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Differentiating Phonemic and Spectrografhic Speech Characteristics of DAF Susceptibility

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DIFFERENTIATING PHONEMIC AND SPECTROGRAPHIC SPEECH CHARACTERISTICS OF DAF SUSCEPTIBILITY

by

Peter J. Alfonso

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
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August 1973

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Peter J. Alfonso

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CHAPTER I

INTRODUCTION

Review of the Literature

Since the publication of "Cybernetics" (1948) and "Human Use of Human Beings" (1950), Norbert Wiener's concepts of communication and feedback have greatly influenced scientific investigation, particularly in the field of speech and hearing science. Fairbanks (1954) and Mysak (1966), for instance, have utilized Wiener's self-regulating theory to construct communication models in which speech performance is automatically controlled via continual monitoring of the output. Their work and the research of others have indicated that the speaker's auditory feedback of his own speech serves a crucial role in regulating his speech performance. Thus, speech that falls within the normal limits of acceptability demands, along with other requirements, an efficient feedback system.

Black (1951) and Lee (1950), working independently, reported on the effects of time delays in the auditory feedback system. Among other findings, they described the disturbance in speech performance of individuals experiencing excessive delay in auditory feedback as consisting of primarily prolongations and repetitions.

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Since then a considerable amount of work has been undertaken comparing this type of induced aberration of normal speech that Lee (1951) termed "artificial stuttering" with actual stuttering. For the most part, the underlying hypothesis has been that if the two speech patterns are alike, then perhaps stuttering can be attributed to an aberrated endogenous temporal feedback system. However, the research comparing stuttering and delayed auditory feedback (DAF) speech has not been completely definitive. Consequently, the link drawn between stuttering and the speech produced under DAF may not be as apparent as originally thought.

Yet, as a potential source of information about cybernetic influences on the speech of both stutterers and non-stutterers, the effects of DAF offer many possibilities and challenges, the most notable of which appears to be the variability of speech behaviors demonstrated under DAF. For normal speakers, Yates (1963) found that: a) approximately 20 percent exhibited severe dysfluencies, b) approximately 20 percent seemed unaffected, and c) about 60 percent demonstrated disruption in speech performance at a level somewhere in between the two extremes. Although a variability has also been noted in the effect of DAF on the speech performance of stutterers (Neelley, 1961; Soderberg, 1969), there has been no acceptable explanation to date as to

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why excessive delay in auditory feedback affects some to a greater degree than others.

One of the first factors to be isolated that apparently contributes to subject variability was sex. Black (1955) found that females took longer than males to read short phrases under delay. Sutton, Roehrig, and Kramer (1964) also found that females took longer than males in reading tasks under DAF. They (Sutton et al., 1964) also reported that there were no significant sex differences in correct word rate in terms of articulation. However, Lerche and Nessel (1956) found that males made more articulation errors than females during reading under DAF conditions. Guttman (1954) and Buxton (1969) found no intersex differences in the production of artificial stuttering. In contrast, Bachrach (1964) and Mahaffey and Stromsta (1965) found males to be more vulnerable to artificial stuttering under DAF than females. However, Burke, Neilson, and Yates (1967) reported that the greater susceptibility for males existed only during the initial exposure; subsequent experience with DAF eliminated the sex differences.

Subject age and magnitude of delay also appear to critically influence DAF speech. Chase, Sutton, First, and Zubin (1961) found that younger children (four-six years) were less affected than older children (seven-nine years) by DAF when the delay time was held constant at

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200 msec. MacKay (1968), using subjects ranging from four to 26 years of age and delay times of 100, 200, 375, 525, and 750 msec., found a correlation between increasing age and improved performance under all delay times. The delay time that produced the greatest interference with speech varied inversely with age; the younger subjects experienced most disruption with long delay times while the older subjects experienced maximal disturbance at 200 msec. delay.

The intensity of the delayed auditory feedback signal also seems to alter the characteristics of DAF speech. While lower intensity levels also produce disruption, the greatest speech disturbances seem to occur at 80 dB SL (Tiffany and Hanley, 1954), and, as with age and magnitude of delay, there appears to be a significant interaction between feedback level and delay time (Butler and Galloway, 1957).

In one of the few experiments that attempted to more accurately define DAF speech performance, Fairbanks and Guttman (1958) noted speech differences, in terms of articulation errors, as a result of various delay times. They reported that certain delay times are more likely to produce articulatory errors and that different types of articulation errors are more likely to occur at different delay times.

There is little doubt that certain of the above-

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mentioned factors have contributed to the variability of the results of the effects of DAF on speech performance. Likewise, the subjectivity inherent in judgments made by different individuals in the analysis of speech sounds by phonemic transcription has made comparison of the studies difficult.

Spectrographic analysis, which could isolate information undetectable to the ear and aid in phonemic transcription, has had limited use in DAF investigations. Rawnsley and Harris (1954) found spectrographic differences in the speech of normal-speaking subjects under DAF and normal delay conditions, but the use of single words in the speech task in their study limits the generality of their findings.

With the information now available as a result of analysis-by-synthesis procedures, it appears reasonable to suggest that spectrographic analysis of DAF and normal delay speech (in sex, age, and delay time controlled groups) could become a useful tool in more accurately defining the characteristics of DAF speech. This information could be utilized to identify the information bearing elements in the spectrographically displayed speech signal. Hence, speech could be analyzed spectrographically to define more precisely those characteristics that serve to differentiate the various forms of DAF speech.

Stromsta (1962) determined the normal transmission

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delays of the air-bone-tissue conducted pathways. Burke (1971) summarized the results as follows: a) the delay associated with the bone-conduction pathway (from the superior medial incisors to the mastoid process) is differentially affected by frequency, and varies from 0.5 msec. at 125 Hz with a gradual decrease to approximately 0.2 msec. at 2000 Hz; b) the delay associated with the tissue pathway (from the region of the vocal cords to the mastoid process) is differentially affected by frequency, and varies from 9.0 msec. at 160 Hz with a gradual decrease to approximately 1.1 msec. at 2000 Hz; c) the delay associated with the internal pathway of minimum delay (from the region of the vocal cords to the mastoid process irrespective of media) is differentially affected by frequency, and varies from 2.0 msec. at 160 Hz with a gradual decrease to 0.3 msec. at 1600 Hz; and d) the delay associated with the external air-conduction pathway (from the vocal cords through the pharynx and oral cavity to the tympanic membrane) is approximately 1.0 msec. and is independent of frequency. In view of these findings, the term "normal-delay" is used throughout this study to mean the normal feedback delays inherent in air-bone-tissue conducted pathways.

Statement of Research Problem

There has been a paucity of work devoted to the

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most consistently reported variable in DAF investigation, that of the varying intersubject susceptibility to DAF even when such factors as sex, age, and delay time have been controlled. Consequently, over twenty years of research has succeeded in isolating only gross differences in the speech performance of those who are minimally and those who are maximally affected by an excessive delay in auditory feedback. Summaries of previous investigations seem to indicate that those speakers who demonstrated little articulation disturbance under DAF also decreased their rate of speech, apparently through vowel prolongation (Fairbanks, 1955; MacKay, 1968). Those speakers who showed the greatest disruption of speech under DAF characteristically seemed to maintain their habitual speech rate and to demonstrate syllable or whole word repetitions (MacKay, 1968; Van Riper, 1971).

This study was designed to describe, quantitatively by phonemic transcription and qualitatively by spectrographic analysis, the DAF speech characteristics of normal-speaking adult male subjects who had previously demonstrated either high or low susceptibility to DAF. Basically this study investigated whether or not there are characteristics of DAF speech that can serve to differentiate the two susceptibility groups. Intergroup comparisons were based on phonemic assessments of a) sound and syllable repetitions, b) word repetitions,

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c) prolongations, d) pauses between syllables and words, e) inappropriate phonemic intensity accents, f) phoneme substitutions, g) omissions, h) distortions, and i) the use of connected speech, which has been defined for the purpose of this study as the omission of the natural pauses between syllables and words found in normal speech. Spectrographic analysis included assessment of the first and second formant transitions, vowel formant configurations, and phonation time measurements.

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CHAPTER II

METHOD

Subjects

A total of 52 graduate and undergraduate male students from Western Michigan University, ranging in age from 18 to 25 years, were screened for normal speech and hearing in order to be eligible to serve as experimental subjects for this study. Normal speech was defined as the absence of clinical symptoms of any speech disorder and the use of Standard American English as their native language. Informal speech screening was performed during pre-test interviewing and analysis of the test data. Normal hearing was determined on the basis of bilateral air-conduction thresholds of 25 dB or better (ISO, 1964) at the following frequencies: 500, 1000, 2000, and 4000 Hz. Hearing screening was conducted in a sound treated chamber (IAC Model 1203A) using a clinical audiometer (Beltone, Model 14A). On the basis of the above criteria, three subjects were rejected due to hearing loss greater then 25 dB and three subjects were considered to have demonstrated clinical symptoms of lisping, stuttering, and cleft palate speech. The mean age for the remaining 46 subjects who qualified and provided data for this study was 21 years and five months. None of the 46 sub-

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jects was familiar with or had previously experienced DAF.

Apparatus

Subjects were located in a sound treated room with an ambient noise level of 48 dB as measured by a sound level meter (Bruel and Kjaer, Model 2203). A boom mounted microphone (Electro-Voice Slimair, Model 636) was positioned so that its diaphragm was centered at the midline of the mouth of each subject. The microphone was placed in a horizontal position to reduce breath stream noise from plosive phonemes. Individual measurement from the entrance of the left external auditory canal to the left corner of the mouth for each subject was made. This distance averaged 13 cm. The individual measurement was used as the distance that each subject was required to maintain between the microphone and his lips and closely approximated the distance of the normal air-conduction feedback pathway from the lips to the ear. A high back chair was used so that mouth to microphone distance was neither unduly uncomfortable nor difficult to maintain.

The speech signals detected by the microphone were passed out of the test room to a delayed auditory feedback recorder (Al-Tronics, DLF 4). A delay time of 180 msec. was maintained throughout the experiment. A stereo tape recorder (Sony, Model TC-5600) was coupled to the input of the delay unit to record all test data at seven

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and a half inches per second. The feedback signals were presented to the ears of the subjects by earphone receivers (ANB-H1) fitted with MX-41/AR cushions.

<u>Feedback intensity level</u>

The microphone and earphones used in the collection of data were also used in calibrating the equipment for an intensity level setting that was a constant 10 dB above each speaker's normal intensity level. The intensity level of the feedback signal was set prior to data collection and maintained at the same level throughout the experiment.

An assistant alternately produced front and back vowels while regulating his output at zero VU on the input meter of the delay unit. Mouth to microphone distance was determined on the basis of ear canal to lip measurement as described above and was maintained throughout. A sound level meter (Bruel and Kjaer, Model 2203) was held parallel to the microphone and an intensity reading was obtained for each vowel. The speaker's average intensity was calculated from the intensity levels of these vowels as the speaker maintained zero VU on the input meter of the delay unit. The earphone receivers were then coupled to the sound level meter and the assistant again produced the same vowels while maintaining zero VU on the input meter. The output amplifier of the delay

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unit was then adjusted to indicate (on the sound level meter through the earphones) 10 dB above the level obtained at the distance of the microphone from the lips. The results of this calibration were such that all speakers perceived their own speech, in both the normal delay and the 180 msec. delay conditions, at a level approximately 10 dB above their normal speech feedback intensity level, regardless of the individual variance in speaker intensity.

Stimulus Materials

For the purpose of phonemic analysis, test materials that represented all of the phonemes in the English language were considered desirable. In order to control the selection of phonemes used by each subject and to be able to compare the same phonemes under normal delay and DAF conditions, reading materials that sampled the greatest majority of the English phonemes were selected.

A second but equally important factor was the selection of materials suitable for spectrographic analysis. These should be nearly equal in natural intensity and of limited duration in order to facilitate the production of spectrograms. Also considered essential was selection of materials that did not allow uncontrollable pause time between words and phrases, so that only actual speech time would be considered in analysis of speech duration.

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Walker and Black (1950) publsihed a list of phrases designed to serve as standardized test materials in studies involving comparisons of either rate or intensity of reading. They standardized a series of 450 five syllable phrases for natural intensity and duration using young male adults. From this series, ten phrases were selected as test materials for this study. These phrases, representing nearly all of the phonemes used in the English language, were of similar intensity and duration. Five additional phrases were chosen to serve as practice items.

Table 1 lists the ten test phrases and five practice phrases used in this study. Entries are recorded in the following order: phrase, mean relative intensity (reported as the average of the three highest root-mean-square values of intensity taken during the reading of each phrase), standard deviation of the values represented by the mean (intensity), duration (in seconds), and standard deviation (duration). These values were obtained from Walker and Black (1950).

Table 2 shows the distribution of phonemes, categorized according to manner of production, for the ten test phrases. A total of 123 phonemes was produced by each subject in the normal delay condition; the same 123 phonemes were again produced during the 180 msec. delay condition. Percentages (in manner of production categories) of the total amount of phonemes produced by

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Table 1. List of ten test phrases and five practice phrases read by the subjects in this study. Values in parentheses represent a) mean r.m.s. intensity, b) standard deviation of mean intensity, c) mean speech duration, and d) standard deviation of mean duration (Walker and Black, 1950).

Test Phrases

1. show you what I mean (33.1, 4.22; .91, .13)
2. to circle the field (33.2, 3.68; .93, .18)
3. should never carry (34.0, 4.43; .89, .11)
4. to a poor surface (31.8, 3.75; .98, .17)
5. you have the best chance (33.4, 4.66; 1.07, .10)
6. reaching and landing (32.2, 4.17; 1.17, .14)
7. vary your pattern (34.2, 4.54; .91, .11)
8. we get out farther (34.0, 4.77; .94, .14)
9. adjust our distance (33.1, 4.48; .92, .18)
10. the throttle is closed (32.7, 4.24; 1.17, .20)

Practice Phrases

1. the tail is higher (32.6, 3.82; .97, .22)
2. turn into the wind (33.2, 3.95; .93, .16)
3. so I'll take over (32.7, 4.50; .99, .16)
4. follow the sequence (32.9, 4.58; .97, .18)
5. the edge of the field (31.8, 4.85; .98, .20)

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Table 2. List of phonemes taken from the ten test phrases as per manner of their production, frequency and percentage of occurrence. Subjects were required to produce these phonemes in each experimental condition.

Manner-of-production categories	Phonemes	Frequency	Percentage
Front vowels	{i, ɪ, e, ɛ, æ, a}	24	19.5
Mid vowels	{ɜ, ɝ, ə, ɚ}	17	13.8
Back vowels	{ʌ, u, ʊ, o}	12	9.8
Plosives	{p, t, k, d, g, b}	21	17.1
Fricatives	{f, v, s, z, θ, ð, ʃ}	23	18.7
Semi-vowels	{w, l, r, j}	12	9.8
Glottal	{h}	1	0.8
Nasals	{m, n, ŋ}	10	8.1
Affricatives	{tʃ, dʒ}	3	2.4
	Totals	123	100.0

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each subject are shown in parentheses. Table 2 shows that of the 246 phonemes produced by each subject, 106 (43.1%) were vowels whereas 140 (56.9%) were consonants.

Procedures

Subjects were seated in the sound treated testing room where mouth to microphone measurements as well as chair and microphone adjustments were made. Emphasis was placed on the importance of maintaining the same mouth to microphone distance throughout the readings. No mention of DAF or its effects were made until after the data were collected.

Schwartz (1961) has reported on the observed differences in test results of nearly identical DAF studies where only the instructions given to the subjects differed. He contends that one possible factor contributing to variance between the results of similar DAF studies may be the failure to stipulate whether the subjects should speak as fast as they can, attempt to maintain normal rate, or try to articulate as correctly as possible while under the influence of DAF. In order to minimize such variance, instructions were given until all subjects understood that they:

1) were participating in a speech science experiment that required the reading of short phrases,
2) would be hearing their own voice through the earphones they were wearing,
3) should read as they normally read aloud,
4) should read each phrase without stopping, and

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5) should maintain the same distance from the microphone.

When each subject indicated he understood the procedures, a card with printed instructions was presented for the subject to read while the experimenter read aloud the identical information. The following is a duplicate of these instructions:

> "Try to hold the same distance from the microphone throughout these readings. When I signal, read the printed phrase aloud <u>without</u> <u>stopping</u>, as you would normally read these words. I will signal again for you to read the next phrase. Remember to speak directly into the microphone.
>
> When you are through, we will repeat the procedure a second time."

The subjects were then allowed to read the five practice items in the normal delay condition and at the feedback intensity used during actual testing. The experimenter was located outside of the test booth where a window permitted the use of visual signals to indicate when to begin reading the next phrase. A three to five second pause was included before the reading of each phrase. When the practice period indicated the subject understood the procedures, actual testing began. In certain cases, further instruction was given.

All practice and test phrases were printed in large type on small white cards. The test phrases were randomized for each subject to reduce ordering effect. Odd numbered subjects first read the ten test phrases in the normal delay condition, then read the ten test phrases in

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the DAF condition. Even numbered subjects followed the reverse order.

Defining susceptibility groups

This experiment was designed to observe the speech differences that occurred while experiencing 180 msec. delay to the air-conduction auditory feedback system between those subjects who had demonstrated high and those who had demonstrated low susceptibility to DAF. For the purpose of this study, susceptibility to DAF was determined on the basis of a duration ratio, the duration of the speech attempt during 180 msec. delay divided by the duration of the speech attempt during normal delay.

The test data were fed from the stereo tape recorder to a pressure level recorder (Bruel and Kjaer, Model 2305) at a paper speed of 30 millimeters per second. Total duration of speaking time for each subject in the normal and DAF conditions was made by millimeter rule. As an example of duration measurement, the speaking time for the test phrase "vary your pattern" began with the initiation of speech for the initial phoneme /v/ through the final phoneme /n/ and included all phonatory and pause times between these two phonemes. Where sound or word repetition occurred as the result of an initial reaction to DAF, such as "vary (initial reaction pause) vary your pattern," the initial reaction was not

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included in duration measurement. Any pause greater than .33 seconds occurring in the initial test phrase during DAF constituted an initial reaction pause.

Susceptibility to DAF was expressed in duration ratio measurement. Those subjects with high duration ratios (180 msec. delay speaking time/normal delay speaking time) who demonstrated a greater speaking time under DAF than during the normal delay conditions were defined as most susceptible to the effects of DAF. Those subjects with low duration ratios were defined as least susceptible to DAF. Duration ratios were used to normalize the effects of individual speaking rate variability.

Figure 1 shows individual subject duration ratios as a function of the number of subjects for the entire population serving in this study. The mean duration ratio for all subjects was 1.36, while the standard deviation of the value represented by the mean was 0.24. Figure 1 shows that four subjects fell beyond 2.5 standard deviations above the mean in the direction of high susceptibility. These four subjects represented eight percent of the test population. Also shown is that the four least susceptible subjects (in terms of duration ratio) fell 1.5 standard deviations or more below the mean, and represented the bottom eight percent of the test population. The mean duration ratio for the four subjects who

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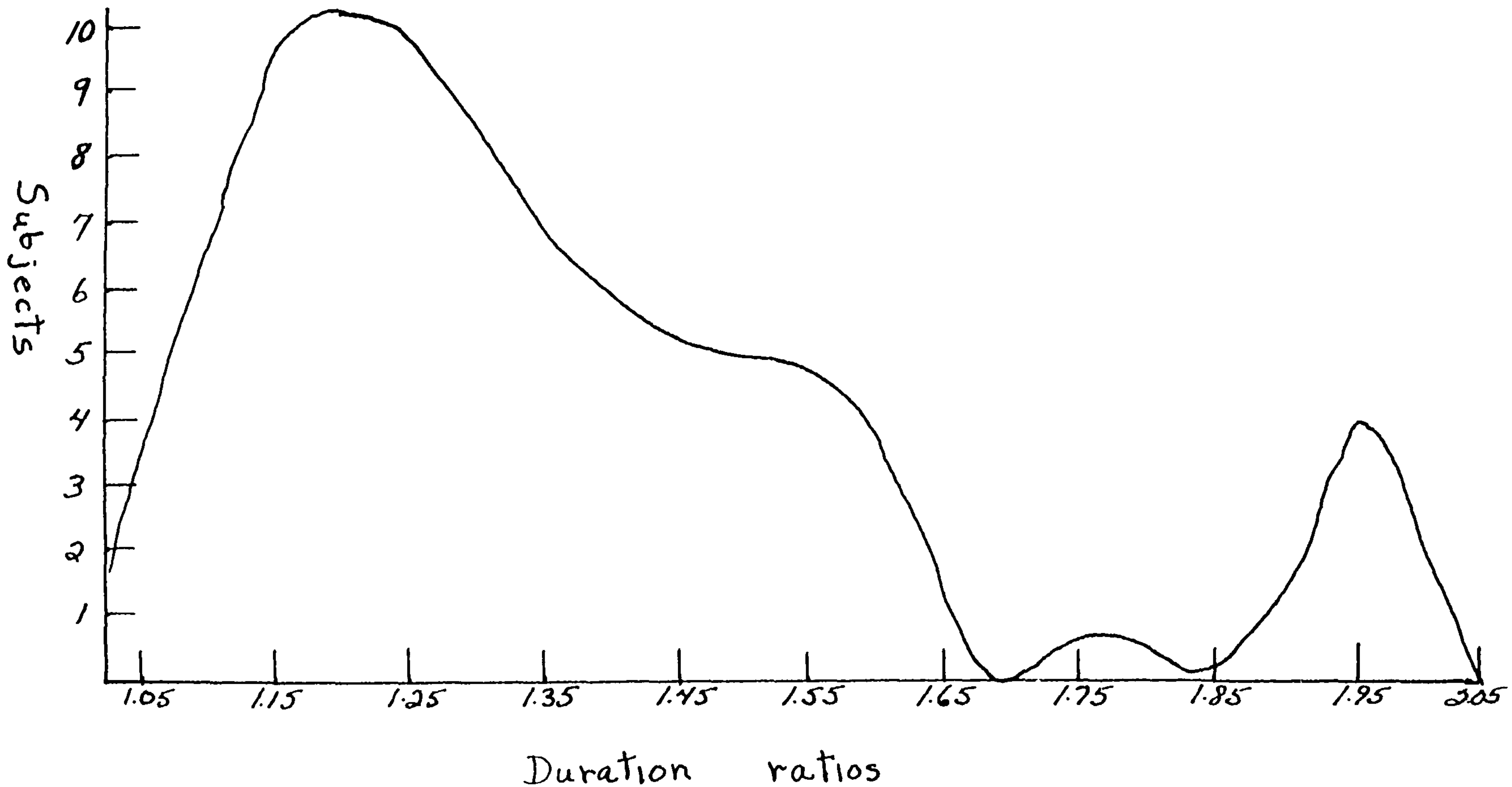
Figure 1. Total number of subjects per duration ratios for the entire (N=46) test population. Mean duration ratio, 1.36; standard deviation, 0.24. The bimodal configuration indicates two sub-populations within the distribution. The curve to the right represents the four members of the high susceptibility group and is 2.5 standard deviations above the mean.



comprised the high susceptibility group was 1.98 and indicates that it took these speakers nearly twice as long to produce the same ten phrases under DAF as under the normal delay condition. The mean duration ratio for the least susceptible group was 1.06, indicating little difference between delay conditions. These eight speakers, representing 16 percent of the entire test population, were considered to be the highest and lowest susceptible subjects to the effects of DAF, and provided the data for phonemic and spectrographic analysis of DAF susceptibility in this study.

Transcription Procedures

A tape was prepared from the master tapes and was used for phonemic transcription. The presentation order of conditions (180 msec. or normal delay), subjects (one, two, three, or four), and groups (high or low susceptibility) was randomized.

Two graduate students in speech pathology transcribed the data under forced choice instructions by selecting a symbol of the International Phonemic Association (IPA) for every sound perceived. The judges were also instructed to transcribe phoneme prolongation by (—), accented phonemes by ('), and to distinguish between repetitions of single phonemes such as /vvvɛri/ and consonant-vowel repetitions as in /vɛvɛvɛri/. Both

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judges used the same tape recorder (Sony, Model TC-105A) and were allowed as many trials as necessary to complete the transcription.

The phonemic transcription for each of the members in both susceptibility groups is shown in Appendix 1.

Scorer reliability

Reliability between the judgments of the two scorers of the phonemic and extra-phonemic speech components that occurred in the normal and the DAF conditions was calculated. In certain cases, where agreement based on phonemic transcription was not possible, spectrograms of the phonemes in question were consulted and used as the basis for final decisions.

The coefficient of reliability was determined to assess the agreement in articulation, prolongations, pauses, inappropriate accents, connected speech, and repetitions as perceived by the two judges. Using the Pearson correlation coefficient (Welkowitz, et al., 228-32, 1971), a correlation of +.98 was found.

Spectrograph Procedures

The 80 test phrases produced by the members of the susceptibility groups were played back (Ampex, Model 602) from the master tapes and fed into a sound spectrograph (Kay Sona-graph, Model 6061A). Scale magnification (Mod-

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el 6076C) was utilized throughout in order to observe the speech spectrum from 80 to 3500 Hz.

In accordance with the information obtained from phonemic transcriptions, spectrographic analysis of front vowel prolongation, vowels preceding phoneme omissions, and repetitions were made from the speech samples of all high susceptibility group members. Areas of special interest were formant transitions from the vowel of the preceding syllable to the vowel under analysis, formant transitions from the vowel under analysis to the following phoneme, and the configuration of the vowel during prolongation. Formant frequencies and patterns of transitions were compared to similar sounds produced in identical contexts in normal delay conditions.

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CHAPTER III

RESULTS

Non-parametric statistics were used in this study when it was felt that the underlying assumptions of parametric statistics could not be met. Specifically, the symbol system commonly used for transcribing the perception of speech sounds (IPA) lends itself to a numerical measurement no more sophisticated than nominal and ordinal techniques. As was the case in this study, transcription is governed by the use of a forced-choice classification system where the sound perceived is categorized as one phoneme from a system of phonemes. The total number of the sounds in each phonemic category, as well as the extra-phonemic factors such as pauses and prolongations, were then assigned a rank order or ordinal value.

Accordingly, a non-parametric test, the Kolomogorov-Smirnov Two Sample Test (Siegel, 1956) was selected as the statistical test of difference between the two susceptibility groups for the nine categories of speech alterations considered during phonemic transcription. This test was selected because it is not based on the assumptions of normal distribution and is most sensitive to analysis of differences in central tendency of small

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samples utilizing ordinal measurement techniques.

Statistical differences between groups

Table 3 shows the phonemic and extra-phonemic factors that were considered in phonemic analysis. Each numerical value represents the frequency of occurrence for each of the nine categories in the DAF condition that did not similarly occur in the normal delay condition. Intergroup differences were tested by the Kolomogorov-Smirnov Two Sample Test, where D = maximum $\{Sn_1(x) - Sn_2(x)\}$. Significant intergroup differences were found at the .05 level of confidence for five of the nine categories a) the use of sound and syllable repetitions, b) phoneme prolongations, c) pauses between syllables and words, d) inappropriate accents (phonemic accents that did not occur in the identical context and phoneme in the normal delay condition), and e) phoneme omissions.

Results of Phonemic Analysis

Sound and syllable repetitions

Table 4 indicates that the sound and syllable repetitions that occurred during the DAF condition but not under the normal delay condition occurred on plosive, fricative, and vowel sounds for the high susceptibility group members. Using the procedures described in Welkowitz, et al (1971), a Chi Square Test for One Variable

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Table 3. High susceptibility and low susceptibility group scores for each of the nine manner-of-production categories. Each value represents frequency of occurrence in DAF condition not observed in the identical context in normal delay condition. Significant intergroup differences between susceptibility groups are indicated by astericks.

Manner-of-production categories	Low Susceptibility Group	High Susceptibility Group
Sound and syllable repetitions	1	13*
Word repetitions	1	4
Prolongations	10	102*
Pauses	4	21*
Connected speech	9	12
Inappropriate accents	14*	4
Substitutions	3	6
Distortions	0	0
Omissions	4	12*

*(P 0.05)

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Table 4. Intergroup totals of repetitions per manner-of-production categories. Each value represents the repetitions in the DAF condition not seen in the identical context in the normal delay condition. Numbers in parenthesis indicate expected frequencies of repetitions based on the phoneme percentage data of Table 2.

Manner-of-production categories	Low Susceptibility Group	High Susceptibility Group
Front vowels	0	3 (2.5)
Mid vowels	0	1 (1.8)
Back vowels	0	1 (1.3)
Plosives	0	2 (2.2)
Fricatives	1	6 (2.4)
Total	1	13 (10.2)

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Problems was administered to determine whether the repetitions occurred in any of the categories of manner-of-production sounds (plosives, fricatives, and vowels) as a factor other than chance. The expected frequency of repetitions per manner-of-production category was calculated based on the information from Table 2. Expected frequency scores are shown in parentheses in Table 4. This test yielded no significant differences at the .05 level of confidence. While sound and syllable repetitions occurred more often in the speech of high susceptible subjects, the results indicated that the repetitions did not occur significantly more in any one of the specific manner-of-production categories.

Prolongations

As indicated in Table 3, the high susceptibility group members produced prolongations of phonemes significantly more during DAF than the low susceptibility group. Table 5 offers an illustrative analysis of the prolongations and shows prolongation frequency per manner-of-production category for each of the two groups. The expected frequencies are listed in parentheses and were derived from Table 2 in the same manner as that used for repetitions. A Chi Square test was administered to test whether the prolongations occurred in any of the categories of vowels, fricatives, semi-vowels, and nasals a

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Table 5. Total number of prolongations per manner-of-production categories for the high susceptibility and low susceptibility groups. Each value represents the number of prolongations observed in the DAF condition not seen in identical context in the normal delay condition. Numbers in parenthesis indicate the expected frequency of prolongations based on the phoneme percentage data of Table 2. The asterick indicates a significant intergroup difference.

Manner-of-production categories	Low Susceptibility Group	High Susceptibility Group
Front vowels	4	51*(19.9)
Mid vowels	1	14 (14.1)
Back vowels	2	21 (10.0)
Fricatives	3	6 (19.1)
Semi-vowels	0	6 (10.0)
Nasals	0	4 (08.3)
Total	10	102 (81.4)

*(P 0.01)

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significantly greater number of times. This procedure indicated that the observed frequency of prolongations, according to manner-of-production categories, exceeded the chance probability of their occurrence (X^2=73.5; df=5; p<0.001). In order to test for the significance of variance attributable to prolongations as a function of the categories of vowels, fricatives, semi-vowels, and nasals within the high susceptibility group, an analysis of variance (Winer, 1962, pp. 105-116) was performed for the individual subject data shown in Appendix 1 and summarized in Table 5. As summarized in Table 6, the intra-group scores for the high susceptibility members indicated significantly different performance as a function of manner-of-production categories (F=8.53; df=5,15; p<0.01). Use of the Tukey (A) Procedure (Winer, 1962, pp. 80-87) indicated a significantly greater occurrence of prolongations of front vowels by the high susceptibility group in the DAF condition (q=47; df=6,15; p<0.01). The frequency of occurrence of prolongations in fricatives, semi-vowels, nasals, mid and back vowels were not found to be significant. Results of these tests indicate that prolongations occur a significantly greater number of times in the DAF speech of high susceptibility subjects, and that a significant number of prolongations made by high susceptibility subjects occur more often during productions of front vowels.

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Table 6. Summary of analysis of variance for high susceptibility intra-group prolongation scores taken from Appendix. Value of F (8.53) indicates significantly different prolongation performance as a function of front, mid, and back vowels, fricatives, semi-vowels, and nasals.

Source of variation		SS		df	MS	F
Between people		58.80		3		
Within people		532.70		20		
Treatment	398		5		79.60	8.53
Residual	134.70		15		8.98	
Total		591.50		23		

$*F_{.99}(5,15) = 4.56$

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Pauses

As indicated in Table 3, the intergroup difference in frequency of occurrence for pauses between words and syllables was significant at the .05 level of confidence. These scores demonstrate that the high susceptibility group members paused more often while speaking under the DAF condition then while speaking during the normal delay condition. On the other hand, little difference was observed between conditions for the low susceptibility group. Fifteen of the 21 pauses made by the high susceptibility group occurred between words and syllables that were correctly produced.

Inappropriate accents

The low susceptibility group used inappropriate accents, defined as a recognizable increase in intensity, on certain phonemes 14 times in the DAF condition whereas no such observations were made under the normal delay condition. The high susceptibility group used this technique four times. As indicated in Table 3, this intergroup difference was significant at the .05 level of confidence. Phonemic analysis indicated that all 14 such accents used by the low susceptibility group occurred on vowels; whereas twelve of the accents occurred on front vowels, the remaining two occurred on back vowels.

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Omissions

Table 3 indicates that the high susceptibility group omitted phonemes twelve times under DAF that were produced in the normal delay condition. The low susceptibility group omitted four such phonemes. This difference between groups was significant at the .05 level of confidence. Phonemic analysis indicated that whereas all of the 12 omissions made by the high susceptibility group occurred on final sounds in words, all of the omissions made by the low susceptibility group occurred in the initial position of words. All of the omissions made by both groups occurred on consonants.

Results of Spectrographic Analysis

Sound and syllable repetitions

Nine different repetitions were studied. In eight of the nine cases, the formant transition from the vowel in the syllable that preceded the repetition to the vowel of the repetition in the DAF condition was not similar to the comparable formant transition observed in the normal delay condition. For example, in the configuration [hævðəbəbɛst] shown in Figure 2, no formant transition into the repetition /bə/ from the preceding syllable /ðə/ was noted. Also found was that the repeated vowel, in this example the /ə/ in /bə/, was often more similar to

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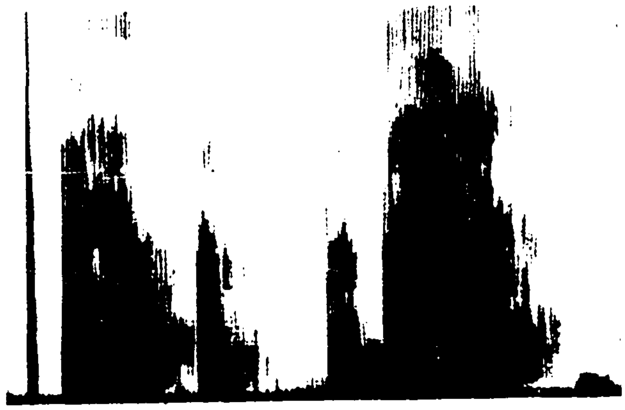
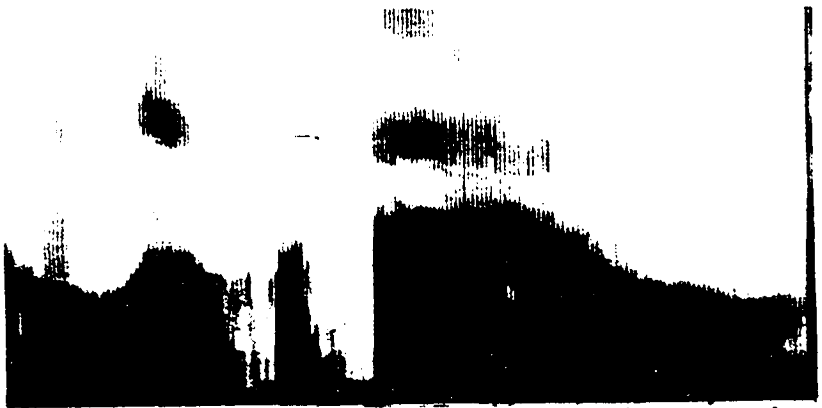
Figure 2. Sound spectrograms showing repetitions in the phrase (A) <u>have the best</u> and (B) <u>circle the field</u>.



h æ v ð ə   bə b ɛ   s   t

2(A)



Kl ð ə fə f i l d

2(B)

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the preceding vowel, /ə/ in /ðə/, than the correct vowel /ɛ/ in /bɛst/. In the remaining case, the DAF formant transition resembled the transition seen in the normal delay condition. In this repetition, an articulatory movement from the back vowel /u/ to the front vowel /æ/ was made in the configuration [juhæhæv].

In all nine cases, th[juhæhgraphs revealed that the repetitions consisted of consonant-vowel configurations or isolated vowels. Although three of the 13 repetitions were phonemically perceived by the judges as isolated consonant repetitions, spectrograms of these repetitions showed that the repeated consonants were actually consonant-vowel configurations. Repetitions of isolated consonants were not observed in any of the spectrographic data. As represented in Figure 2 in the configuration [sɜklðəfəfild] the vowels in these three cases were more similar to the vowels in the preceding syllable, /ə/ in /ðə/, than the correct vowel, /i/ in /fild/.

The vowels in five of the repetitions under DAF were of greater duration than the same vowels in the normal delay condition. However, due to the design of the experiment, it was impossible to determine if vowel prolongation during repetition was due to the repetition itself or the effect of DAF. The mean duration of the vowels in repetition was approximately 80 to 100 msec. longer than the measured duration of the same vowels in the nor-

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mal delay condition.

The formant configurations of the vowels in the repetitions were noticeably flat and little transition to the target syllable was noted. The vowels appeared to come to an abrupt arrest. In instances where two repetitions occurred before the target syllable was produced, the two repetitions were of equal duration. Initiation of the correct vowel was distinct; no transition occurred from the last repetition to the correct syllable. In most cases, the correct syllable, when first produced correctly following the repetition, was prolonged.

Figure 2 shows a spectrograph of the configuration [ðəbəbɛst]. Demonstrated are the a) formant similarities between the vowel /ə/ in /bə/ and the vowel /ə/ in /ðə/, b) lack of formant transition from the repetition /bə/ to the correct syllable /bɛ/, and c) prolongation of the correct vowel /ɛ/. Also shown in Figure 2 is the configuration [ðəfəfild]. This phrase was transcribed as [ðəffild]. Both judges failed to perceive the vowel-like phoneme revealed in the spectrograph. Shown is the similarity of the repetition to the previous vowel, and prolongation of the correct vowel. Neither of the repetitions shown in Figure 2 are examples of repeated vowel prolongations.

Prolongations

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Spectrographs of three different front vowel prolongations for each of the high susceptibility subjects were analyzed. In all 12 cases, formant transition from the preceding vowel (shown in Figure 3 as /u/ in the syllable /tu/) to the prolonged vowel (/e/ in Figure 3) was identical to the transition seen in the normal delay condition. With the exception of duration, transition into the prolonged vowel appeared normal in all respects. The mean duration of the prolonged vowels was found to be 225 msec., 2.82 times longer than the mean duration of the same vowels produced in the normal delay condition. Formants f1 and f2 were at the same frequency as in the normal delay condition. The most conspicuous difference between the two delay conditions was the extended and flat configuration of the first two formants.

Transitions under DAF from the prolonged vowel to the following phoneme were similar to the transitions that occurred in the normal delay condition, except that the transitions under DAF covered a longer period of time. In all 12 vowels studied, the frequency in Hz. at the point of cessation of phonation was similar to the corresponding point in the normal delay condition.

Figure 3 compares the configuration /tue/ in both delay conditions. Demonstrated is the similar transition of f1 and f2, as well as the relatively flat contour of f2 during prolongation. Also shown in both spectro-

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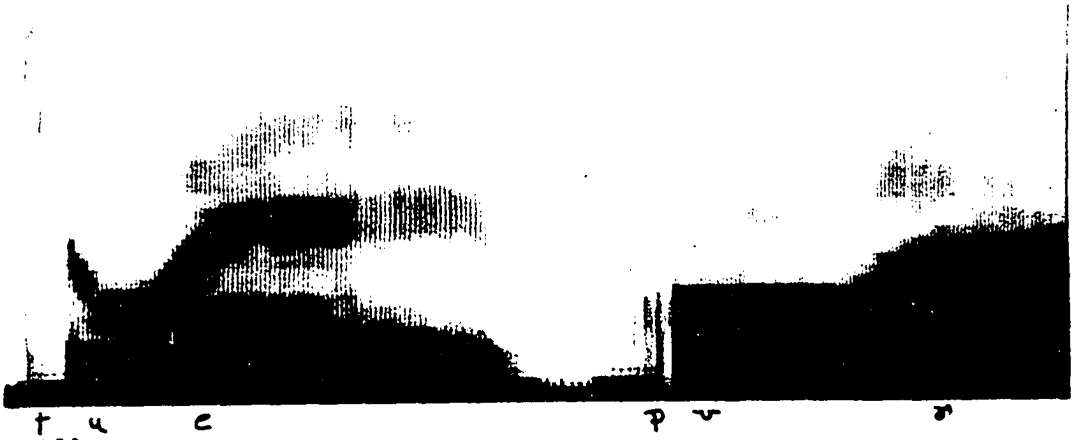
Figure 3. Sound spectrograms showing (A) prolongations in the DAF condition and (B) the same phenomena in the normal delay condition in the phrase to a poor.



3(A)

3(B)

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graphs is the initiation of the next word (pʊð).

Omissions

All phoneme omissions occurred after a vowel prolongation and on final sounds in words. Formant transition into the vowel preceding a phoneme omission in the DAF condition appeared similar to the transition observed in the normal delay condition for all of the eight omissions studied. With the exception of the formant irregularities appearing at the end of the vowel in the direction of the omission, formant configurations of vowels preceding omissions appeared to be similar to the configurations seen in prolonged vowels. Transition at the end of the vowel preceding an omission was different from that seen in the normal delay condition; in some cases no formant transition was observable in the DAF condition. Figure 4 shows spectrograms of the word (tʃæns) in the normal delay and DAF conditions. Although initiation of these words appears similar to that seen in the normal delay condition, no transition during the vowel /æ/ or into the nasal /n/ is demonstrated. Yet, this word, produced under DAF, was perceived and transcribed as /tʃæn/ by both judges.

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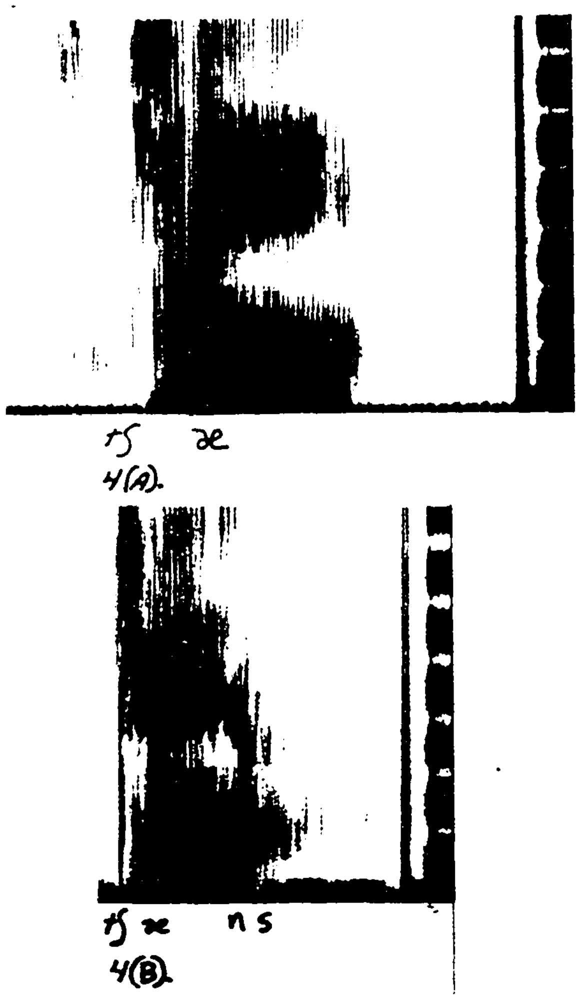
Figure 4. Sound spectrograms showing (A) omission of /ns/ in the word *chance* in the DAF condition and (B) the same word in the normal delay condition.



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CHAPTER IV

DISCUSSION

Susceptibility groups

Figure 1 is a display of the total number of subjects (ordinate) that obtained particular duration ratios (abscissa). The entire test population of 46 subjects is included in this display. The configuration of the curve is bimodal, suggesting that there were two subpopulations within the distribution. The peak of the asymmetric curve to the right is beyond 2.5 standard deviations above the mean, and represents the four members of the high susceptibility group. While Yates (1963) found that approximately 20 percent of normal-speaking adults were most susceptible to DAF, the distribution of this test population identified eight percent of the speakers as high susceptibility subjects. An equal number of subjects were selected from the opposite end of the distribution to serve as the low susceptibility group, and represented a group of four speakers lying 1.5 standard deviations below the mean.

Fluency

High susceptibility subjects were found to demon-

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strate significantly more sound and syllable repetitions than low susceptibility subjects. However, repetitions did not occur in either group to any great extent. Of the 492 phonemes produced by the high susceptibility group under DAF, repetitions occurred on 13 phonemes, or 2.6 percent of the phonemes spoken under DAF. Further analysis indicated that repetitions in the high susceptibility group members were likely to occur in any phonemic context, and were therefore inconsistent in their occurrence. Also observed was that ten of the 13 repetitions occurred during the reading of the first two phrases under DAF, suggesting that adaption to DAF resulted in increased fluency. The results indicated that repetitions do occur a significantly greater number of times in subjects most susceptible to DAF. Perhaps such a factor can be used to differentiate the two groups even though repetitions occur infrequently and appear irregularly. However, this DAF speech characteristic may only be evident when subjects are first introduced to DAF.

In all nine cases of repetitions studied, spectrographic analysis revealed that repetitions of sounds or syllables did not occur unless vowels were produced. In the three cases where phonemic analysis indicated that there were repetitions of single consonants, spectrograms of the repetitions revealed evidence of vowel production. Further spectrographic analysis indicated that in almost

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all cases the repetitions involved an incorrect vowel rather than the vowel required to produce the desired syllable. In most instances the incorrect vowel appeared to be the same vowel as that from the syllable immediately preceding the repeated syllable. Consequently, formant transition into the vowel under repetition was not similar to the transition observed for the same syllable in the normal delay condition.

Abrupt cessation of phonation in all vowels of repeated syllables was also noted. No formant transition was observed from the vowel of a repeated syllable to the next phoneme, indicating that the speaker made a rapid articulatory change from the repeated syllable to the following sound. When the correct syllable was produced after one or more repetitions of a sound or syllable, the vowel of the correct syllable was prolonged.

Where normal formant transition was not observed during vowels of a repeated syllable, spectrographic analysis of front vowel prolongations of high susceptibility subjects showed that these sounds were initiated as they were under the normal delay condition. Phonemic analysis also concurred that the prolonged vowels were the correct sounds that the subjects were required to make. Formant transition from the prolonged vowel into the following phoneme was also similar to the transition observed under the normal delay condition. The most con-

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spicuous spectrographic characteristic during prolongation was the flat configuration of the formants, indicating that the speaker was holding a fixed articulatory position during the prolongation.

Phonemic analysis indicated that the use of prolongations by high susceptibility subjects was the most distinguishing characteristic observed between the two groups. High susceptibility subjects prolonged 21 percent of all the phonemes they were required to read under DAF, while low susceptibility subjects prolonged two percent of the same phonemes. Further statistical analysis indicated that a significantly greater number of the prolongations made by high susceptibility subjects occurred on front vowels.

Another factor of fluency that served to differentiate the two susceptibility groups was non-phonatory pauses between words and syllables. This technique occurred 21 times in the high susceptibility group as compared to four times in the low susceptibility group. Intragroup comparison of the high susceptibility group members indicated that there was an inverse relationship between the use of prolongations and pauses. As an example, the subject who used the most pauses between words and syllables (46 percent of the total pauses for the group) used the least prolongations (10 percent of the group total); the subject who used the most prolonga-

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tions (35 percent of the group total) used the least pauses (4 percent of the group total). Phonemic analysis indicated that pauses and prolongations were never used in succession within the same phrase. Of the four categories (repetitions, prolongations, pauses, and omissions) that differentiated the susceptibility groups, pauses and prolongations were the two categories that showed high intersubject variability within the high susceptibility group. The frequency of occurrence of these two factors raises the possibility that either prolongation or pause was the adaptive mechanism used by the high susceptibility subjects to initiate phonemes under DAF without producing phonemic errors.

Articulatory performance

The incidence of substitutions, distortions, and omissions was used to measure articulation performance in this study. No sound distortions were noted by phonemic analysis for either susceptibility group. The total incidence of phoneme substitutions was also low, occurring in only 1.2 percent of the total phonemes under the DAF condition for the high susceptibility group and in less than 0.6 percent for the low susceptibility group. The only articulatory measurement that showed a significant difference between groups was phoneme omissions, which occurred in the high susceptibility group a greater num-

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ber of times. Phonemic analysis indicated that the high susceptibility group used omissions nearly as many times as repetitions. The omissions appeared on 2.4 percent of the total number of phonemes. Phonemic analysis also revealed that all omissions occurred on final sounds.

Spectrographic analysis indicated that all omissions occurred after prolongation of a vowel. The flat contours of the first and second formants of the vowel preceding the omission were similar to the formant configurations observed in vowel prolongations as discussed above. A differentiating characteristic between vowel prolongation and phoneme omission was the lack of formant transition from the vowel into the following phoneme. This indicated that articulatory positioning toward the omitted phoneme had not taken place.

Fairbanks and Guttman (1958) analyzed articulation performance under DAF as a factor of different delay times. This study agreed in part with their results, even though Fairbanks and Guttman used a 200 msec. delay time as opposed to a 180 msec. delay time used in this study. These authors reported that substitutions and omissions were observed under delay, and that these articulation errors were nearly equal in frequency of occurrence. Their classification of additions showed the most errors, but since repetitions comprised 70 percent of the errors in the addition class, the frequency of

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occurrence of omissions, substitutions, and repetitions reported in their study are nearly equal. Whereas the values reported by Fairbanks and Guttman were representative of the mean of the entire test population, the values reported in the present study were representative of susceptibility groups. Nevertheless, both of these studies were in agreement as to the occurrence of substitutions and omissions in DAF speech. This study also showed that the frequency of occurrence of these errors varied as a function of susceptibility to DAF.

Burke (1971) studied DAF susceptibility and concluded that susceptibility groups differed in terms of reading duration, disfluency, and correct syllable rate. While this study agreed with his findings, it was not possible to more specifically compare articulatory performance in these two studies.

Inappropriate accents

The one category in which the low susceptibility subjects showed a significantly greater frequency of occurrence was inappropriate accents, defined as a recognizable increase in intensity on a certain phoneme in the DAF condition not observed in the normal delay condition. Phonemic analysis indicated that the frequency of occurrence of inappropriate accents was 2.8 percent of the total phonemes produced by the low susceptibility group,

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which is comparable to the frequency of occurrence of omissions (2.4 percent) and repetitions (2.6 percent) which were found to differentiate the high from the low susceptibility group. However, with the exception of the frequency of occurrence, inappropriate accents were similar to prolongations in that a) phonemic analysis indicated that all accents occurred on vowels, and that 12 of the 14 accents occurred on front vowels, b) as in the case of prolongations, spectrographic analysis indicated that the formant transition of the accented vowel from the preceding phoneme and into the following phoneme was similar to the transition observed in the normal delay condition, and c) as with prolongations, no articulatory errors were noted in the accented vowel. These findings raise the possibility that accented vowels during DAF reflect the adaption mechanism used by low susceptibility subjects to produce speech sounds free from errors of articulation or fluency.

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CHAPTER V

CONCLUSIONS

This study was designed to describe the differentiating characteristics of speech obtained under DAF from normal-speaking subjects who had previously been categorized as having demonstrated either high or low susceptibility to DAF. Results of phonemic and spectrographic analyses of the speech obtained under the conditions of this study from these populations tend to support the following conclusions:

1. The most frequently observed differentiating characteristic of high susceptibility DAF speech was front vowel prolongation. Spectrographic analysis permitted the hypothesis that front vowel prolongation allowed the speaker to move from the prolonged vowel to the following phoneme without producing any speech errors. The prolonged vowel, with the exception of an increase of duration, was always phonemically correct. Prolongations remained evident in the DAF speech of high susceptibility subjects regardless of the time period spent under delay.
2. Pauses between words and syllables also significantly differentiated the two susceptibility groups. It was hypothesized that the use of pauses was another technique used by high susceptibility subjects to speak without

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producing errors of articulation or fluency since no such errors were observed in phonemes preceding or following a pause. The appearances of pauses and prolongations in DAF speech were inversely related. As in the case of prolongations, pauses were evident throughout the DAF speech condition.

3. Although the frequency of repetitions was low and irregular in appearance, and diminished as the speaker adapted to DAF, a significantly greater number of repetitions occurred in the DAF speech of high susceptibility group members. Spectrographic analysis indicated that repetitions always involved a vowel. In most cases the repeated vowel was not the same sound required to produce the correct syllable that followed the repetition. Also shown were irregularities in formant transitions into the repeated vowel, and the lack of any formant transition from the repeated vowel to the correct phoneme that followed the repetition.

4. The occurrence of phoneme omissions also differentiated the two susceptibility groups, with high susceptibility subjects using omissions a significantly greater number of times. Omissions occurred on final sounds in words, after prolongations of vowels, and nearly as frequently as repetitions. Spectrographic analysis showed a lack of formant transition from the prolonged vowel toward the omitted phoneme.

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5. The low susceptibility group used accents (defined as increases in intensity) significantly more often than did the high susceptibility group. A similarity between the high susceptibility group's use of prolongations and the low susceptibility group's use of accents was noted. This was indicated by the findings that a) most accents occurred on front vowels, b) spectrographic analysis indicated normal formant transitions, and c) no phonemic errors occurred where accents were observed.

6. Word repetitions and phoneme substitutions were noted in the DAF speech of both groups but significant intergroup differences were not found. In addition, both groups were equally likely to omit pauses under DAF that occurred between syllables and words in the normal delay condition.

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APPENDIX

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High Susceptibility Subject Number One

normal delay condition; 180 msec. delay condition

1. juhæv ðəbɛstʃæns; juhæv juhæv—ðəbɛbˈɛs—tʃæn
2. ðəθradlɪzklozd; ðəθra—dl ˈɪz klozd
3. tusɝkl ðəfild; tusɝ—kl ðə fild
4. tɥəˈpʊɚ sɝfəs; tuə pˈʊ—ɚ sɝ—fə
5. vɝi jʊɚpædɚn; vɝi jʊɚ pædɚ
6. ədʒʌst avɚdɪstəns; ədʒʌ—st av—
dɪstən
7. ritʃɪŋ ɛnlændɪŋ; ri—tʃɪ—ŋ ɛnlæ—ndɪŋ
8. wigɛtaʊt faɚðɚ; wi gɛt aʊt faɚ ðɚ
9. ʃoju wʌtaɪmin; ʃo ju wʌt aɪ min
10. ʃʊdnɛvɚ kæɚi; ʃʊ—nɛvɚ kæɚ

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	1
Word repetitions	0	2
Prolongations	0	11
Pauses	9	13
Connected speech	n/a	0
Accents	1	3
Substitutions	0	0
Distortions	0	0
Omissions	0	7

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High Susceptibility Subject Number Two

normal delay condition; 180 msec. delay condition

1. ʃʊdnɛvɚkæɚi; ʃ ʃʊʃʊdnɛvə kæɚi
2. wigɛtaʊt faɚðɚ; wigɛtaʊ___ faɚð___ɚ
3. ritʃɪŋənlændɪŋ; ri___tʃɪŋ___ɛn___læ___ndɪŋ___
4. ðəθradlɪzklozd; ðəθra___dl___ɪzklo___zd
5. tuəpʊɚsɜfɪs; tuo pʊ___ɚsɜfɪs
6. ədʒʌstaɚdɪstəns; ədʒʌsta___ʊɚdɪ___stəns
7. tusɜklðəfild; tusɜkl___ðəfi___ld
8. ʃojuwʌtaɪmin; ʃo___jujuwʌaɪ___mi___n
9. vɛri jʊɚpædɚn; vɛɚ___jʊ___ɚpæ___dɚ___n
10. juhævðəbɛstʃæns; juhæhævðəðəbɛ___stʃæ___ns

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	3
Word repetitions	0	2
Prolongations	0	24
Pauses	1	2
Connected speech	n/a	0
Accents	1	0
Substitutions	0	3
Distortions	0	0
Omissions	0	3

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High Susceptibility Subject Number Three

normal delay condition; 180 msec. delay condition

1. ʃʊdnɛvɚ kæɚi; ʃʊ ʃʊ_dnɛ___vvɚ kæ__ri
2. tusɝkl ðifild; tusɝkkl ðəffi___l_d
3. wi gɛtaʊtfaɚðɚ; wigɛtaʊ___tfa___ɚðɚ
4. ʃo__juwʌtaɪmin; ʃo_ju__wʌ___daɪ___mi_n
5. ðiθradl ɪzklo_zd; ðiθra___dl__ɪ__zklo__zd
6. ju hæv ðibɛs tʃæns; ju__hæ__v ði__bɛ__s tʃæ__ns
7. tuepʊɚ sɝfɪs; tu__e___pʊ___ɚsɝ__fɪ___s
8. ədʒʌst ɚdɪstəns; ədʒʌstaɚ___dɪs_tə__ns
9. ritʃɪŋ ɛnlændɪŋ; ri__tʃɪ__ŋ ɛɛ ɛnlæ_ndɪ_ŋ
10. vɛri jɚpædɚn; vɛ___ri___jɚ__pæ___dɚ__n

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	6
Word repetitions	0	0
Prolongations	2	36
Pauses	11	1
Connected speech	n/a	10
Accents	0	0
Substitutions	0	2
Distortions	0	0
Omissions	0	0

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High Susceptibility Subject Number Four

normal delay condition; 180 msec delay condition

1. tuəpʊɚsɝfɪs; tuépʊ—ɚsɝ—f—ɪs
2. ədʒʌstar dɪstəns; ədʒʌhʌstarɝ dɪs—stətəns
3. ðəθradl ɪz klozd; ðə θra—dl— ɪz kla—zd
4. ʃowʌtaɪmin; ʃo—ju—wʌtaɪmi—n
5. wigɛtaʊt farðɚ; wi gɛtaʊ—t far—ðɚ
6. jʊl hæʊðəbɛstʃæns; ju—hæ—vðəbɛs—tʃæ—ns
7. tusɝklðəfild; tu—sɝ—kl—ðəfi—ld
8. ritʃɪŋ ɛnlændɪŋ; ri—tʃɪŋɛn—læ—ndɪŋ
9. vɝi jɚpædɚn; vɜɚ—i—jɚ—pæ—dɚn
10. ʃʊdnɛvɚ kæɚi; ʃʊ—dnɛ—vɚkæ—ɚi

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	3
Word repetitions	0	0
Prolongations	0	31
Pauses	2	5
Connected speech	n/a	2
Accents	0	1
Substitutions	0	1
Distortions	0	0
Omissions	1	0

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Low Susceptibility Subject Number One

normal delay condition; 180 msec. delay condition

1. vɛri jʊɚpædɚn; vɛɚ vɛrijɚ p'ædɚn
2. ədʒʌstaɚ dɪstəns; ədʒʌst'aɚdɪstəns
3. ju hæv ðəbɛs tʃæns; juhævðə b'ɛstʃəns
4. ʃʊdnɛvɚ kæri; ʃʊdn'ɛvɚ kæri
5. tʌsɝ'kl ðəfild; tʌsɝklðəfild
6. ðəθradl ɪzklozd; ðəθradlɪzklozd
7. wigɛtavt fɝ'ðɚ; wigɛtavt fɝ'ðɚ
8. tuəpʊɚ sɝ'fɪs; tuəpʊɚsɝfɪs
9. ʃoju wʌtaɪmin; ʃojuwʌtaɪmin
10. rɪtʃɪŋ ɛnlændɪŋ; rɪtʃɪŋɛnlændɪŋ

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	* 1
Word repetitions	0	0
Prolongations	0	0
Pauses	8	0
Connected speech	n/a	7
Accents	0	4
Substitutions	0	1
Distortions	0	0
Omissions	0	0

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Low Susceptibility Subject Number Two

normal delay condition; 180 msec. delay condition

1. ʃojuwʌtaɪmin; ʃo ʃojuwʌtaɪmin
2. ədʒʌst ardɪstəns; ədʒʌstardɪstəns
3. təsɝklðəfild; təsɝklðəfild
4. tu epvɚsɝfɪs; tuəpvɚsɝfɪs
5. vɝi jɚpædɚn; vɝi jɚpædɚn
6. ðəθradlɪz klozd; ðəθradlɪz klozd
7. ʃvdnɛvɚkæri; ʃvdnɛvɚkæri
8. ritʃɪŋ ɛnlændɪŋ; ritʃɪŋ ɛnlændɪŋ
9. juhævðəbestʃæns; juhævðə bɛs tʃæns
10. wigɛtavt farðɚ; wigɛtavt farðɚ

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	0
Word repetitions	0	1
Prolongations	0	0
Pauses	5	2
Connected speech	n/a	2
Accents	1	0
Substitutions	0	2
Distortions	0	0
Omissions	0	0

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Low Susceptibility Subject Number Three

normal delay condition; 180 msec. delay condition

1. wigɛtavtfaɚðɚ; wigɛtav_tfa_ɚð_ɚ
2. tuəpvɚsɝfɪs; tuəpvɚs_ɝfɪs
3. ʃvdnɛvɚkæɚri; ʃvdnɛvɚkæɚ_ri
4. ðəθradlɪzklozd; ðəθrádlɪz kló_zd
5. jə hævðəbɛstʃæns; jə ævðəbɛstʃæns
6. ritʃɪŋ ənlændɪŋ; ritʃɪŋən læ_ndɪŋ
7. vɝijɚpædɚn; vɝijɚpæɚn
8. tusɝklðəfild; tusɝklðəfild
9. ədʒʌstaɚdɪstəns; ədʒʌstaɚdɪ_stəns
10. ʒojuwʌtaɪmin; ʃowʌtaɪmi_n

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	0
Word repetitions	0	0
Prolongations	0	9
Pauses	0	0
Connected speech	n/a	0
Accents	0	3
Substitutions	0	0
Distortions	0	0
Omissions	0	3

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Low Susceptibility Subject Number Four

normal delay condition; 180 msec. delay condition

1. ʃojuwʌtaɪmin; ʃoju wʌtaɪmˈin
2. ədʒʌstaɚdɪstəns; ədʒʌst ˈaɚdɪsəns
3. ritʃɪŋɛnlændɪŋ; ritʃɪŋˈɛn lændɪŋ
4. ʃʊdnɛvɚkæɚi; ʃʊdnˈɛvɚkæɚi
5. vɝijʊɚpædɚn; vɝijˈʊɚpædɚn
6. tuepʊɚsɝfɪs; tuepʊɚs__ɝfɪs
7. wigɛtaʊtfaɚðɚ; wigɛtˈaʊtfaɚðɚ
8. tusɝklðəfild; tusɝklðəfild
9. juhævðəbɛstʃæns; juhævðəbɛ__stʃæns
10. ðəθradlɪzklozd; ðəθrˈadlɪzklozd

	Normal Delay	180 msec not seen in normal delay
Sound & syllable repetitions	0	0
Word repetitions	0	0
Prolongations	0	1
Pauses	0	2
Connected speech	n/a	0
Accents	0	7
Substitutions	0	0
Distortions	0	0
Omissions	0	0

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