., & FELDSTEIN, S. Markovian model of time patterns of speech. *Science*, 1964, 144, 884-886.
- LIEBERMAN, P. *Intonation, perception and language*. Cambridge, Mass: M.I.T. Press, 1967.

NOTES

1. We thank Professor Alex Heller of the City University of New York for the derivation of the chi-square formula.
2. Also at City College of the City University of New York.
3. Analogue to digital conversion of the vocal signal at 0.3-sec intervals was performed, with a voice relay time constant that bridged pauses less than 0.2 sec.
4. Multiplication of m by 0.3 sec converts the range of sequential constraint into a time measure.
5. These were the 25 monologues reported for Condition B, plus 25 additional monologues for the same condition analyzed since publication.

Fig. 1. Cumulative percentages of talkers having converged at each sample interval under two significance criteria, .01 ($\chi^2 = 5.412$) and .05 ($\chi^2 = 2.706$).