Effects of Word Length on Lip EMG Activity in Apraxia of Speech

Monica S. Hough and Richard J. Klich
Kent State University, Kent, Ohio

Apraxia of speech is a speech disorder in which the motor mechanisms of sequencing, timing, and coordination are disturbed (Kent and Rosenbek, 1983). The disorder is considered to be phonetic in nature since sounds are distorted or substituted because of disturbed neuromotor control.

Researchers generally agree on the following characteristics of apraxia of speech: (1) initiation difficulties exhibited as repetitions of sounds, syllables, or words; (2) a predominance of articulatory substitution and/or distortion errors; (3) more errors as phonetic complexity of an utterance increases; (4) variability of production on repeated trials of polysyllabic words; and (5) errors related more to place than manner of production.

Comparatively few studies have emphasized vowel production in apraxia of speech. Investigations of the acoustic parameters of vowels, such as Kent and Rosenbek (1983), have revealed prolongations, centralization, and slow and inaccurate articulator movements to spatial targets in apraxia of speech. In addition, Collins, Rosenbek, and Wertz (1983) observed that vowel durations are appreciably longer for apraxic than for normal speakers.

One factor affecting vowel duration is word length. Specifically, House (1961) observed that, for normal speakers, the duration of the vowel in a stem word decreases as the length of the word increases. Collins, Rosenbek, and Wertz (1983) found similar results for apraxic speakers. Furthermore, the percentage of time devoted to vowel production systematically decreased for both normal and apraxic speakers as words become longer. This durational reduction may be interpreted as rule-governed phonologic behavior reflecting low-level linguistic knowledge (Lehiste, 1970). These findings suggest that apraxic speakers may retain sensitivity to low-level phonologic encoding.

A similar pattern of durational reduction may be expected in the articulatory gestures underlying vowel production for normal speakers if muscle activity associated with the vowel is influenced by word length. That is, EMG records may reveal a systematic decrease in the duration of muscle activity and/or a decrease in the percentage of time devoted to muscle activity underlying vowel production as words increase in length. Since apraxic speakers also demonstrate reduced vowel duration as words increase in length, it may be that they also systematically reduce the duration of underlying muscle activity associated with vowel production.

Our investigation was of the timing relationships of EMG activity underlying vowel production as a function of changes in word length in normal and apraxic speakers. We specifically examined the onset and offset of EMG activity of lip muscles.

METHOD

Subjects. The subjects were two speakers demonstrating apraxia of speech who were matched to two normal speakers on the basis of age, gender,

height, and weight. All were native English speakers with speech discrimination scores of at least 75% at 40 dB HL. Both apraxic subjects had suffered left CVA's and apraxia of speech was their primary communication deficit. Apraxia of speech was diagnosed on the basis of results on a test for oral movement during speech and nonspeech tasks developed by the first author. The criteria for diagnosis of apraxia of speech were similar to those employed by Fromm, Abbs, McNeil, and Rosenbek (1982); specifically: 1) effortful trial and error groping articulatory behavior, 2) dysprosody throughout segmentally fluent and dysfluent productions, 3) frequent sound substitutions and distortions, 4) inconsistency in presence and nature of errors on repeated productions of the same utterance, 5) difficulty in initiating utterances, and 6) imitative speech better than spontaneous speech.

Materials and Procedures. The experimental speech sample consisted of the vowel /u/ in three sets of words of increasing length (suit, soothe, sue/ suitable, soothing, suing/ suitability, soothingly, suingly). Each word in a set was repeated ten times by each subject. Altogether, each subject produced the vowel ninety times.

Bipolar surface electrodes were placed just below the vermillion zone of the lower lip, near the right corner of the mouth. Both the raw and integrated EMG signals were recorded simultaneously with the waveform of the audio signal. The total duration of each word and the duration of /u/ (in msec) were measured from the audio waveform.

The onset of EMG activity was measured relative to the onset of voicing for the /u/ in each word. This interval was defined as the "EMG onset interval" (EOI). It represented the time in which lip muscle activity was present before the onset of the vowel.

We measured another interval from the onset of vowel voicing to the onset of the reduction of EMG activity during the vowel. This was defined as the "EMG termination interval" (ETI). It represented the time for lip muscle activity to decrease after the vowel onset.

Relative differences between apraxic and normal speakers on utterance duration were accounted for by converting the EOI and ETI (in msec) to percentage measures relative to the total duration of each word. That is, the EOI and ETI were divided by the total word duration and converted to a percentage which expressed EOI and ETI durations relative to total word duration.

RESULTS

Word duration means increased as word length increased for all three sets of words for both normal and apraxic speakers. All mean durations were longer for the apraxic speakers, with the exception of two one-syllable words (soothe and sue) for the apraxic speaker in the first pair of subjects.

The absolute mean EOI durations are shown in Figure 1. Only the means are shown -- the standard deviations for both apraxic subjects typically were about three times greater than those for the normal subjects. No systematic decreases in means as word length increased were observed for the apraxic or normal speakers. Furthermore, no systematic differences were found within each pair of speakers. The EOI's typically were longer for the apraxic speaker in the first pair, but tended to be the same or longer for the normal subject in the second pair.

The absolute mean ETI durations are shown in Figure 2. In almost every case, the means for the apraxic speakers are much longer than those for the

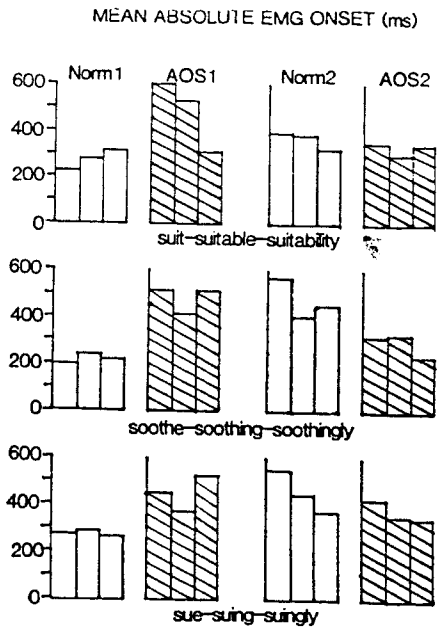

Figure 1. Mean absolute EMG onset for the paired normal and apraxic speakers. AOS = apraxia of speech. Norm = Normal.

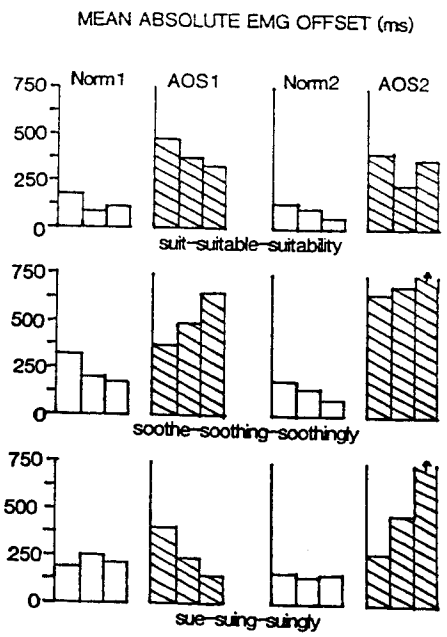

Figure 2. Mean absolute EMG offset for the paired normal and apraxic speakers.

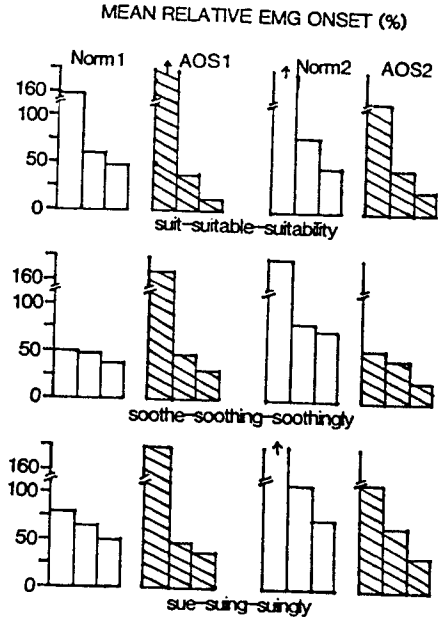

Figure 3. Mean relative EMG onset for the paired apraxic and normal speakers.

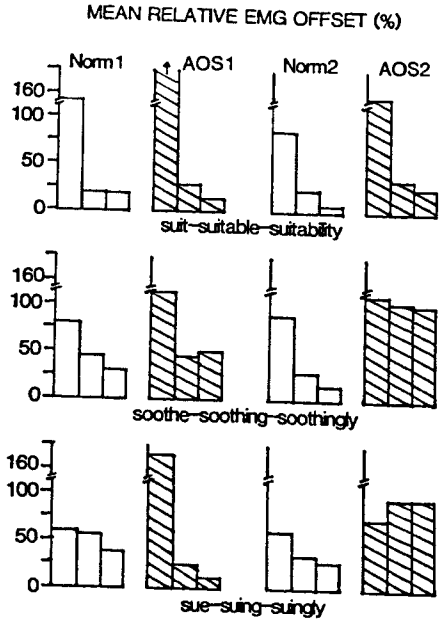

Figure 4. Mean relative EMG offset for the paired apraxic and normal speakers.

normal speakers. This is particularly true for the one-syllable words. Again, no systematic trends associated with word length were found. In two of the three sets (suit/suitable/suitability and soothe/soothing/soothingly), the means tended to decrease with increases in word length in both normal speakers. The ETI also decreased with word length in 2 of the 3 sets for the apraxic subject in the first pair. In the second pair, the ETI tended to increase with word length for the apraxic subject.

The mean relative EMG onsets are shown in Figure 3. For all subjects and all three word sets the relative mean EOI decreased as word length increased. That is, EMG onset systematically became shorter as word length increased. Furthermore, in the polysyllabic words, the relative means for the apraxic speakers tended to be shorter than those for the normals.

The pattern for a relative decrease as word length increased also was seen in the mean relative EMG termination. As shown in Figure 4, this pattern was noted particularly for the normal subjects in all three word sets. Each apraxic subject demonstrates the pattern in only two of the word sets. Furthermore, the relative ETI's on the one-syllable words are longer for the apraxic speakers as were the mean absolute ETI's.

DISCUSSION

These data support findings of Collins et al. (1983) that word duration systematically increases as word length increases for both normal and apraxic speakers. Typically, word durations are greater for the apraxic speakers and probably reflect their disturbance in motor timing.

The findings for absolute mean EOI and ETI suggest that word length has no systematic effect on the duration of muscle activity underlying the lip rounding gesture for apraxic and normal speakers. This finding may be explained by a theoretical framework set forth by Kent (1983), in which articulatory targets are specified within a space coordinate system of the vocal tract. Temporal plans regulate the sequencing of gestures. The plans depend upon initial and/or current conditions, past experience, and desired outcome as factors in formulating speech motor performance. These factors seem to be more important than word length in determining the onset and offset of EMG activity associated with lip rounding for the vowel.

On the other hand, the mean relative EOI data revealed a systematic reduction in the precentage of time spent in preparing for lip rounding for all subjects as words became longer. These results suggest a linguistic influence on the timing of motor activity underlying lip rounding. Furthermore, similarity of the effects for the apraxic and normal speakers suggest that this linguistic influence is resistant to lesions resulting in apraxia of speech.

The results for relative ETI indicated that normal subjects systematically reduced the percentage of time used to terminate muscle activity as word length increased. This systematic effect was not observed as clearly for the apraxic subjects. In the longer words, this suggests that the apraxic speakers had comparatively more difficulty timing the offset of muscle activity when other articulatory gestures followed the target lip rounding gesture. Furthermore, the greater absolute and relative means of ETI for the apraxic speakers on one-syllable words suggests a more general problem with terminating muscle activity. This problem may be associated with neuromotor factors that restrict control of the offset of motor

activity. It also may be due to reduced effectiveness of lower-level phonological influences. That word length affected ETI in some instances for apraxic speakers and in all cases for normal subjects suggests that this phonological influence is applied at the offset as well as the onset of motor speech activity. It may be less influential in apraxia of speech because of a "higher level" planning deficiency, particularly if one views apraxia of speech as having a phonological or phonemic component. However, it also may be that limited neuromotor control interacts in some way to reduce the effect of the phonological influence in terminating muscle activity.

In summary, the results of our study indicate that word length affects the timing of muscle activity at the onset of words in both normal and apraxic speakers. Word length also influences the offset of muscle activity, but its effect is less systematic in apraxia of speech.

REFERENCES

Collins, M., Rosenbek, J.D., and Wertz, R.T. Spectrographic analysis of vowel and word duration in apraxia of speech. Journal of Speech and Hearing Research, 26, 224-230, 1983.

Fromm, D., Abbs, J., McNeil, M., and Rosenbek, J.D. Simultaneous perceptual-physiological method of studying apraxia of speech. In R. Brookshire (Ed.), Clinical Aphasiology: Conference Proceedings, 1982. Minneapolis, MN: BRK Publishers, 251-262, 1982.

House, A. On vowel duration in English. Journal of the Acoustical Society of America, 33, 1174-1178, 1961.

Kent, R.D. The segmental organization of speech. In P.F. MacNeilage (Ed.), The Production of Speech. New York, NY: Springer-Verlag, 57-89, 1983.

Kent, R.D. and Rosenbek, J.C. Acoustic patterns of apraxia of speech. Journal of Speech and Hearing Research, 26, 231-248, 1983.

Lehiste, I. Suprasegmentals. Cambridge: MIT Press, 1970.

DISCUSSION

Q: How do biomechanical variables interact with your findings? Do you think these data can be accounted for by an hypothesized phonological impairment?

A: I believe that apraxia of speech is a motoric deficit and the ETI findings of this investigation are the result of limited neuromotor control interacting with a linguistic variable to reduce the effectiveness of its influence in terminating muscle activity. I mentioned the phonological component since there is not a definitive answer on the underlying deficit in apraxia of speech. There are some researchers who continue to suggest that specific data, such as those in the present investigation, can be accounted for by viewing apraxia of speech as having a phonological as well as a motoric component.

Q: What populations might you want to use as a control group for the apraxic speakers?

A: Aside from normal subjects?

Q: Yes.

A: Possibly dysarthric subjects and individuals identified as demonstrating fluent aphasia.

Q: What do you think the EMG patterns for fluent aphasias might be, based on decreasing word length?
A: It is difficult to say because we are discussing a low-level linguistic influence. The severity of linguistic involvement might play a role in the results.

Q: How long postonset were the apraxic subjects?
A: Both were chronic patients beyond two years postonset.

Q: What were their speech patterns like?
A: They both had difficulty initiating speech, with laborious productions, distortions, and occasional substitutions. Both subjects, however, could speak and communicate.

Q: I would like to make a comment about linguistic influences. There are other conditions that we have to deal with that are also influenced regularly and consistently by linguistic variables, including the dysarthrias and stuttering. There is literature that suggests that the integrity of production of cleft palate speech is also influenced by linguistic variables. I think that all this bears remembering when we are dealing with this troublesome issue of what the condition is really like.
A: Thank you. That is a very good point.

Q: What do these data represent in regard to whether these were correct productions or reasonable facsimiles, and were they repetitions?
A: Yes.

Q: How many attempts did you have to get before you got the data that you analyzed?
A: For the apraxic speakers, it was mainly initiation problems or restarts and sometimes they attempted between two to four times beforehand, but not on every utterance. Sometimes they were able to repeat the target utterance right away.

Q: Did you keep the equipment running through these initiation problems?
A: Absolutely, all through each subject run.

Q: I'm just wondering what the data you didn't analyze might tell you.
A: That is interesting because it is something we are in the process of examining. I do think that both subjects, even though they showed the patterns I discussed, were different in some respects. One of the patients had more of a true timing deficit. He seemed to be able to select and sequence phonetic gestures appropriately but his timing of production just seemed to be off target. The other patient seemed to have difficulty in selecting the gesture. She would sometimes write down the word correctly and say, "I can't say it -- that's the word I want to say -- you just told me it." She was selecting the phonemes appropriately but she could not select the gestures.