

# Temporal Coordination of Phonation and Articulation in a Case of Verbal Apraxia: A Voice Onset Time Study

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A study of voice onset time (VOT) in stop production was undertaken in order to investigate the hypothesis that the voicing feature errors in the speech of an apraxic patient (Sands, E. S., Freeman, F. J., & Harris, K. S. 1978, *Brain and Language*, 6, 97-105) were related to deficits in temporal coordination of phonation and articulation. Results demonstrated that the VOTs of the apraxic subject differed markedly from those of normal subjects. The apraxic productions did not include voicing lead for voiced stops. Lag times for voiced stops were longer than normal, while those for voiceless stops were shorter than normal, yielding a compression of the two categories and a marked overlap.

## INTRODUCTION

In our discussion of the results of an analysis of progressive changes in articulatory patterns in verbal apraxia, we (Sands, Freeman, & Harris, 1978) hypothesized that the voicing errors that occurred in 34% of our subject's residual errors resulted from defective temporal coordination of phonation and articulation. A large portion of the subject's voicing errors occurred on stops. Thirty-three percent of his initial voiceless stop productions were perceived by listeners as being voiced.

The present study proposed to test the temporal coordination hypothesis in relation to stop production.

## PROCEDURE AND RESULTS

In order to test the hypothesis that J. P.'s residual problem was one of coordination of upper articulatory and laryngeal events, voice onset time (VOT) was measured for initial stops. The procedures essentially followed

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those used in a classic study of voicing in stops by Lisker and Abramson (1964, 1967). The subjects read a randomized list of words beginning with the six English stops (p/b, t/d, k/g). Wide-band spectrograms were made from the recordings. On spectrograms the oral release of stop occlusion is marked by an abrupt change of acoustic energy, while glottal pulsing is indicated by regularly spaced vertical striations. The time between the release of occlusion and onset of voicing can thus be measured. By convention, the burst is considered as zero time. Glottal pulsing preceding the burst (voicing lead) is measured and expressed as a negative number, while glottal pulsing following the burst (voicing lag) is measured and expressed as a positive number. In the apraxic production there was some instability in voicing not often found in normal productions. Occasionally a few pulses of voicing would occur, and then voicing would cease, to begin again later in the production. For this reason the first pulse of "continuous" voicing was measured.

The results are presented in Figs. 1-3. In each of these figures the top graph presents data on J. P., while the middle and lower graphs present the normative VOT data of Lisker and Abramson (1967).

In their study, Lisker and Abramson (1967) examined VOT for syllable initial stops in both isolated words and words in sentence context. The middle and lower graphs of Fig. 1 illustrate their findings for the bilabials /b/ and /p/. The temporal categories for /p/ and /b/ are relatively discrete with an

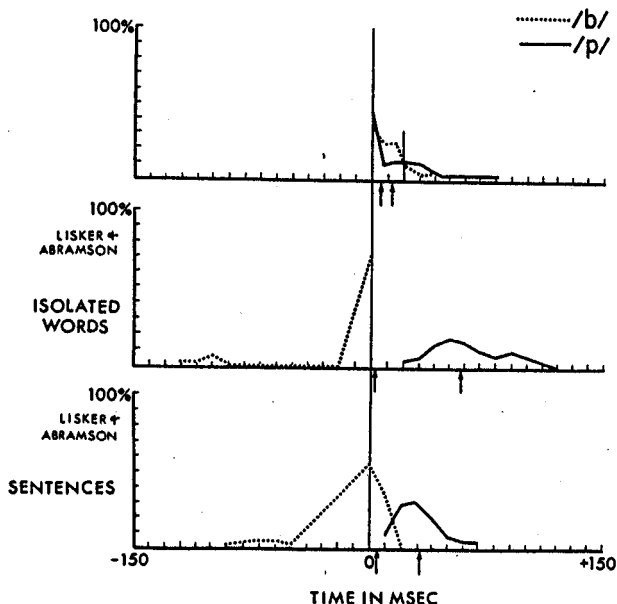


FIG. 1. Comparison of apraxic and normal VOT for bilabial stops.

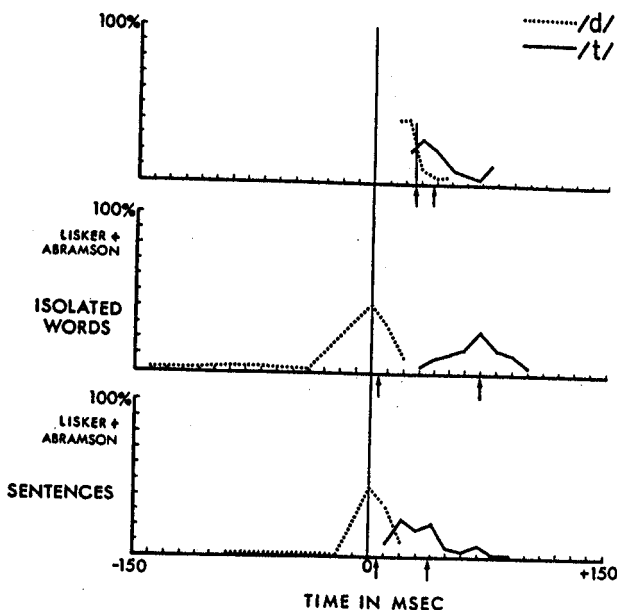


FIG. 2. Comparison of apraxic and normal VOT for alveolar stops.

overlap in the sentence condition only. The /b/ in isolated words ranges from a long lead of  $-130$  msec to a brief lag. In sentences the normals shortened their lead time and occasionally showed a brief voicing lag. Means were calculated separately for voicing lead and voicing lag. (Since J. P. always showed voicing lag, the mean lag times for normals are marked on the figures with arrows.) The /p/ in isolated words ranges from  $+20$  to  $+120$  msec, with a mean of  $+59$  msec (indicated by an arrow in the middle graph). Data for /p/ and /b/ in sentence context are presented in the same format in the bottom graph. The mean lead times for /b/ and /p/ differ by 57 msec for the isolated words and by 28 msec for the words in sentences.

In contrast, J. P. never used a voicing lead. His ranges for both /p/ and /b/ are markedly compressed and show significant overlap. His means for /p/ and /b/ (indicated by arrows in the top graph) differ by only 6 msec. When a line is drawn at the intersection of the VOT distributions for J. P., 70% of his productions fall to the left of this line, and only 30% fall to the right.

Figure 2 presents data for the alveolar stops in parallel format. Normals again show relatively discrete temporal categories for production of these phonemes. For normals the mean lag times differ by over 60 msec for isolated words and by over 30 msec for words in sentences. For /t/ and /d/ J. P.'s categories were again compressed with a difference between means of only 14.5 msec.

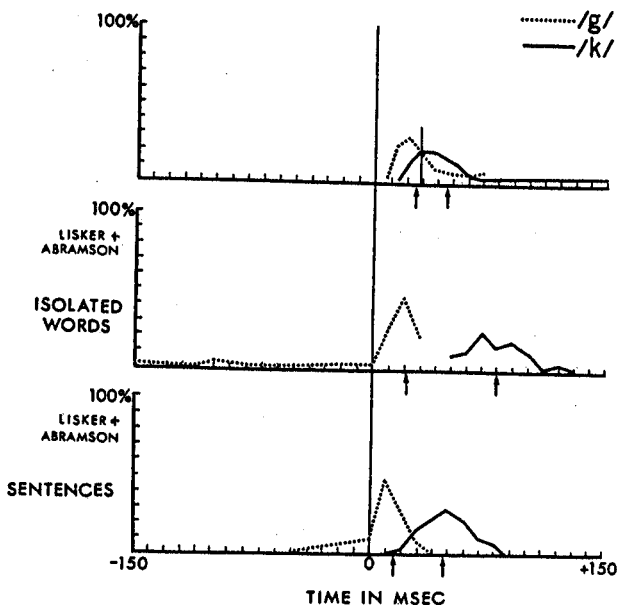


FIG. 3. Comparison of apraxic and normal VOT for velar stops.

The pattern for velar stops /k/ and /g/ (Fig. 3) is very similar. J. P. shows compression of the categories, with the mean for /g/ and the mean for /k/ differing by only 21 msec. Again there is a marked overlap of the two categories.

## DISCUSSION

After analysis of the stop productions was completed, these results were compared with the listener perceptions of J. P.'s stops on the articulatory assessment administered in the earlier study (Sands et al., 1978).

In the VOT study it was found that 30% of J. P.'s /p/ productions fell to the right of the intersect line, while in the articulation study, 37.5% of his /p/ productions were perceived as being /p/. Seventy percent of his /p/ productions had shorter lag times and fell to the left of the intersect line, and 50% of his /p/ productions were perceived as /b/. Despite the use of different sets of utterances, there appears to be a relationship between the subject's VOT and listener perceptions.

The category overlap for his /k/ and /g/ productions also appears to relate directly to listener perceptions. Listeners in the articulation study perceived 75% of J.P.'s /g/ productions correctly, while perceiving 25% of his /g/ productions as /k/. On the VOT study, 78% of J.P.'s /g/ productions fall to the left of the intersect line, while 22% are to the right. A similar relation-

ship between production and perception exists for /k/. Listeners in the articulation study perceived 37.5% of J.P.'s /k/ productions as being voiced and 62.5% as being voiceless. Since 36% of J.P.'s /k/ productions fall to the left of the intersect line, while 64% fall to the right, the intersect line is a highly accurate division of what listeners perceive as /k/ and /g/. The alveolar stops could not be compared in this manner because errors in the articulatory study included manner and place as well as voicing.

There is a well-known hypothesis, expressed by Jakobson (1968), among others, that the defect found in apractic articulation can be considered a regression to a more primitive form of articulation, that of young children. Fortunately, VOTs have been extensively studied in young children, in their earliest word productions and in babbled utterances containing stop-like articulations (Kewley-Port & Preston, 1974). They show that the earliest examples of apical stops, produced around 6 months of age, have uniform distributions along the VOT continuum. Later, the distribution of stops collapses to an interval corresponding to that of American English voiced stops. When recognizable words are first produced, the range of "d" words is quite like short-lag /d/ production in adults. The earliest /t/ words, however, are produced with a voicing lag which would be ambiguously categorized as /t/ or /d/. The VOT distributions produced by J.P. are quite similar to children in this developmental stage; that is, productions have a short lag.

Voice onset time studies of other apraxic speakers are necessary to determine whether this problem is idiosyncratic or a common feature of the disorder. Studies of other temporal parameters, such as fricative and vowel duration, will be necessary to the further understanding of temporal coordination deficits in apraxia. Research in these areas has been undertaken, and preliminary results have been reported (Jensen, MacDonald, & McGurk, 1975; Freeman, Gray, & Sands, 1976). Finally, the authors, as clinicians, were interested in the applicability of these findings to the development of therapeutic strategies. Results of a therapeutic program for teaching voicing lead and lag to J.P. (Leavitt, Sands, & Freeman, 1977) are encouraging.

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