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Apraxia of Speech: Perceptual Analysis of Trisyllabic Word Productions Across Repeated Sampling Occasions

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Purpose: Early apraxia of speech (AOS) research has characterized errors as being variable, resulting in a number of different error types being produced on repeated productions of the same stimuli. Conversely, recent research has uncovered greater consistency in errors, but there are limited data examining sound errors over time (more than one occasion). Furthermore, the influence of conditions of stimulus presentation (blocked vs. random) on sound errors remains uncertain. The purpose of this investigation was to examine the effects of repeated sampling and conditions of stimulus presentation on speech sound errors for 11 speakers with AOS/aphasia.
Method: Trisyllabic words consisting of 7 target phonemes in the initial position served as stimuli. On 3 occasions, stimuli were elicited under 2 conditions: blocked (by phoneme) and randomized presentation. Speech productions were analyzed via narrow phonetic transcription.
Results: Findings revealed a similar overall mean percentage of errors in both conditions and across sampling occasions. Distortions were the dominant error type.
Conclusion: There was no obvious pattern of responding across sampling occasions or conditions of stimulus presentation. The dominant error type differed among target phonemes, but there appeared to be some degree of consistency in the error types produced for the majority of target phonemes.

Key Words: apraxia of speech, variability, perceptual analyses, aphasia

Acquired apraxia of speech (AOS) is a sensorimotor speech disorder involving damage to the dominant language hemisphere of the brain (McNeil, Robin, & Schmidt, 2009). Phoneme distortions, distorted sound substitutions, slow rate of speech, and disturbed prosody are the primary identifying features of AOS (McNeil et al., 2009). However, there are other speech behaviors that frequently co-occur with AOS but do not distinguish it from other disorders. These behaviors include articulatory groping, perseverative errors, increasing errors with increasing word length, and speech initiation difficulties (McNeil et al., 2009; Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006).

The characteristics used to diagnose AOS have continued to evolve since the first description of the disorder and remain controversial with regard to a number of speech behaviors (McNeil et al., 2009). Specifically, the variability or consistency of speech sound errors in speakers with AOS has not been determined. Variability of speech sound errors has been regarded as a primary feature of AOS (Deal & Darley, 1972; Johns & Darley, 1970). Early research depicted errors as being variable based on the location of the error within a word (i.e., initial, medial, final position of words; Johns & Darley, 1970; LaPointe & Johns, 1975) and the type of error that was produced (i.e., distortion, distorted substitutions, substitutions) on repeated productions of the same stimuli (Johns & Darley, 1970; LaPointe & Horner, 1976; Mlcoch, Darley, & Noll, 1982). Articulatory variability was deemed to be even greater on more complex speech tasks (i.e., monosyllabic vs. multisyllabic words; Johns & Darley, 1970; LaPointe & Horner, 1976; Mlcoch et al., 1982).

The seminal study by Johns and Darley (1970) suggesting a high degree of variability offered limited data for this initial descriptor of AOS, but is often cited as evidence of variability of errors in speakers with AOS. Johns and Darley examined the articulatory accuracy of 10 individuals with AOS on monosyllabic words sampled under different conditions of stimulus presentation (i.e., random and blocked by word with one-to-one model/response condition and one model to three responses condition); this was found to have no influence on errors. Furthermore, there were no data presented regarding the location of the errors within words or

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the error types produced on repeated productions of the same stimuli in a single session. The authors only provided anecdotal evidence regarding the variability of performance in speakers with AOS.

The variability among AOS speakers reported in early AOS research may be the consequence of participant selection criteria by allowing the inclusion of speakers with phonemic paraphasia (McNeil et al., 2009). As a result, the nature of some sound errors is reflective of linguistic (phonologic) rather than motoric deficits. The majority of AOS research has involved participants with co-occurring aphasia due to the rare occurrence of individuals with "pure" AOS.

Research that has involved speakers with pure AOS as well as carefully selected speakers with AOS and accompanying aphasia has uncovered greater consistency in speech sound errors (Mauszycki, Dromey, & Wambaugh, 2007; Mauszycki & Wambaugh, 2006; Mauszycki, Wambaugh, & Cameron, 2010a, 2010b; McNeil, Odell, Miller, & Hunter, 1995; Odell, McNeil, Rosenbek, & Hunter, 1990; Shuster & Wambaugh, 2003; Skenes & Trullinger, 1988; Wambaugh, Nessler, Bennett, & Mauszycki, 2004).

McNeil et al. (1995) examined the consistency of error location and variability of error type via narrow phonetic transcription on repeated productions with four speakers with relatively pure AOS. Stimuli included 10 mono-, bi-, and trisyllabic words with three consecutive productions elicited from participants. The types of errors that occurred varied on average by only 13% (0%–16% range). Errors occurred in the same location of words on average 90% of the time (86%–94% range). These findings revealed a greater degree of consistency for errors in speakers with pure AOS.

Research with carefully selected individuals with AOS and aphasia found that error types may be influenced by phonemes (Mauszycki et al., 2010a, 2010b; Wambaugh et al., 2004). Wambaugh et al. (2004) analyzed repeated productions of monosyllabic words with initial stop consonants that were produced by an individual with AOS and aphasia. On three occasions, stimuli were elicited via blocked (by phoneme) and randomized presentation. Variability in types of errors produced by the individual ranged from 0% (i.e., the same type of error was produced for a phoneme) to 58%. The most predictable errors were found in the blocked condition with voiced phonemes; variability ranged from 0% to 33%. Phonemes more frequently in error were produced with fewer error types suggesting some consistency for sound errors based on the severity of the disruption for a particular phoneme. This was one of the first investigations to examine speech sound errors over time as well as conditions of stimulus presentation. However, this study only involved one individual with AOS and aphasia, thus limiting external validity. Nonetheless, findings suggest that AOS speakers may exhibit patterns of responding with certain phonemes that may further be influenced by the conditions of stimulus presentation.

Mauszycki et al. (2010a, 2010b) conducted two investigations examining speech sound errors in speakers with AOS on three sampling occasions. These investigations systematically examined group performance of 11 speakers with AOS and aphasia. Stimuli consisted of seven word-initial phonemes /h, f, m, s, d, r, n/ in mono- and bisyllabic words. Stimuli were presented in two different conditions—blocked (by phoneme) and random. Perceptual analyses were conducted using narrow phonetic transcription and revealed that group performance was similar in both conditions of stimulus presentation across sampling times, with a comparable number of errors. In both studies, the group frequently exhibited a dominant error type for phonemes across conditions and sampling occasions, indicating a pattern of consistency.

The consistency or variability of speech sound errors in individuals with AOS may have implications for treatment planning. If speech sound errors are consistent across time (i.e., same type of error produced for a phoneme/phonemes on repeated sampling occasions), then treatment could involve a phoneme-specific approach. Conversely, if speech sound errors are variable across time (i.e., different types of errors produced for a phoneme/phonemes on repeated sampling occasions), then a nonphoneme-specific treatment could be used.

The majority of research examining the variability of sound errors in individuals with AOS has involved perceptual analyses. The bulk of these investigations has employed broad phonetic transcription to describe speech behaviors in participants with AOS. A limited number of studies have used narrow phonetic transcription (Odell, McNeil, Rosenbek, & Hunter, 1990, 1991; Mauszycki et al., 2010a, 2010b; McNeil et al., 1995; Shuster & Wambaugh, 2000). Results from these investigations uncovered subtle articulatory information that likely could not be captured with broad phonetic transcription. Studies employing narrow phonetic transcription revealed a greater number of distortion errors. This differed from traditional AOS findings using broad phonetic transcription in which more substitution errors were found.

Given the ongoing controversy among researchers and clinicians whether speech sound errors are variable or consistent in speakers with AOS (Croot, 2002), additional research is warranted. Research examining the variability of sound errors over time (i.e., beyond a single session) has been limited. Also, only a few investigations have examined the impact of conditions of stimulus presentation (i.e., random vs. blocked) on speech sound errors, and these findings have been mixed (Mauszycki et al., 2010a, 2010b; Wambaugh et al., 2004). Based on the recent research examining variability in carefully selected speakers with AOS (Mauszycki & Wambaugh, 2006; Mauszycki et al., 2007, 2010a, 2010b; McNeil et al., 1995; Wambaugh et al., 2004), it hypothesized that speech sound errors would be invariable (i.e., limited to a few error types) within and across sampling occasions based on findings that error patterns occurred for certain phonemes (Mauszycki & Wambaugh, 2006; Mauszycki et al., 2007, 2010a, 2010b; Shuster & Wambaugh, 2000, 2003). It also hypothesized that conditions of stimulus presentation may further influence sound errors. Specifically, the blocked condition would elicit the same error pattern when exemplars with the same initial phoneme were presented in succession; hence, more consistent sound errors.

The purpose of this investigation was to further examine variability of speech production in a group of individuals with AOS and aphasia. Of specific interest were the effects of repeated sampling and conditions of stimulus presentation (i.e., random and blocked by phoneme) on the variability of error types examined via narrow phonetic transcription.

Method

Participants

Eleven nonhospitalized individuals with AOS and aphasia participated in this study: six females and five males ranging in age from 25 to 63 years (*M* = 49 years, *SD* = 12 years). Participants were at least 3 months post onset of a brain injury. For 10 participants, the mechanism of brain injury was a cerebral vascular accident (nine embolic and one hemorrhagic). For one participant, a traumatic brain injury (penetrating skull fracture) was the mechanism of injury. Time post onset ranged from 4 months to 15 years (*M* = 4 years, *SD* = 4 years 9 months). Although some participants were receiving speech therapy at the time of this study, their treatment was suspended during the week of data collection (i.e., 1 week). All participants were native English speakers and passed a pure-tone air conduction hearing screening at 35 dB at 500 Hz, 1,000 Hz, and 2,000 Hz in at least one ear. All participants had negative histories for mental illness, alcohol/substance abuse, and neurological problems other than the presence of AOS and aphasia. Table 1 displays a summary of participant characteristics.

A certified speech-language pathologist (SLP; i.e., the first author) determined the diagnosis of AOS, and a confirmatory diagnosis of AOS was independently made by another certified SLP who is an internationally recognized expert in AOS. The presence of AOS was evaluated perceptually by both SLPs using live and/or audio-recorded samples. The criteria established by McNeil et al. (2009) were used to make the diagnosis of AOS: disturbed prosody, speech production characterized by difficulty producing speech sounds, consistently reduced rate of speech, and segregated syllable production. The preceding symptoms may have been accompanied by the following behaviors, but these behaviors were not used to make the diagnosis of AOS: articulatory groping, repeated production attempts, and awareness of errors. Table 2 provides a summary of the participants' assessment results.

Experimental Design

The experimental design of this investigation was a single-group, repeated measures design. The study was designed to analyze the number and types of speech sound errors produced over three sampling occasions in two different conditions of stimulus presentation. Stimuli were elicited on three different sampling occasions over a 7-day period with each participant. Each sampling occasion was separated by 2 days (e.g., Tuesday, Friday, and Monday), with each administration occurring at the same time of day on each sampling occasion.

On each sampling occasion, stimuli were elicited under two conditions: blocked and randomized presentation. The *blocked* condition consisted of all exemplars of a target phoneme presented sequentially (e.g., all initial /s/ words). The word order within the block was randomized as was the order of the blocks. In the blocked condition, participants were presented with a word and were required to produce that word five times, with a model before each production. In the *random* condition, each target word was randomly presented five times among all exemplars.

In both conditions (i.e., blocked, random), each exemplar (168 words) was elicited five times, resulting in 840 productions in each condition, for a total of 1,680 productions per sampling occasion. Over the three sampling occasions, 5,040 tokens were elicited from each speaker. However, only a subset of words is presented in this study (i.e., 28 trisyllabic words). Thus, 140 productions per condition per sampling occasion resulted in a total of 840 tokens for the current analysis.

The order of the conditions was pseudorandomized within and across each sampling occasion. Data collection sessions lasted no longer than 3 hr with a rest break between sampling conditions.

Instrumentation and Data Collection

For the experiment, participants were seated in a quiet room. A digital recorder (M-Audio Microtrak 24/96) and a high-quality, head-mounted microphone (AKG Acoustics C420) were used to acquire the speech signals for perceptual analyses. A microphone-to-mouth distance of ~7 cm was maintained within and across participants to ensure that recording conditions were uniform.

The sampling was conducted by an SLP who was certified by the American Speech-Language-Hearing Association (ASHA). The SLP provided a verbal model for each stimulus item at a normal rate of production and asked the participant to repeat the model. No feedback regarding the accuracy of productions was provided.

Experimental Stimuli

Twenty-eight trisyllabic words served as the experimental stimuli. There were four exemplars for each of the seven word-initial target phonemes (i.e., /h, f, m, s, d, r, n/).

TABLE 1. Study participants' characteristics.

Characteristic	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Age	35	56	46	47	56	25	41	62	63	58	52
Gender	Male	Female	Female	Male	Female	Female	Male	Female	Female	Male	Male
Education (in years)	18	14	12	13	10	12	14	15	13	20	11
Etiology	CVA	CVA	CVA	CVA	CVA	CVA	TBI	CVA	CVA	CVA	CVA
Years;months post onset	1;9	2;9	1;2	15;7	0;9	0;9	6;1	0;4	9;4	4;10	0;8

Note. CVA = cerebral vascular accident, TBI = traumatic brain injury.

TABLE 2. Study participants' assessment results.

Assessment tool	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Apraxia Battery for Adults—2 (Dabul, 2000)											
Level of impairment	Mild AOS	Mild-mod AOS	Mod-severe AOS	Mod-severe AOS	Mod-severe AOS	Severe AOS	Mod-severe AOS	Mild AOS	Mild AOS	Mod-severe AOS	Severe AOS
Western Aphasia Battery (Kertesz, 1982)											
Aphasia quotient	94.0	71.2	45.1	83.6	76.7	42.7	36.9	92.5	97.3	47.0	52.6
Classification	Anomic	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Anomic	Anomic	Broca's	Broca's
Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981)											
Word level	92%	94%	98%	84%	78%	82%	90%	98%	100%	92%	90%
Raven's Coloured Progressive Matrices (Raven, Raven, & Court, 1998; 36 possible)											
Total score	33	30	28	30	30	35	32	33	31	36	28

Note. AOS = apraxia of speech.

Selection of experimental stimuli was guided by findings from phoneme frequency research in adult speech (Mines, Hanson, & Shoup, 1978). Mines et al. (1978) examined the occurrence of phonemes in the initial, medial, and final position of words in casual conversation (i.e., interview) with 26 speakers of American English. Phoneme selection was based on the frequency of occurrence in the initial position with the seven phonemes selected across the frequency continuum (e.g., /h/ = 92%, /f/ = 63%, /m/ = 38%, /s/ = 37%, /d/ = 25%, /r/ = 15% /n/ = 12%) (Mines et al., 1978). Trisyllabic words consisted of CVC (consonant–vowel–consonant)-V-CVC structure, with primary stress on the first syllable, and were constrained by the position of the target phoneme (i.e., initial). The following words served as experimental stimuli: *hesitate, habitat, homicide, halogen, feminine, physical, fabulous, pheromone, magazine, marathon, monotone, medicate, sanitize, sedative, silicone, salivate, dedicate, deficit, dominate, decorate, radical, relative, renovate, ridicule, nominate, navigate, negative,* and *nicotine.*

Data Analyses

Audio recordings were used to perceptually analyze speech samples via narrow phonetic transcription. Both vowel and consonant segments were transcribed; however, only the target phonemes are reported for the purpose of this investigation. On occasion, when speakers audibly groped to find an articulatory position or sound in the initial position of words, these attempts were noted but were not phonetically transcribed. Only the participant's first complete production of each stimulus item was analyzed. However, on ~12% of the stimulus items, participants attempted a subsequent production when an error had been made.

The analysis for each transcribed target phoneme segment involved coding segments as either correct or incorrect. Productions were determined to be correct if they were perceived as phonologically correct, undistorted production of the target phoneme based on transcriptions from the *Cambridge English Pronouncing Dictionary* (Jones, 2003). Then, each target phoneme that was perceived as incorrect was coded according to predetermined categories of the error type used, which included substitutions, distortions, distorted substitutions, and omissions (Odell et al., 1990). A *substitution* was considered a phonetically accurate production of a non-target English phoneme. A *distortion* was considered an attempt at the target phoneme that did not cross the phoneme boundary but was produced with perceptible place, timing, manner, or voice deviation(s) from the accurate production. A *distorted substitution* was a production that not only crossed phoneme boundaries of the target phoneme but was also a distortion of the substitution. An *omission* was a deleted phoneme.

Statistical analyses. The Friedman test was used to examine the effects of the independent variable (i.e., conditions of stimulus presentation) on the number of errors produced in each condition across the three sampling occasions overall and for each target phoneme (i.e., a test for the blocked condition; time 1, 2, 3, then the random condition; time 1, 2, 3). This nonparametric test for related samples was used (with alpha set at 0.05) due to concerns of violating normality assumptions associated with the repeated measures analysis of variance (ANOVA). Post hoc comparisons were conducted using the Wilcoxon Signed Ranks test if significant differences were revealed (via the Friedman test) using the Holms step-down procedure to adjust for Type I error with alpha set at 0.05 for each set of comparisons (i.e., three comparisons for each stimulus condition). Subsequent statistical analyses involved comparing the number of errors produced in each condition of stimulus presentation by sampling occasion in order to examine the effects of stimulus presentation overall and for each target phoneme (i.e., Time 1: blocked vs. random). The nonparametric Wilcoxon Signed Ranks test was used due to concerns with violating assumptions associated with the parametric test. Again, the Holms step-down procedure was used to adjust for Type I error, with alpha set at 0.05.

Dependent Measures

Dependent measures included the mean percentage of errors and dominant error type by phoneme and were computed for each participant in both conditions of stimulus presentation at each sampling occasion.

Mean percentage of errors by phoneme. The mean percentage of errors by phoneme was computed by determining the mean number of times the target phoneme was in error and dividing by the total number of occasions the phoneme occurred. This computation produced a percentage that allowed comparison among target phonemes for the same participant and/or across participants. This measurement was calculated overall and for each target phoneme in both conditions of stimulus presentation at each sampling occasion for the group as well as each speaker to determine if there was any pattern of performance by condition and/or occasion.

Dominant error type by phoneme. The dominant error type was computed on erred productions overall by conditions of stimulus presentation and for each target phoneme within/across sampling occasions. A percentage was calculated by determining the number of productions that were produced with a dominant error type and dividing by the total number of erred productions.

Reliability

For each participant at each sampling occasion, 15% of the productions were randomly selected for re-analysis by narrow phonetic transcription as well as error classification for the purpose of establishing inter- and intrajudge reliability. Interjudge reliability for overall item-to-item agreement for narrow phonetic transcription for target phonemes was calculated at 83%, including transcription differences that were considered functionally equivalent (i.e., partially devoiced /d/ vs. partially voiced /t/) (Shriberg, Kwiatkowski, & Hoffman, 1984). Overall item-to-item interjudge agreement for error classification on inaccurate target phonemes was 90%. For intrajudge reliability, the overall item-to-item agreement for narrow phonetic transcription for target phonemes was computed at 92%, including transcription differences that were deemed functionally equivalent. The overall item-to-item agreement for error classification on inaccurate target phonemes was 95%.

Results

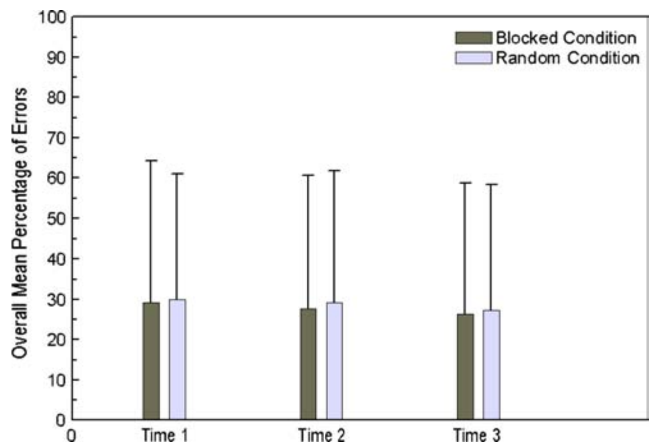
Overall Mean Percentage of Errors

The *overall* mean percentage of errors and standard deviation for the seven target phonemes for the group in each condition across sampling occasions is displayed in Figure 1. The overall mean percentage of errors varied between 26% and 29% for the group. The overall mean percentage of errors was slightly greater (i.e., 1%–2%) at each sampling occasion in the random condition in comparison to the blocked condition.

Statistical analyses by condition across sampling occasions. The Friedman test was used to examine the effects of the condition of stimulus presentation on the overall number of errors produced in each condition across the three sampling occasions. The results revealed no statistically significant differences across the three sampling occasions in the blocked or random conditions of stimulus presentation.

Statistical analyses between random and blocked conditions. The Wilcoxon Signed Ranks test was used to examine the effects of the condition of stimulus presentation on the overall number of errors produced for each sampling occasion (e.g., blocked time 1 vs. random time 1) using the Holms step-down procedure. The analyses revealed no statistically significant differences between the blocked and random conditions at sampling occasion 1, 2, or 3.

FIGURE 1. The overall mean percentage of errors and standard deviation (error bars) for the seven target phonemes in the blocked and random conditions across the three sampling occasions.



Mean Percentage of Errors by Phoneme

The mean percentage of errors occurring for each phoneme from the least number of errors to the greatest number of errors in the blocked condition was /h, m, n, r, d, f, s/; the breakdown from least to greatest mean percentage of errors in the random condition was /h, m, n, f, r, d, s/. The mean percentage of errors and standard deviation for each target phoneme in both conditions across sampling occasions is depicted in Figure 2. The *mean difference* between the two conditions at each sampling occasion *among all target phonemes* was 5%, with a range of 0% to 14%.

For both /m/ and /n/, there was a greater number of errors in the random condition on each sampling occasion. The mean difference between conditions for /m/ was 7% (range of 5%–8%) and for /n/ was 6% (range of 3%–9%). There was also a greater number of errors for /f/ in the blocked condition on each sampling occasion in comparison to the random condition. The mean difference between conditions for /f/ was 8%, with a range of 2%–14%.

Statistical analyses by condition across sampling occasions for each phoneme. The Friedman test was used to examine the effects of the condition of the stimulus presentation on the number of errors that was produced in each condition across the three sampling occasions for each target phoneme. The results revealed no statistically significant differences among target phonemes across the three sampling occasions in either condition of stimulus presentation.

Statistical analyses between random and blocked conditions for each phoneme. The Wilcoxon Signed Ranks test was used to compare the conditions of the stimulus presentation on the number of errors produced at each sampling occasion for each target phoneme (e.g., blocked time 1 vs. random time 1) using the Holms step-down procedure. The

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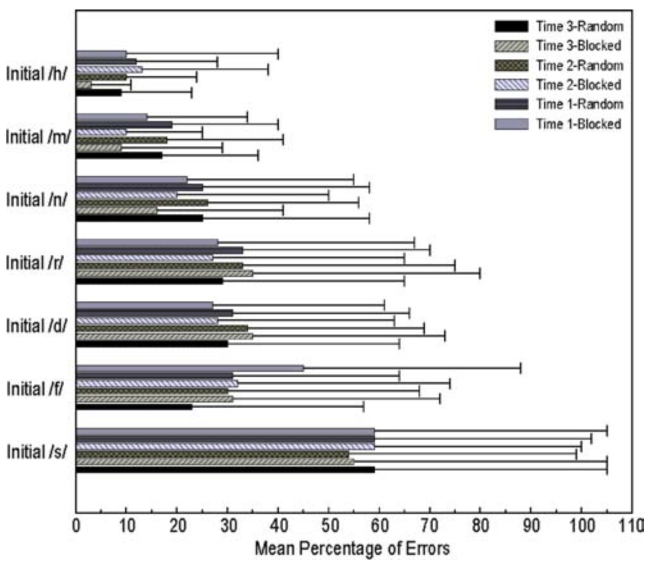
FIGURE 2. The mean percentage of errors and standard deviation (error bars) for each target phoneme in the blocked and random conditions across the three sampling occasions.



results did not identify statistically significant differences among the target phonemes between the blocked and random conditions at sampling occasion 1, 2, or 3.

Individual participant performance compared to group performance by phoneme. For each phoneme, the performance of individual speakers was examined to identify participants who produced a disproportionate number of errors in comparison to group performance. The following participants' number of errors exceeded the group mean by more than 1 *SD*: Participant 5 (/d/, /f/, /m/, /r/), Participant 6 (/d/, /h/, /m/, /n/), Participant 10 (/f/, /r/), and Participant 11 (/d/, /f/, /h/, /m/, /n/, /r/). The number of errors produced by these speakers for the outlined phonemes was similar in both conditions of stimulus presentation.

Dominant Error Type by Phoneme

Across all phonemes, the dominant error type was distortions. However, the dominant error type differed across phonemes as well as by sampling occasions and/or conditions. Tables 3 and 4 summarize the number of errors and error types via percentage for each phoneme at the three sampling occasions in the blocked and random conditions, respectively. The dominant error type for the target phonemes /d/, /r/, /f/, /s/ was distortion errors, and the dominant error

TABLE 3. The number of errors and the percentage of error types for each target phoneme at each sampling occasion in the *blocked condition,* with the dominant error type in bold.

Phoneme	Sampling occasion	Number of errors	Error type % Distortion	Substitution	Distorted substitution	Omission
/h/						
	Time 1	22	5	23	**63**	9
	Time 2	27	11	**44**	30	15
	Time 3	7	14	14	**72**	NA
/m/						
	Time 1	30	**57**	30	10	3
	Time 2	22	**59**	36	5	NA
	Time 3	20	30	**60**	10	NA
/n/						
	Time 1	47	4	**51**	43	2
	Time 2	43	14	**65**	7	14
	Time 3	35	23	**68**	9	NA
/r/						
	Time 1	60	**66**	12	22	NA
	Time 2	58	**79**	16	3	2
	Time 3	76	**87**	9	4	NA
/d/						
	Time 1	59	**42**	34	19	5
	Time 2	60	**42**	22	36	NA
	Time 3	77	**60**	13	27	NA
/f/						
	Time 1	98	**70**	17	11	1
	Time 2	81	**91**	4	5	NA
	Time 3	68	**72**	24	4	NA
/s/						
	Time 1	129	**77**	11	12	NA
	Time 2	129	**94**	5	1	NA
	Time 3	120	**75**	18	6	1

Note. NA = no errors.

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TABLE 4. The number of errors and the percentage of error types for each target phoneme at each sampling occasion in the *random condition,* with the dominant error type in bold.

			Error type %			
Phoneme	Sampling occasion	Number of errors	Distortion	Substitution	Distorted substitution	Omission
/h/						
	Time 1	25	20	24	24	**32**
	Time 2	21	19	**43**	29	9
	Time 3	19	21	26	**42**	11
/m/						
	Time 1	42	**60**	26	12	2
	Time 2	38	**66**	29	5	NA
	Time 3	37	**59**	30	11	NA
/n/						
	Time 1	55	15	**65**	15	15
	Time 2	57	21	**49**	28	2
	Time 3	55	15	**63**	20	2
/r/						
	Time 1	73	**60**	29	10	1
	Time 2	71	**69**	14	17	NA
	Time 3	63	**81**	15	2	2
/d/						
	Time 1	68	**37**	29	34	NA
	Time 2	74	**47**	20	30	3
	Time 3	65	**43**	32	23	2
/f/						
	Time 1	67	**64**	24	10	2
	Time 2	66	**69**	14	14	3
	Time 3	50	**70**	22	6	2
/s/						
	Time 1	130	**67**	20	13	NA
	Time 2	119	**72**	22	6	NA
	Time 3	129	**79**	16	4	1

Note. NA = no errors.

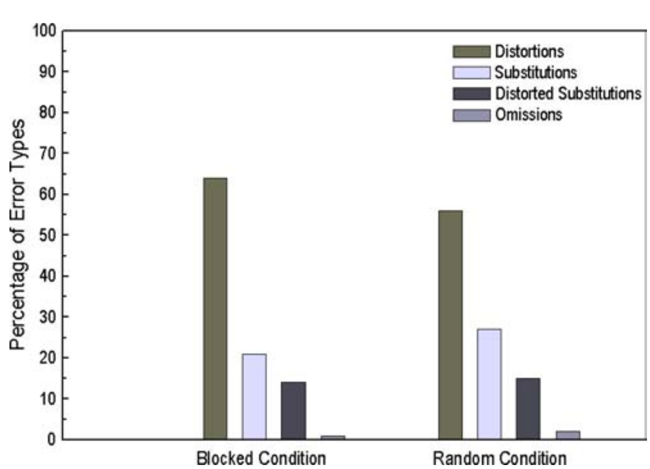
type for target phoneme /n/ was substitution errors. The dominant error type for /h/ varied between substitutions and distorted substitutions in the blocked condition. In the random condition, the dominant error type for /h/ differed at each sampling occasion from substitution, distorted substitution, and omission errors. For the target phoneme /m/, distortion errors were the dominant error type in both conditions of stimulus presentation; however, on one occasion in the blocked condition, substitutions were the dominant error type.

The percentages of different error types produced by conditions of stimulus presentation are displayed in Figure 3. Overall, the dominant error type for the group was distortion errors in both conditions of stimulus presentation followed by substitutions, distorted substitutions, and omissions. The blocked condition had a higher percentage of distortion errors, with 64% in the blocked condition and 56% in the random condition. The random condition had a slightly higher percentage of substitutions, distorted substitutions, and omission errors. The percentage difference for substitution errors was 6% and 1% for both distorted substitution and omission errors between the two conditions.

Discussion

This study investigated the number of speech sound errors and the dominant error type in trisyllabic word productions containing seven target phonemes in the initial-word position for 11 speakers with AOS and aphasia. Particularly, the effects of the condition of the stimulus presentation (blocked vs. random) and repeated sampling on errors.

FIGURE 3. The overall percentage of error types in the blocked and random conditions.



Mean Percentage of Errors

Repeated sampling had no influence on the number of errors produced by the group, as indicated by a similar overall mean percentage of errors and standard deviation across conditions and sampling occasions. Seldom has the stability of errors been evaluated in speakers with AOS and aphasia, but results from this investigation are comparable to research (Haley & Gottardy, 2007; Haley, Wertz, & Ohde, 1998) that found speech intelligibility for a group of speakers with AOS to be relatively similar across repeated sampling sessions that were conducted on the same day.

Recent research has indicated that the number of speech sound errors produced by individual speakers with AOS and aphasia may vary across repeated sampling occasions and be reflective of specific sound errors as well as the location of a sound/phoneme within syllables (i.e., syllabic position, syllabic structure, and phoneme difficulty) (Mauszycki & Wambaugh, 2006; Wambaugh et al., 2004). In the present study, repeated sampling occasions had no influence on the number of errors produced for target phonemes by this group of speakers with AOS. For this investigation, analyses for individual speakers were not conducted. However, individuals who produced a disproportionate number of errors were identified for each target phoneme. Four speakers (Participants 5, 6, 10, and 11) had a greater number of sound errors (i.e., +1 *SD*) for two or more target phonemes, and their performance was similar in both conditions of the stimulus presentation. Interestingly, these four speakers had more severe AOS (i.e., moderate-severe AOS or severe AOS). However, not all speakers with more severe AOS (e.g., Participants 3, 4, and 7) exhibited this pattern among target phonemes. Undoubtedly, additional information could be gained by analyzing the performance of individual speakers across all variables (e.g., sampling occasions, blocked vs. random conditions of stimulus presentation) examined by group performance in this investigation.

Perhaps further analyses would reveal a different pattern of performance for the group or individual speakers based on sampling occasions. Analyses examining the influence of syllabic position, syllabic structure, and syllable frequency on sound errors may be useful based on research conducted by Aichert and Ziegler (2004) identifying a greater number of errors on words with a lower syllable frequency.

Certainly, repeated practice of the experimental stimuli had the potential to influence the performance of each speaker in such a short span of time (i.e., 7 days). Repeated practice could have promoted motor learning and consequently led to fewer errors on subsequent sampling occasions. Conversely, repeated practice of incorrect productions could have served to increase the number of errors produced due to a lack of feedback on erred productions, thus providing reinforcement for speakers. Motivation is another factor that could have influenced the performance of each speaker and undoubtedly could have waned over the three sampling occasions, leading to an increase in the number of errors produced by the group. Nonetheless, it seems that repeated sampling had no influence on the number of errors that were produced by this group.

Conditions of Stimuli Presentation: Blocked Versus Random

The condition of the stimulus presentation did not promote a distinctive pattern of responding across all of the target phonemes. For three target phonemes (/f, m, n/), there was a slight difference in the number of errors produced between conditions of stimulus presentation at each sampling occasion. For /f/, there were more errors produced in the blocked condition, and more errors were produced for /m, n/ in the random condition at each sampling occasion. However, on most sampling occasions, the mean difference between the conditions of the stimulus presentation for these phonemes was not considerably different from the overall mean difference for all phonemes. The present findings are similar to previous research that found no obvious pattern of responding due to conditions of stimulus presentation on repeated word productions in the same session (Johns & Darley, 1970; LaPointe & Horner, 1976). However, findings differ from recent research by Wambaugh et al. (2004), who uncovered a predominant pattern of performance based on conditions of stimulus presentation for a speaker with AOS and aphasia in the production of monosyllabic words on repeated sampling occasions. Wambaugh et al. found that the blocked condition promoted a more consistent pattern of responding that limited the number of error types produced for phonemes. In the current investigation, there appeared to be no consistent pattern of responding for the group for either condition of stimulus presentation across the seven target phonemes (with minor exceptions for individual targets /f, m, n/). Subsequent analyses examining both group and individual performance might reveal different patterns of performance based on the condition of the stimulus presentation and provide greater insight into the slight differences in the number of errors for those three target phonemes. Perhaps the use of repetition to elicit stimuli in this study facilitated the same production of stimulus items (i.e., correct or incorrect), thus limiting the influence of the condition of the stimulus presentation. The use of other methods to elicit stimuli might uncover different patterns of responding in blocked and random conditions of stimulus presentation.

Dominant Error Type by Phoneme

For the majority of target phonemes, distortion errors were the dominant error type. These findings are consistent with previous research with speakers with pure AOS (McNeil et al., 1995; Odell et al., 1990) as well as speakers with AOS and aphasia (Mauszycki et al., 2010a, 2010b). The participants in the current investigation presented with AOS/aphasia, and the bulk (i.e., 64% blocked and 56% random) of their speech sound errors (regardless of condition of stimulus presentation) were distortions. Distortions are considered to reflect deficits in motor planning involving impaired recall or adaptation of movement, including maintaining and/or monitoring the parameters of movement for speech production (i.e., deficient temporal and spatial parameters) based on the schema theory and its application to AOS (Ballard, Grainer, & Robin, 2000; McNeil et al., 2009; Van der Merwe, 2009).

Participants in the present investigation exhibited a dominant error type for target phonemes more frequently in error regardless of the condition of the stimulus presentation and/or sampling occasion. In contrast, when speakers produced a lower number of errors for a target phoneme, no dominant error type emerged for this group of speakers with AOS. Results are similar to prior research examining speech sound errors across sampling occasions in speakers with AOS and aphasia. Results from those investigations discovered that phonemes more frequently in error were produced with fewer error types, indicating some consistency for sound errors based on the severity of disruption for a particular phoneme (Mauszycki et al., 2007, 2010a, 2010b; Wambaugh et al., 2004).

Findings from this investigation revealed a relatively high degree of consistency in speech sound errors for target phonemes despite conditions of the stimulus presentation and repeated sampling occasions. The majority of errors were reflective of a motoric-based impairment (although it should be noted that the individuals in this study also presented with aphasia). Performance across repeated sampling occasions has not been well studied in speakers with AOS, and this is one of the first studies to analyze repeated trisyllabic word productions in a group of AOS speakers. The goals of this study were necessarily restricted due to the large number of tokens and the use of narrow phonetic transcription to conduct analyses. Word-initial phonemes were chosen based on previous research that revealed consistent error patterns for phonemes (Mauszycki et al., 2007, 2010a, 2010b; Shuster & Wambaugh, 2000; Wambaugh et al., 2004).

Although the analyses in this investigation were restricted to seven target phonemes, there may be reason to extrapolate these findings to other phonemes to a limited extent. That is, these phonemes were selected specifically to represent the continuum of frequency of occurrence of American English phonemes; unstudied phonemes fall within this frequency range. Additionally, place and manner of production and voicing are varied across the experimental phonemes. Consequently, it is likely that findings would be similar with unstudied phonemes; however, this hypothesis requires verification through further study. Repetition of stimulus items was used in order to minimize aphasia/word finding errors because the goal of the study was to analyze sound errors produced on seven target phonemes. Although generalization of these findings may be limited based on the speaking task, the task is similar to those used in a clinical setting with apraxic speakers for the purpose of evaluation and treatment.

This investigation captured detailed articulation information that would have been overlooked had narrow phonetic transcription not been employed. Findings revealed greater consistency in the error types produced for the majority of target phonemes. Certainly, additional information could be obtained regarding the nature of AOS by examining all phonemes in each stimulus item. Future research should include analyses for both group and individual performance of speakers with AOS in order to provide a better understanding of speech sound errors, including the consistency or variability of these errors. Although this group of speakers was consistent with regard to their errors over sampling times, it is essential to demonstrate consistency (or lack of consistency) within speakers if this trait is to be used for diagnostic purposes. Consistent group performance should not be used to infer consistent individual performance. Inconsistency in individual speakers may have been masked by the group analyses; conversely, consistency within individuals may have accounted for the consistent group performance. Individual analyses appear to be essential in determining patterns of consistency and variability in speakers with AOS. If a particular trait or pattern of performance is to have clinical utility in the differential diagnosis of a disorder, then the majority of *individuals* should demonstrate the trait/pattern.

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