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# Consistency, Variability, and Target Approximation for Successive Speech Repetitions Among Apraxic, Conduction Aphasic, and Ataxic Dysarthric Speakers

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The classification and differential diagnosis of apraxia of speech (AOS), conduction aphasia (CA), and many of the dysarthrias remain matters of theoretical and clinical concern and controversy (Rosenbek & McNeil, 1991). Differential diagnosis is traditionally based on analyses of several speech features: speech error types such as sound substitutions or distortions, linguistic error types following a feature or markedness analysis, and prosodic analyses to potentially distinguish phonetic (motoric) from phonemic (linguistic) level errors. Differential performance is also thought to be reflected in the *consistency of error location*, in the *variability of error type*, and on the *degree of approximation toward the target achieved on successive attempts* toward a single target production.

No single set of criteria is shared among clinicians or researchers regarding the direction of prediction or magnitude of effect for the three variables of consistency of error location, variability of error type, and successive approximations to differentiate AOS, phonemic paraphasia, and dysarthria. However, there appear to be patterns of performance that many clinicians use to guide their differential diagnostic efforts. Inconsistency of error location (Wertz, LaPointe, & Rosenbek, 1984), variability of error type (Wertz et al., 1984), and improved ability to reach the target on successive attempts[1] (Darley, 1982; Johns & Darley, 1970; Wertz et al., 1984) are three traits reported to characterize apraxic speech. Increasingly accurate phonemic approximations to the target across successive efforts (Joanette, Keller, & Lecours, 1980) and speech errors that are consistent in location and nonvariable in type[2] have been considered characteristic of subjects who produce phonemic paraphasias, such as CA subjects (Joanette et al., 1980). Dysarthric speakers are traditionally described as producing errors that are consistent in error location and nonvariable in type (Darley, Aronson, & Brown, 1975; Wertz et al., 1984).

Although these distinctions exist clinically, insufficient data exist to justify their adoption. Therefore, the current study sought to contribute to the data base by investigating differences in consistency of error location, variability of error type, and pattern of articulatory error on successive efforts on the same utterance among carefully selected AOS, CA, and ataxic dysarthric (AD) subject groups.

# METHOD

## Subjects

Sixteen subjects participated in the study, four in each of the following categories: AOS, CA, AD, and a normal control group. Identification of the presence of AOS, CA, and AD was made perceptually using guidelines consistent with those described above. Performance on various speech measures was analyzed to generate the speech diagnosis for each subject; these measures included the *Apraxia Battery for Adults* (ABA) (Dabul, 1979), verbal subtests from the *Porch Index of*

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1. See LaPointe and Horner (1976) for evidence that alterations in error place, type, or number are not always reported for apraxic subjects on successive productions of the same utterance.

2. Conduction aphasic subjects' substitution errors have been reported to be "highly unsystematic" in the sense that a predictable pattern of replacements when errors occur is not apparent (Nespoulous, Joanette, Ska, Caplan, & Lecours, 1987). This observation, however, is derived from cross-word error analysis; that is, the variability of error type is not derived from successive productions of the same word, as is the case for the data in the current investigation.

*Communicative Ability* (PICA) (Porch, 1967), conversational speech, Cookie Thief description from the *Boston Diagnostic Aphasia Exam* (BDAE) (Goodglass & Kaplan, 1983), and each subject's repetition of his or her own utterances on this picture description task. Subjects within each group exhibited no speech or language disorder other than the specified speech–language diagnosis. Criteria for subject selection are outlined in Table 1. Full subject description and classification procedures are detailed in an earlier paper (Odell, McNeil, Rosenbek, & Hunter, 1990).

All subjects were administered additional measures, including the *Revised Token Test* (RTT) (McNeil & Prescott, 1978), the *Word Fluency Measure* (Borkowski, Benton, & Spreen, 1967), the *Coloured Progressive Matrices* (Raven, 1962), the BDAE (Goodglass & Kaplan, 1983), and an oral mechanism structural-functional exam. The speech, language, and cognitive status of the subjects in each of the four groups is described in Table 2. The normal subjects will not be discussed in this article as they produced too few errors for meaningful analysis.

## Experimental Stimuli

The speech stimuli consisted of single words that were either two, three, or five syllables in length, taken from the Repeated Words subtest of the ABA. Subjects repeated each word three times after the examiner's live voice model. Productions were audiotaped for later analysis. Perceptual judgments and narrow phonetic transcriptions were conducted by two experienced transcribers using the principles of the International Phonetic Alphabet (judgment and reliability figures for each analysis are included in the appropriate sections in the following text). No restrictions were placed on subjects regarding response time, production rate, or whether each repetition of the target was completed. All subjects attempted the required three repetitions of each target.

## Analysis

Four types of analyses were undertaken. Two analyses, *consistency of error location* and *variability of error type,* focused on errors of sound segments within final productions on each trial. The remaining analyses, labeled *starters* and *attempts,* dealt with speech aberrations prior to the ultimate productions of words. Description of each analysis procedure and reporting of the associated findings are discussed below in separate sections.

**Table 1. Summary of Biographical and Descriptive Data for the Normal Control (N), Speech Apraxic (AOS), Conduction Aphasic (CA), and Ataxic Dysarthric (AD) Subjects**

| | *Subjects* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Measure* | *N1* | *N2* | *N3* | *N4* | *N5* | *AOS1* | *AOS2* | *AOS3* | *AOS4* |
| Gender | M | M | M | M | M | M | M | M | M |
| Age | 67 | 57 | 63 | 64 | 69 | 59 | 62 | 54 | 72 |
| S-F Exam.[1] | WNL | WNL | WNL | WNL | WNL | WNL[2] | WNL | WNL | WNL[2] |
| Total RCPM[3] | 32 | 33 | 33 | 29 | 31 | 27 | 28 | 30 | 28 |
| Total WFM[4] | 51 | 30 | 57 | 34 | 34 | 13 | 4 | 11 | 31 |
| O.A. PICA[5] | 14.73 | 14.84 | 14.65 | 14.51 | 14.53 | 14.66 | 14.33 | 14.53 | 14.96 |
| O.A. RTT[6] | 14.35 | 14.83 | 14.81 | 14.15 | 14.88 | 13.94 | 12.08 | 12.23 | 14.07 |
| BDAE Aud. Comp.[7] | 119 | 117 | 112 | 117 | 117 | 116 | 113 | 118 | 116 |
| BDAE Speech Ratings:[8] | | | | | | | | | |
| 1. Artic. Agility | 7 | 7 | 7 | 7 | 7 | 2 | 4 | 3 | 1 |
| 2. Phrase Length | 7 | 7 | 7 | 7 | 7 | 7 | 4 | 4 | 4 |
| 3. Melodic Line | 7 | 7 | 7 | 7 | 7 | 3 | 4 | 4 | 2 |
| BDAE Total Sent. Rep. w/o Errors[9] | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 1 | 1 |
| Apraxia Bat. For Adults:[10] | | | | | | | | | |
| 1. Total Limb | 48 | 50 | 50 | 50 | 49 | 47 | 50 | 48 | 45 |
| 2. Total Oral | 50 | 50 | 49 | 50 | 49 | 43 | 37 | 49 | 43 |

| | *CA1* | *CA2* | *CA3* | *CA4* | *AD1* | *AD2* | *AD3* | *AD4* |
|---|---|---|---|---|---|---|---|---|
| Gender | M | M | M | M | F | M | M | F |
| Age | 48 | 66 | 60 | 62 | 44 | 53 | 55 | 32 |
| S-F Exam. | WNL | WNL | WNL[11] | WNL[11] | ABN[12] | ABN | ABN | ABN |
| Total RCPM | 33 | 26 | 32 | 27 | 32 | 28 | 18 | 36 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total WFM | 7 | 9 | 16 | 11 | 62 | 49 | 6 | 61 |
| O.A. PICA | 13.98 | 14.39 | 14.13 | 14.87 | 14.90 | 14.70 | 14.30 | 14.20 |
| O.A. RTT | 10.80 | 12.08 | 13.04 | 13.94 | 13.61 | 14.53 | 14.17 | 14.87 |
| BDAE Total Aud. Comp. | 110 | 115 | 117 | 114 | 117 | 117 | 113 | 119 |
| BDAE Speech Ratings: | | | | | | | | |
| 1. Artic. Agility | 6 | 5 | 5 | 5 | 1 | 4 | 3 | 2 |
| 2. Phrase Length | 7 | 5 | 5 | 5 | 7 | 7 | 7 | 7 |
| 3. Melodic Line | 7 | 5 | 7 | 5 | 4 | 7 | 6 | 2 |
| BDAE Total Sent. Rep. w/o Errors | 1 | 1 | 1 | 3 | 8 | 7 | 7 | 7 |
| Apraxia Bat. For Adults: | | | | | | | | |
| 1. Total Limb | 40 | 45 | 50 | 50 | 50 | 48 | 40 | 47 |
| 2. Total Oral | 48 | 49 | 49 | 49 | 49 | 50 | 49 | 49 |

*Notes:*

[1]S-F Exam—Structural–Functional Examination.

[2]WNL—There was a questionably right-sided lingual weakness on clinical examination that was not confirmed with additional testing for this subject.

[3]Total RCPM—Total number correct on the Raven *Coloured Progressive Matrices.*

[4]Total WFM—Total *Word Fluency Measure* score.

[5]O.A. PICA—Overall score on the *Porch Index of Communicative Ability.*

[6]O.A. RTT—Overall score on the *Revised Token Test.*

[7]BDAE Aud. Comp.—Total number correct on all four auditory comprehension subtests of the *Boston Diagnostic Aphasia Examination.*

[8]BDAE Spch. Rtg.—Ratings assigned for articulatory agility, phrase length, and melodic line from the rating of speech characteristics section of the *Boston Diagnostic Aphasia Examination.*

[9]BDAE Total Sent. Rep. w/o Errors—Total number of sentences repeated without articulatory errors from the sentence repetition subtest of the *Boston Diagnostic Aphasia Examination.*

[10]Apraxia Bat. for Adults—Total score on the limb and oral apraxia subtests from the *Apraxia Battery for Adults.* (A score of 50 represents error-free performance.)

[11]WNL—There was a question of oral sensory diminution on clinical examination in this subject.

[12]ABN—Multiple oral sensorimotor abnormalities were exhibited by all dysarthric subjects.

**Table 2. Criteria for Subject Selection of Each of the Four Subject (Normal Control, Apaxic, Conduction Aphasic, Ataxic Dysarthric) Groups**

*Normal control*

1. Normal speech and language as determined by a battery of tests
2. Normal neurologic examination

*Apraxic*

1. Presence of
   a. Effortful trial-and-error groping on the initiation of speech gestures
   b. Frequent single-feature sound substitutions
   c. Articulation and prosody as accurate on imitation as on spontaneous speech
   d. Variability of articulation and prosody on repeated trials of the same utterance
   e. *Boston Diagnostic Aphasia Examination* (BDAE) ratings between 1 and 4 on articulation agility, phrase length, and melodic line
2. Without evidence of weakness or incoordination of the speech musculature when used for reflexive or automatic acts
3. At or above the 1st percentile for normal subjects on the average of subtests II, III, V, VI, VII, VIII, X, and XI of the *Porch Index of Communicative Ability*
4. A score of 22 or above on the Raven *Coloured Progressive Matrices*

*Conduction aphasia*

1. Without evidence of apraxia of speech as defined above or dysarthria as defined below
2. Presence of
   a. Frequent sound substitutions occurring more frequently in repetition than spontaneous speech
   b. BDAE speech ratings between 4 and 7 on articulation agility, phrase length, and melodic line

*Ataxic dysarthria*

1. Same cognitive and linguistic inclusion criteria as the apraxic subjects defined above
2. Neurologic history and examination consistent with a lesion or disease involving the cerebellar system
3. Diagnosis of ataxic dysarthria using Darley, Aronson, and Brown's (1969) perceptual criteria

# CONSISTENCY OF ERROR LOCATION

## Definition and Calculation

Each sound segment was analyzed for error within each of the three trials per target. Errors occurring two or three times on the same sound segment across the three consecutive trials were counted. In Figure 1, consistency of error location is demonstrated in the top example; an AOS subject produced a sound segment error on the same sound in the same location across all three trials of the word *banana*. The bottom example illustrates inconsistency; a CA subject produced three different location errors on *butterfly*. All segmental errors were summed across the 30 total word trials, and the percentage was calculated across trials.

## Reliability

Initial transcription of the speech samples was completed by the transcribers using a consensus transcription technique, described by Shriberg, Kwiatkowski, and Hoffman (1984) (see Odell et al., 1990, for

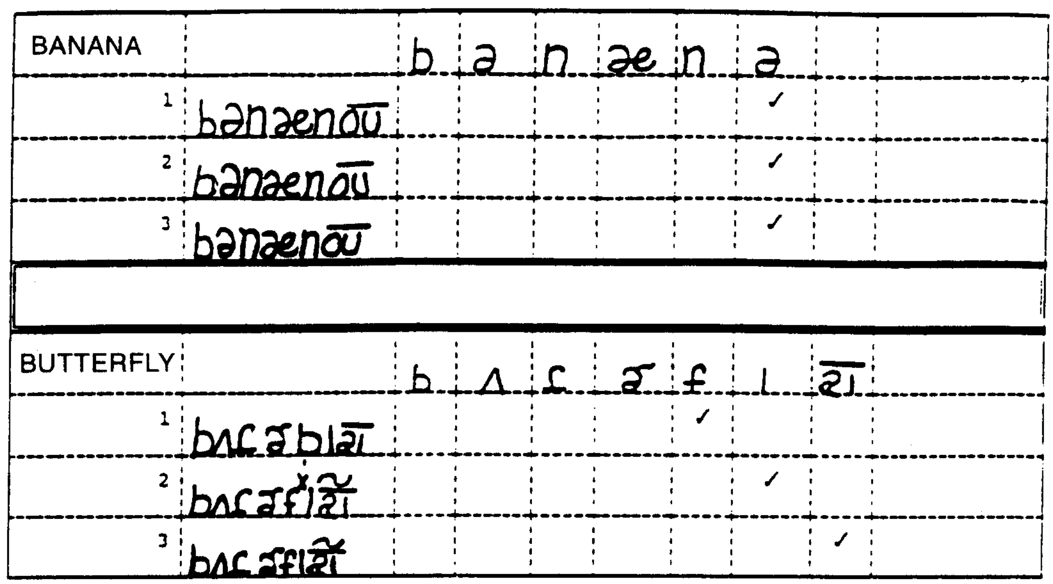


**Figure 1.** Example of the procedures used for measuring consistency of error location. A check indicates presence of an error; the location of error in the linear order of segments in each instance of error was made and compared across trials.

details of the procedure as applied to these data). A subset of the total corpus of words per speech sample was retranscribed by the original transcribers 9 months later. Overall item-to-item agreement at the narrow transcription level on the two transcriptions of consonants was calculated as 77% (Odell et al., 1990; Odell, McNeil, Rosenbek, & Hunter, in preparation); overall item-to-item narrow phonetic transcription agreement of vowels was calculated at 97% for AOS, 96% for CA, and 85% for AD productions (see Odell, McNeil, Rosenbek, & Hunter, 1991, for details).

## Results

As shown in Figure 2, panel A, the AOS group was consistent in location of error productions 90% of the time, with a small range (86% to 94%) across the four subjects. Specific segments in error on one trial were highly likely to be in error on subsequent trials. In contrast, the

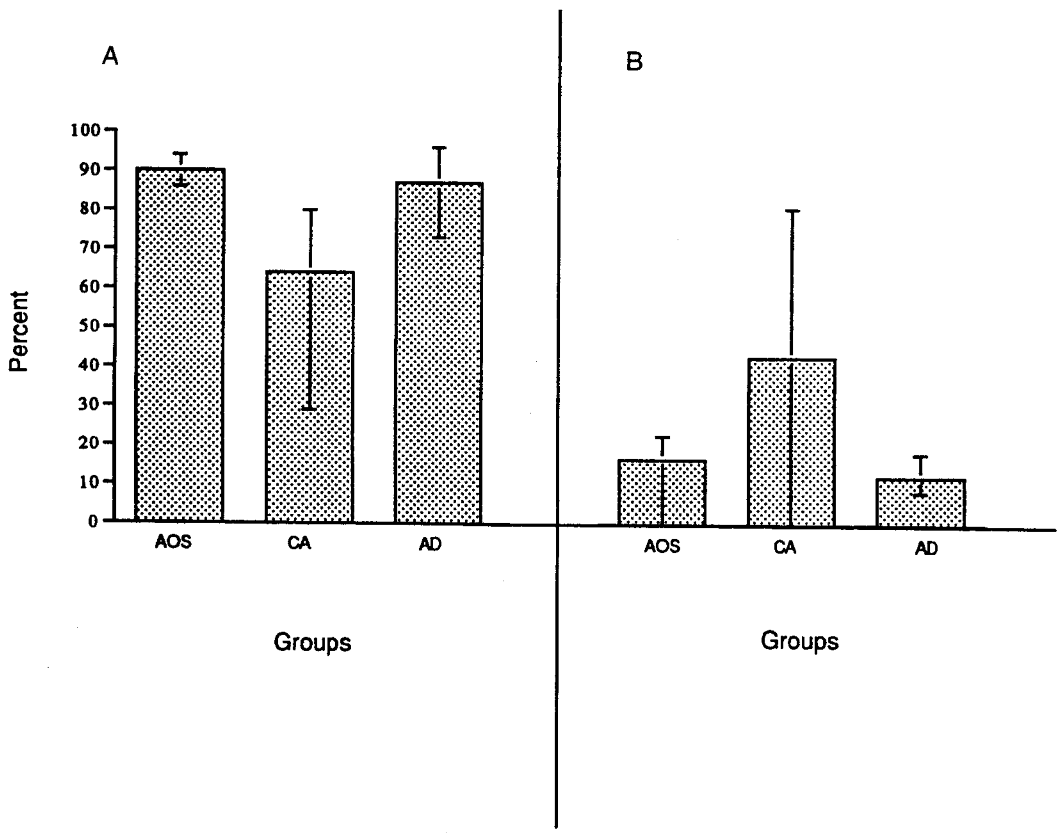


**Figure 2.** Mean levels and ranges of performance on indices of consistency of error location (panel A) and variability of error type (panel B). AOS = apraxia of speech; CA = conduction aphasia; AD = ataxic dysarthria.

CA group was less likely than the AOS group to err in the same location of the word, as evidenced by a mean consistency score of 64%; greater individual variation was seen in this population, as indicated by a performance range of 29% to 80% consistency. The AD group was, like the AOS group, highly consistent in error location, with a mean of 87% and a moderate range of performance from 73% to 96%.

## VARIABILITY OF ERROR TYPE

### Definition and Calculation

Percentage of variability was calculated as the number of error types that differed from each other within the same location of a word, divided by the number of errors in that location. The greater the number of different error types on a particular segment, the greater the variability. This scoring procedure is illustrated in Figure 3. As shown in the top example, one CA subject produced three different errors in the same sound segment of the word *ashtray* across three trials. Nonvariance is seen in the bottom example; an AOS subject produced the same type of error in each of the successive productions of *banana*.

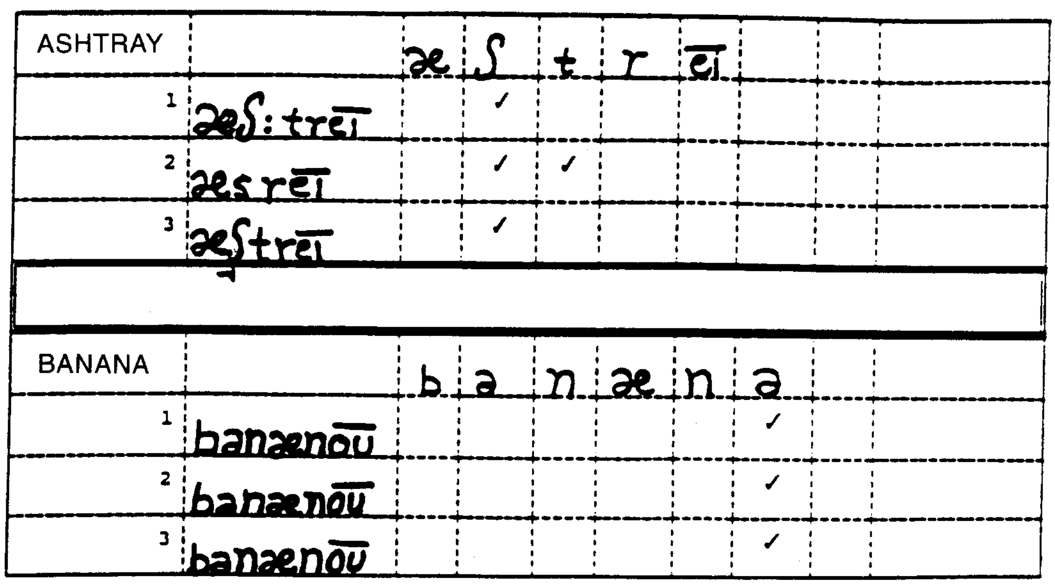


**Figure 3.** Example of the procedures used for measuring variability of error type. A check indicates presence of an error; a comparison was then made of error type across all instances of error on that segment.

## Reliability

See discussion in the consistency of error section, above.

## Results

As shown in Figure 2, panel B, the AOS group's error types varied only 13% (range 0% to 16%), the CA group produced a mean of 26% variability (range 0% to 45%), and the AD group exhibited minimal error type variability of 10% (range 8% to 13%). Thus, the CA group, on average, produced twice as much variety in error type as either the AOS or the AD group; these latter two groups performed similarly. One subject in each of the AOS and CA groups did not make any variable errors, whereas all AD subjects did.

# STARTERS AND ATTEMPTS

## Definitions

An absence of auditorily perceived groping or struggling within all groups led to the analysis of speech behaviors labeled starters and attempts, which we defined as follows:

*Attempt:* Any phonemic or audible nonphonemic utterance occurring prior to the final production that was separated from it by any perceived silence.

*Starter:* An audible initial sound, syllable, or word characterized by a smooth transition into the final production, with no perceivable pauses or breaks.

In all groups, these vocalizations or silences prior to an ultimate production were not perceived as uncontrolled, as the terms *groping* and *struggling* suggest. Flailing searches for the target sound, evidenced as repetitive or uncertain incorrect sounds, were not detected on the audiotapes from which the data were transcribed. Typically, subjects either initiated vocalization fairly clearly, although perhaps incorrectly, or made repeated initial attempts that were close to or on target. An additional reason to avoid the terms groping and struggling was that the transcribers relied fully on audiotapes and had no recourse to video images, which are often the source of evidence for silent groping for articulatory positions. Because they made so few of these types of aberrations, the AD subjects are not included in this discussion.

## Reliability

Within-transcriber reliability was 87% for the detection of errors and 68% for assignment of the same error type (attempt or starter) from the first to the second transcription.

## Results

**Attempts.** Because considerable similarities were found between starters and attempts in type and frequency of occurrence, the ensuing results and discussion focus on attempts, with merely a brief summary of starter findings.

As illustrated in Figure 4, the AOS group produced 22 attempts across all trials (mean: 18%; range: 0% to 57%), whereas the CA group produced a total of 42 attempts across all trials (mean: 35%; range: 13% to 83%). Because in some instances more than one attempt per target was produced, the means and ranges reported here refer to the overall frequency of attempts relative to the entire corpus of words. When target words were preceded by attempts, as shown in panel B of Figure 4, the AOS group produced the target word (at a broad phonetic transcription level) 27% of the time (range: 0% to 53%), while the CA group reached the target production on 71% of all trials (range 48% to 100%).

Considering all productions, not only those preceded by attempts, the AOS group executed correctly (at a broad transcription level) 79% of the target words, with 22 attempts. In contrast, the CA group made more attempts (42) but achieved the target more often (93% of the time). Thus, although CA subjects appeared to have more difficulty with initiation, their ultimate whole word productions were accurate more often than those of the AOS subjects.

Four additional analyses were conducted to describe how the groups approached the target on successive trials. As shown in Figure 5, 46% of the attempts produced by the AOS group occurred on trial 1, 14% on trial 2, and 41% on trial 3. However, the CA group made progressively fewer attempts leading to the final production on each trial (56% on trial 1, 25% on trial 2, and 19% on trial 3). In the process of achieving the target, the CA group was more systematic than the AOS group.

The percentage of attempts according to the apparent length of speech unit that characterized the attempt is exhibited in Figure 6. AOS sub-

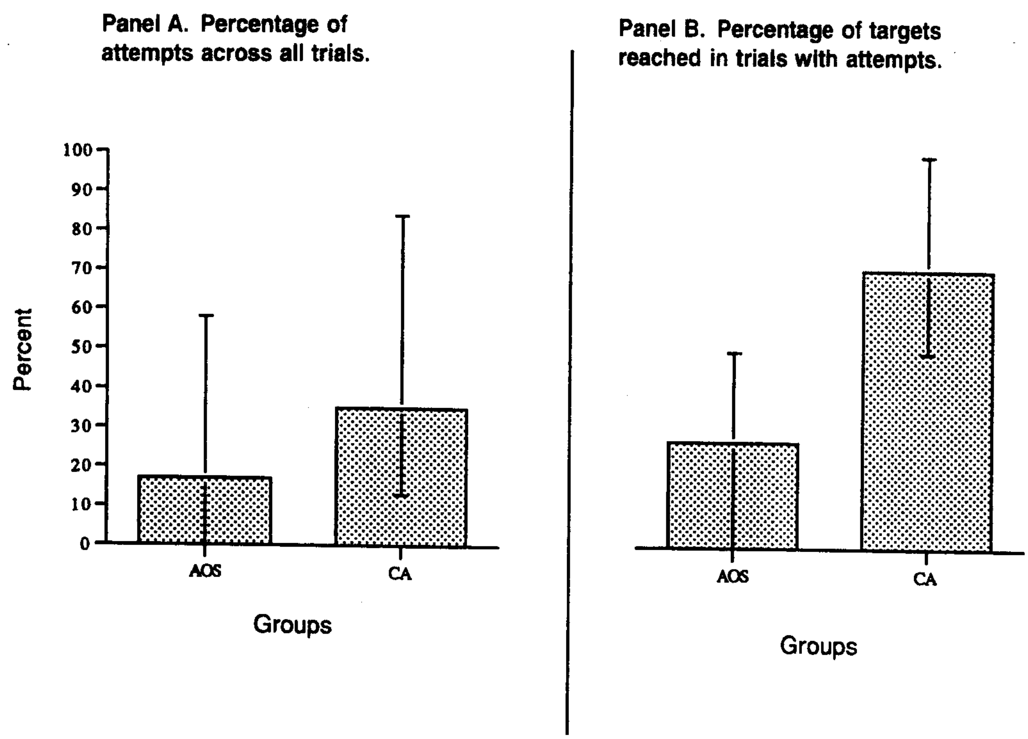


**Figure 4.** Mean levels and ranges of aspects of *attempt* production in the apraxia of speech (AOS) and conduction aphasia (CA) groups.

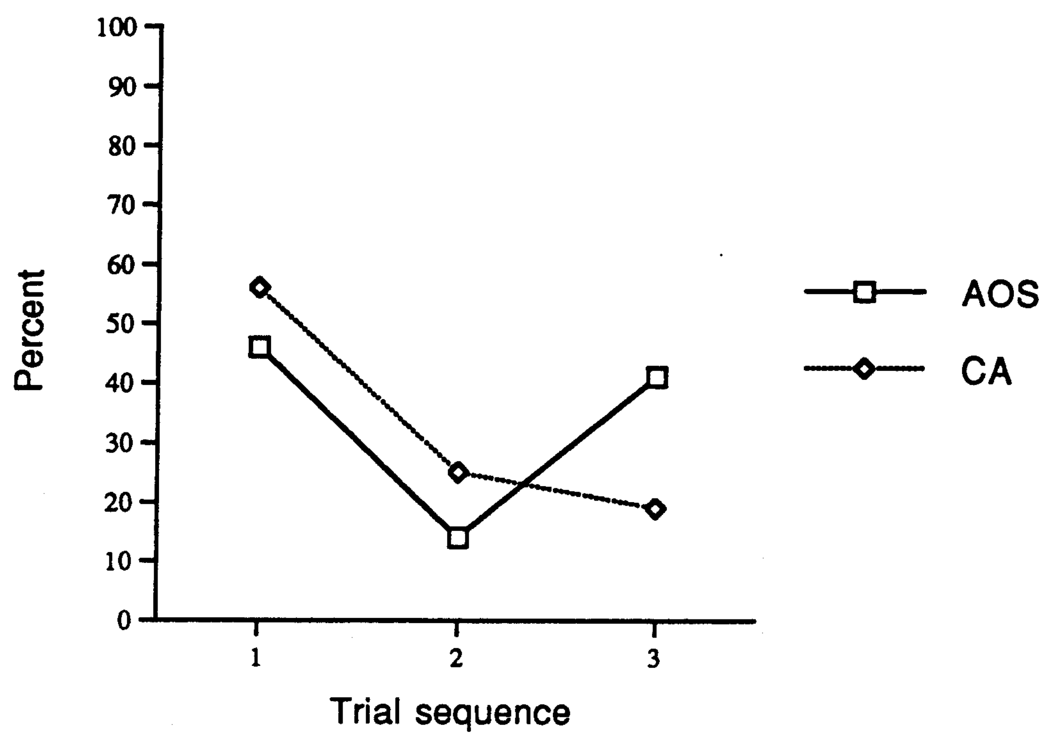


**Figure 5.** Percentage of all attempts produced by the apraxia of speech (AOS) group and by the conduction aphasia (CA) group on each trial.

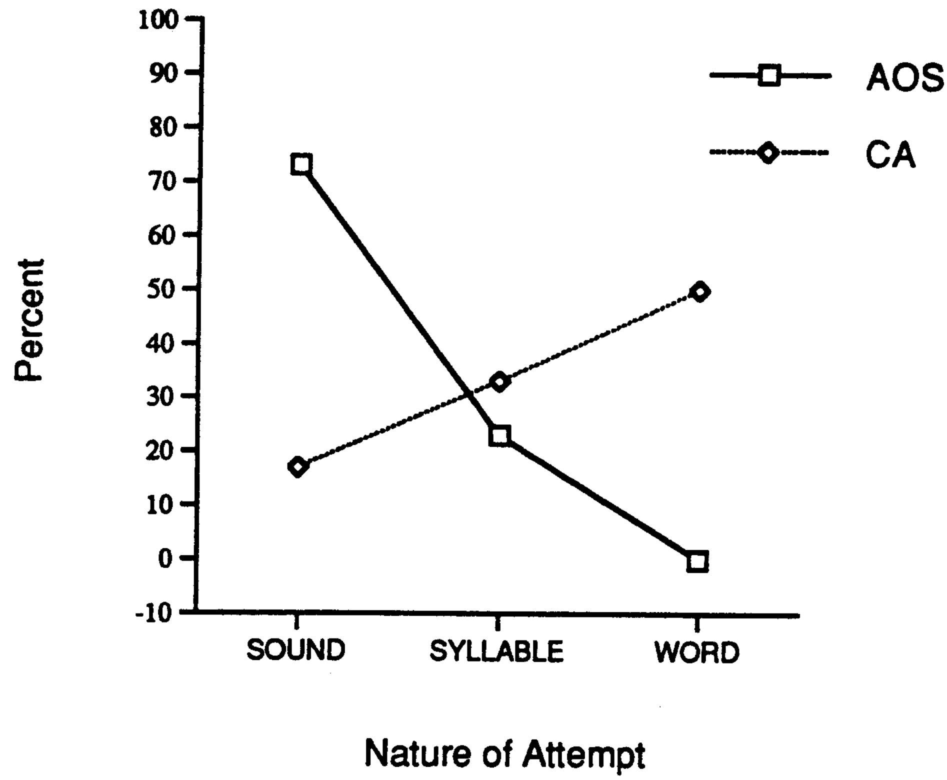


**Figure 6.** Percentage of attempts according to length of speech unit for the apraxia of speech (AOS) group and the conduction aphasia (CA) group.

jects produced primarily attempts at the sound level (73%), substantially fewer at the syllable level (27%), and none at the word level. In contrast, CA subjects produced primarily word level attempts (50%), followed by syllable level (33%) and sound level (17%) efforts.

The number of individual sounds within attempts was counted to determine the percentage of sounds that were shared with the target. Panel A of Figure 7 summarizes these percentages for the AOS and CA groups. A mean of 54% (range: 52% to 58%) of the sounds in attempts were shared with the target in the AOS productions; the CA group produced more sounds in attempts that were also present in the target (71%; range: 49% to 78%).

Finally, the percentage of sound sequences, defined as two or more sounds in sequence that were shared with the target, was also determined. As shown in panel B of Figure 7, only 17% of the AOS group's attempts had shared sound sequences; over three times as many shared sound sequences (60%) were evidenced in the CA group attempts.

**Starters.** The percentage of starters evidenced by the groups at the sound, syllable, or word level was computed. The AOS group pro-

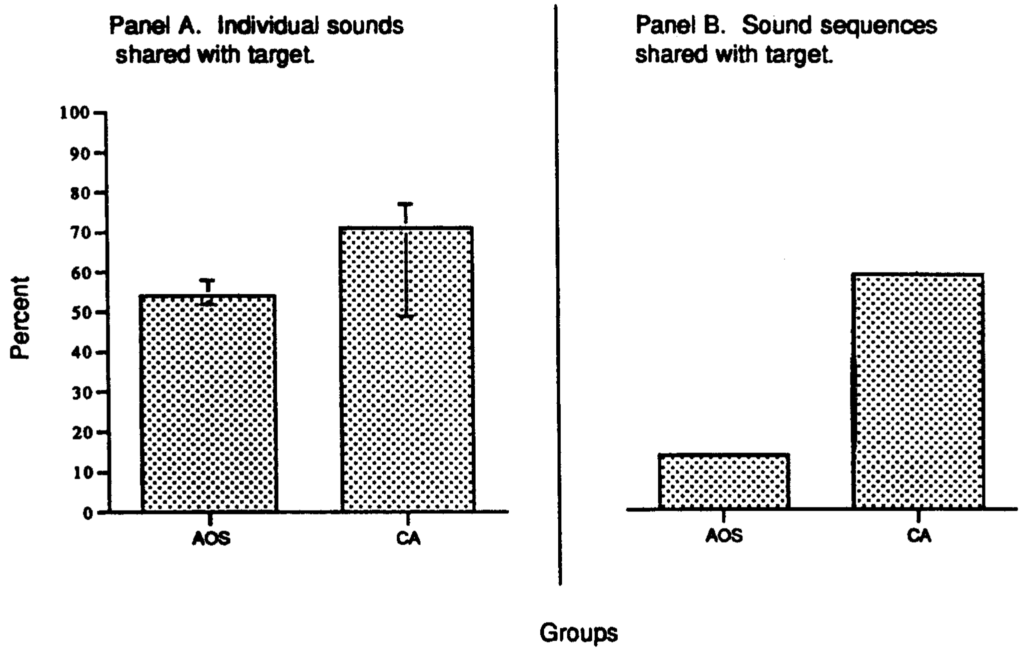


**Figure 7.** Mean levels and ranges of production of various length sound units shared with targets for the apraxia of speech (AOS) group and the conduction aphasia (CA) group.

duced more sound (58%) than syllable (43%) or word (0%) level starters. In contrast, the CA group produced more syllable (43%) than either sound or word (both 14%) level starters. It is the differential pattern rather than magnitude of effects that separates the groups on this metric.

The percentage of starters made on each of the three consecutive trials was computed for the AOS and CA groups. CA subjects produced progressively fewer starters across trials (trial 1 = 56%; trial 2 = 37%; trial 3 = 18%). AOS subjects produced a different pattern, with an equivalent percentage of starters on trials 1 and 3 (43%) but less on trial 2 (17%). Again, the difference in pattern distinguishes these two groups of neurogenic speakers.

## DISCUSSION

As anticipated, intergroup differences were found in consistency of error location, variability of error type, and the nature and eventual achievement of the goal on successive trials. However, aspects of these findings are contrary to accepted clinical beliefs. The observed CA group pattern of low consistency of error location and high error type variation, relative to the AOS group, actually fits the description typically offered for AOS speech (Wertz et al., 1984). The pattern in the AOS group of high consistency of error location and low error type variation also counters the beliefs of many theorists and clinicians. The AD group generally performed as expected and similarly to the AOS group on these two measures. There was greater range of individual performance by subjects in the CA group than in either of the other groups.

Concerning attempts and starters, participants in the CA group differed from those in the AOS group in various ways. They produced fewer attempts across each successive trial, more word level attempts, and more shared isolated sounds and sound sequences with the target, and they achieved the target more often when final productions were preceded by attempts. CA subjects seemed to ultimately benefit more from the production of attempts than did AOS subjects. Also in contrast to AOS subjects, CA subjects produced more syllable than sound or word level starters and progressively reduced the percentage of starters across trials.

These findings differ from the commonly held beliefs about differential articulatory patterns among CA and AOS speakers for single-word imitative productions. However, these findings must be considered preliminary. Several features of this study impose a limitation on the generalizability (external validity) of the results: the small number of subjects in each pathological group, the limited number of speech tokens and repetitions, and the use of bi- or multisyllabic words in contrast to longer utterances. However, it is these stimuli, or ones very similar, that are components of the diagnostic tests for these populations. Other precautions to immediate adoption of the results of this study include the individual variation within groups, the moderate level of transcriber reliability, the lack of established temporal reliability in subject productions, and the possible differences between AOS subjects in this study and other studies.

The sound units upon which attempts occurred may enrich understanding of the sources of error in the speech production process. The finding that CA subjects produced more word level attempts may implicate a deficient speech processing mechanism that affects a linguistic level more than a phonetic–motoric level. In contrast, the AOS subjects' attempts were primarily at the single sound level, consistent with the notion that a phonetic–motoric level is affected more than a linguistic level.

One reason for the disparity between the findings and conclusions of this study and the traditional beliefs about AOS and CA speech may be the deficient agreement in the speech–language pathology discipline regarding which speech behaviors are necessarily encompassed in each diagnostic label, a situation affecting which subjects are selected for inclusion in research and treatment regimens. Some investigators (e.g., LaPointe & Horner, 1976) conceive of AOS errors as encompassing those unambiguously attributable to sound selection and sequencing; they assume that these speech events are part of "motor programming" or "motor planning," stages that they presume are not separated. Other researchers (e.g., McNeil & Kent, 1990; Van der Merwe, in press) conceptualize sound selection and sequencing errors as lying outside the domain of "motor programming" and falling more legitimately in the realm of "phonological processing." In this latter view, selection and sequencing deviations are considered outside of those mechanisms thought to generate AOS errors, and instead are considered diagnostic of aphasic speech production deficits. There is evidence that many researchers (e.g., LaPointe & Horner, 1976) have included individuals with sound selection and sequencing errors in their AOS subject pools. If this criterion of subject selection has occurred, then it is likely that subject groups selected from a different premise would evidence different error patterns.

If the model of speech production on which the subjects for this study were selected is tenable, and if the results of this study are replicated, the study may form the framework for the differential diagnosis of speech motor programming errors associated with AOS from phonological processing (speech planning) errors associated with CA. In addition, this differential diagnosis can serve future research purposes, primarily in subject selection criteria.

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