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VOWEL ERRORS IN APHASIA

By

ERIC KELLER

Department of Linguistic Studies

A Thesis submitted in conformity with the requirements
for the Degree of Doctor of Philosophy in the
University of Toronto

ABSTRACT

The phonological and phonetic deficits of anterior aphasics have been analyzed as either linguistic pathologies or within the framework of clinical symptomatology. This study aims at a description of the articulatory tongue movements in neuromuscular terms.

Seven unilingual English-speaking and two bilingual French and English aphasics who made frequent vowel errors were recorded in spontaneous speech and repetition tasks. Three patients, plus one patient reported in the literature, contributed material on a reading task. 1315 vowel substitutions were collected (215 diphthongal and 251 environmentally motivated errors excluded). Unilinguals showed a consistent tendency towards lowering, unrounding and tensing in spontaneous speech and repetition; the pattern for bilinguals was similar, except that their errors were compounded by a tendency towards fronting which may possibly reflect a regression to an earlier state of linguistic competence. The substitutions on the reading task showed possible signs of interference from the patients' visual associations with spelling pronunciation variants for the vowel concerned.

Phonetically, a subsample of 100 substitutions analyzed on a Kay Sonograph supported the main findings. Moreover, aphasics had higher average $Formant_1$ measurements than normals or dysarthics showed for the same perceived vowel. This was interpreted as another indication that aphasics tended to have wider constriction levels than normals in their oral vocal tract during articulation.

Neural activation is selective for particular extrinsic tongue muscles with high vowels, and more generalized with lower vowels. The tendency towards lower vowels and wider constriction levels thus indicates a loss in the selectivity of neural activation--a notion that also accounts for the tendency towards rounding and tensing. Loss in the selectivity of muscle activation has been described in the literature as resulting from post-central lesions. It is therefore speculated that patients with frequent vowel substitutions have lesions that extend into the postcentral cortex, while those who do not produce frequent vowel errors, have lesions which respect this area.

To Professor Martin Joos

who taught us to put theory
into the context of ample data.

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ACKNOWLEDGEMENTS

This study combined occasional exhilaration with long stretches of immense tedium. It called for a talent for exploring hundreds of dead end streets, for sitting still for long hours and, certainly, for coaxing other people into doing things for me. In some cases, I was able to offer some compensation, but in most, my great thanks and this piece of work form the only gratification I can return.

Chronologically, here are the people I remember the most readily:

Peter H. Salus encouraged me wholeheartedly when I needed it most at the initial stages of the project.

Mrs. Francis Ezerzer, Speech Pathologist at the Toronto Western Hospital, put me in touch with patient ID.

Mrs. Laury Walsh, of the Our Lady of Mercy Hospital, Toronto, helped me record three anterior patients, EL, GP, and DH.

Mrs. Fiona Ryner, of the Toronto Rehabilitation Centre, introduced me to patient AW.

Mrs. Jane Moore, of Sunnybrook Hospital, Toronto, made arrangements so that I could interview patient BW.

Sheila E. Blumstein, of Brown University, kindly let me rerecord her interviews with patient AB, and Andrew Kertesz, of St. Joseph's Hospital, London, Ontario, did the same for patients JR and TK.

I would like to thank the subjects of this study for their time and cooperation.

Sheila Blumstein, Howard Gardner, of the Boston Veterans Administration Hospital, Andrew Kertesz, Roch Lecours, of Hôtel-Dieu de Montréal, and Harry A. Whitaker, of the University of Rochester, each took some time to put me on the right track as the project got underway.

Peter A. Reich arranged for a grant to pay for transcription costs. He also generously let me use his account on the University of Toronto computer.

Jane Naughton, Anne Greenwood and Linda Moran, all students of linguistics, buckled down to the tedious job of transcribing and retranscribing and retranscribing the data.

Anne Greenwood then used up a lot of her spare time to get it all onto punch cards.

Howard Woods and David Coldrick helped me with a number of aspects of the project when I moved to Ottawa.

Discussions with Cornelius von Baeyer, colleague both at the University of Toronto and at the Language Bureau in Ottawa, clarified many issues and helped me tighten up the whole study.

Mr. D. Burrill, Professor of Statistics at the Ontario Institute for Studies in Education, suggested different ways of exploring the data. He also kindly went over my use of statistical measures.

Professors Pierre R. Léon and Jon Barlow, University of Toronto, made arrangements for me to use their Kay Sonographs.

Anne Greenwood and I cooperated on the typing of the manuscript and tables. Anne also compiled the glossary and the bibliography.

I would like to thank all for their help.

Ottawa, August 1975

INTRODUCTION

The study of aphasia is concerned with the breakdown of two related systems: the life support system of part of the brain, and the communicative system of language which that section of the brain mediates. This intimate relationship between the two systems has traditionally necessitated an interdisciplinary approach to aphasia research.

For more than a hundred years, for instance, neurologists have attempted to relate various areas of the brain to specific linguistic functions, such as comprehension or the sequencing of phonological units (cf. Hécaen and Angelergues 1965). For this type of research, neurologists have had to be familiar to some extent with various aspects of language.

In recent years, linguists have sought to isolate some linguistic parameters of various types of aphasia. Such parameters have been expected to reflect aspects underlying the linguistic organization of normal language. As an example, Whitaker (1971) suggested an ordering of levels in the grammar which is congruent with evidence from aphasia. Such research in turn requires at least some familiarity with neurology.

Moreover, researchers from psychology and speech pathology have traditionally applied experimental and statistical methods to the formidable problems of aphasia. As a result, neurologists as well as linguists have been induced to state some of their more recent research results in quantitative form (Lecours et al. 1973, Blumstein 1973b).

The present study reflects all these various traditions. Its results suggest that the postcentral cortex may be crucially involved in the processing of vowels, a finding of some interest to neurology. Linguists, on the other hand, will find that markedness is not a useful parameter in describing the desintegration of vowels in aphasia. A very interesting parameter, in contrast, has proved to be the degree of specificity in neuromuscular activation of the tongue: higher vowels, which require specific activation, tended to be replaced by lower vowels which require less specific activation. And as in the field of psychology, research questions are tackled by means of experimental and quantitative methods.

The central research question of the study, likewise, is one that occupies scholars from a variety of disciplines. It is the following: what happens in the brain and the associated articulatory musculature as we use language? A full answer to this question is of course far off in the future, and will presumably be exceedingly complex if and when it ever becomes known. Meanwhile, research must nibble away at the fringes of this problem. Vowel errors in aphasia appear to be such an area amenable to immediate research.

It is the object of this study to examine vowel errors for clues about what kind of neural activation patterns reach the articulatory muscles in aphasia. Information of this sort will lead to further research hypotheses concerning what kind of interaction is necessary between the brain and the articulators in order to effect normal speech.

As it happens, vowel errors of one group of aphasics are, like all of their articulation errors, particularly open to systematic investigation. These patients share the characteristic that they generally know what they intend to say, but cannot easily articulate these intended utterances.

Instead, they usually make several attempts at the intended utterance before they either come up with the correct sound sequence or give up in frustration. In either case, it is generally possible to deduce what utterance was intended. It is therefore possible to compare large numbers of erroneous vowels with their intended counterparts. Statistical measures can then be applied to find out if any systematic tendencies are evident between what amounts to the "input" (intended sounds) and the erroneous "output" (error sounds) of the final stage of articulation.

In at least two respects, vowel errors are easier to study than consonant errors. First, vowels are more accessible than consonants in spectrographic measurements. This gives us an empirical metric where the nature of the aphasic vowel is concerned, albeit one that remains problematic in many ways. For instance, even the best spectrograms are often open to considerable leeway in interpretation, since measuring spectrographic formants is still as much an art as it is a science.

Second, vowel articulation can be characterized in terms of the action of relatively few interacting muscle groups, while the production of consonants exacts a far more complex description of the action of a great variety of muscle groups. In the case of vowel errors, we can thus deduce a likely erroneous muscle action from a systematic tendency in vowel errors that we have previously isolated. Erroneous muscle actions can in turn provide clues about what is abnormal in the neuromuscular activation patterns issuing from the affected brain. Through the converging results from various separate analyses which make use of these fortuitous aspects of research on vowel errors, it was thus possible to arrive at answers within the central research paradigm described above.

One fundamental assumption made in this approach to vowel errors is that articulation can be treated as a motor skill. Like other human activities which we more readily see as a motor skill, say typing, articulation depends on patterned contractions of specific muscle groups. They, in turn, are activated by specific commands from the brain. As the fourth chapter of this study indicates, it has been profitable to view phonological breakdowns in aphasia from this perspective, since most of the findings were satisfactorily accounted for within the motor skill schema.

Nevertheless, it would be misleading to think that articulation can be described solely in terms of neuromuscular activation patterns. Subsidiary results of this study indicate that central brain processes which feed into the motor process of articulation can also influence errors in aphasia. For instance, two aphasics showed interference from graphic spelling patterns on reading tasks. It would seem, therefore, that brain processes associated with the visual modality have the capacity to influence final articulatory processing. Moreover, two bilingual patients showed interference from their native language which indicates that articulatory processes must be seen in view of previously stored, as well as presently active, neuromuscular patterns. A full description of articulation, even a neurophysiological one, must therefore aim for adequacy within the full extent of possible brain processing.

This study is innovative in a number of ways. The central research question is one that presently occupies few linguists. Even fewer scholars from that discipline share the research methodology just sketched. Among aphasiologists in general, many have applied statistical techniques to a variety of aphasic phenomena, but few have used them to characterize articulatory breakdown in detail. No one, to my knowledge, has heretofore used spectrographic analysis in the study of aphasic speech. Yet all these innovations are in fact nothing but the application of orthodox techniques from a variety of established disciplines. As Joos (1948) illustrated over a quarter of a century ago, progress in a discipline often depends on the crossfertilization occurring at its boundaries with other disciplines.

This study thus had to be written with readers from a variety of backgrounds in mind. Some familiarity with aphasic studies and statistics was assumed. Readers not immediately familiar with aphasia are invited to refer to Hécaen and Angelergues (1965) and Whitaker (1971). Nontheless, terminology entirely familiar to one reader may still be unfamiliar to another. Rather than stopping the flow of the argument by too many definitions, it was decided to explain all special terminology in a separate glossary at the end of the study (pp. 119-124). It is hoped that this procedure proves satisfactory to the maximum number of readers.

I. PROBLEMS OF PHONOLOGICAL APHASIA RESEARCH

A. The Systematicity of Phonological Errors in Aphasia

A basic assumption of phonological research in aphasia is that errors show systematic tendencies. An example of a systematic tendency is the finding that aphasic patients are likely to substitute [p] for [f] (abbreviated: [f] → [p]) (Blumstein 1973b:132). Such tendencies are generally not unique to one language; examples of this type of substitution are easily found in the French literature on aphasia (Dubois et al. 1964:21).

Systematic tendencies should not be confused with phonological rules (e.g. assimilation rules). In the first place, aphasic systematic tendencies admit far more countervailing examples than do well-formulated phonological rules. For instance, the reverse substitution [p] → [f] can also be found in aphasia, as can other types of substitutions, such as [f] → [t], examples of which may be found in Dubois et al. (1964:21) and Fry (1959:56). The substitution [f] → [p] is merely more common. In the second place, aphasic patients generally preserve the phonological rules of the language they speak. So, for instance, when English-speaking aphasics suffix plural s to nouns, they use [z] after voiced consonants and [s] after voiceless consonants, in accordance with the regular assimilation rule for English.

B. Linguistic vs. Neurological Analyses

We can discern two major traditions in the analysis of the phonological aspect of aphasia. The first is the neurological paradigm of French and French Canadian researchers. The second is the more recent American paradigm of analyzing aphasic language in terms of the insights of linguistic theory.

The most outstanding early neurological treatment of this problem is that of Alajouanine et al., *Le Syndrome de désintégration phonétique dans l'aphasie* (1939). Applying the best neurological and phonetic techniques then available, these researchers analyzed the language behaviour of four patients whose difficulties with the articulatory side of language were the most prominent problem. Their main results (p. 118) were couched in neurological terms. In summary, Alajouanine et al. found the following systematic tendencies:

1. These patients experience difficulty in establishing articulatory movements. Muscular contractions of the articulators are preceded by tryout movements and abortive attempts.

2. Articulatory movements have a synkinetic character. This means that the likelihood of a sound being used as a substitution increases with the extent of articulatory musculature involved in producing the sound. (In other words, sounds that involve few muscle groups tend to be replaced by others involving more, because of a heightened synkinetic effect.) This tendency was noted to be especially true of vowels.

3. Most often, in a stable aphasia, movements are excessively forceful. Fricatives and affricates, for instance, tend to be replaced by homorganic stops as a result of this tendency.

4. Once started up, an articulatory movement is abandoned with difficulty. Consonant-vowel transitions are accomplished laboriously.

Unfortunately, many of the logical and experimental steps leading to these provocative findings are not presented in their monograph. It appears that the results are based in good measure on the clinical experience of the authors.

More recently, Lecours and Lhermitte (1969) investigated a large number of consonantal errors. They created a fairly elaborate formalism that characterizes substitutions with respect to their proximate consonants. On the basis of their findings they postulated that internal neural preactivation and post-activation levels for proximate consonants are proportional to the similarity they bear to the consonant being produced at the moment. Though considerably more sophisticated in approach than Alajouanine et al. (1939), they again followed the tradition of using linguistic evidence to support a neurological hypothesis.

An exponent of the theoretical linguistic paradigm, Blumstein (1973a) investigated the possibility that the pathology of language reflected Jakobson's postulated hierarchy of distinctive features (Jakobson 1941:62). For instance, since stops are considered to be higher on the hierarchy than fricatives (a notion derived from child language), aphasics were expected to substitute stops for fricatives. Blumstein's data generally supported Jakobson's feature hierarchy.

The notion of markedness attempts to capture the fact that certain sounds are found more commonly in the world's languages than others. For instance, among three-vowel systems, the combination [ī], [a] and [ū] is more "natural" than the combination [ī], [æ] and [o^u] (Shane 1973:11). [a] and [ū] are thus considered less marked than [æ] and [o^u]. Moreover, it is argued that the less marked sounds are learned earlier in life, and lost to a lesser degree in aphasia, than are the more marked ones. Blumstein (1973a) found that indeed, the Jakobsonian markedness schema was confirmed: there was a general tendency for marked sounds to be replaced by less marked sounds.

Linguistic and neurological analyses are, of course, not mutually exclusive. One can support and further explain the other. In this study, linguistic observations were analyzed statistically and phonetically. The results, however, were interpreted within a neurological framework.

Vowel errors have so far been treated only marginally in the aphasic literature. Typically, researchers collected sufficient data for an investigation of consonants, but found their data base insufficient for positively identifying systematic tendencies in vowels (e.g. Shankweiler and Harris 1966, Trost and Canter 1974). An exception is Schnitzer (1972) who investigated the reading errors of a single aphasic within the theory of generative phonology.

One of the aims of the study was thus to see if the conclusions reached by the above-named researchers on the basis of consonants were borne out by a systematic investigation of a large number of vowel errors. Of particular interest were the claims put forth by Alajouanine et al. (1939) and Blumstein (1973a). However, before proceeding to the description of the methods and analyses of this study, a number of problems distinctive of this type of research must be commented upon.

C. Localization

Patients with circumscribed lesions due to embolic infarcts have been of particular interest to aphasiologists. Because of the topographic extent of the two major divisions of the middle cerebral artery (see Figure 1), such circumscribed aphasia-causing lesions fall into two major types.[1] An infarction of the upper division usually results in a lesion of anterior brain tissue, and the ensuing aphasia is generally known as an anterior, or Broca's, aphasia. An infarction of the lower division generally affects more central and posterior brain tissue, and results in one or a number of aphasic syndromes, such as Wernicke's aphasia, anomia, conduction aphasia, etc.

In this study, two major syndromes will be distinguished. The term "anterior aphasia" will be used for the syndrome which is thought to be due to a lesion in the irrigative territory of the upper division of the middle cerebral artery and the term "posterior aphasia" refers to the syndrome whose likely locus lies in the irrigative territory of the lower division.

When aphasia tests sensitive to this dichotomy are used (such as Goodglass and Kaplan 1972, Kertesz and Poole 1974), anterior aphasics tend to have poor fluency, but comparatively good comprehension. The reverse tends to be true of many posterior aphasics. They tend to show poorer comprehension, but speak quite fluently. Anterior aphasics also give evidence that they know what they intend to say, even though they may have great difficulty in actually saying it. This can be ascertained

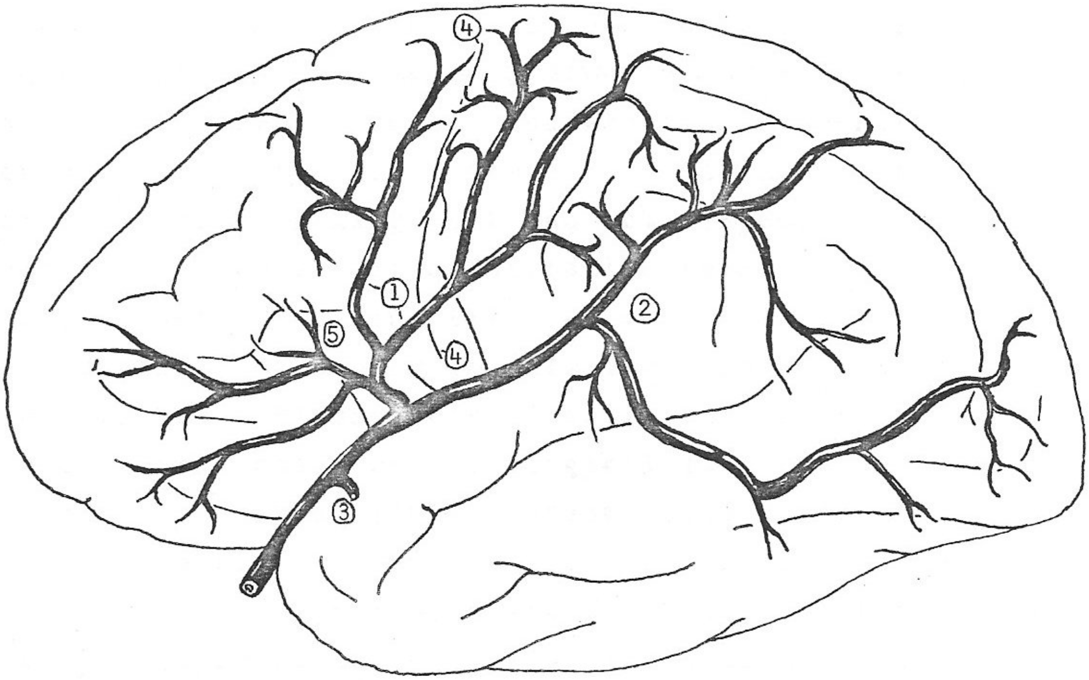


Figure 1. The middle cerebral artery. 1, upper division; 2, lower division; 3, temporal branch (sectioned); 4, Rolandic fissure; 5, lateral frontal branch, irrigating the 3rd frontal convolution (Broca's area). Based on Gray and Goss, 1973.

by asking them to match words given to them in multiple-choice tasks, or sometimes, by asking them to write down the intended word.

Most aphasic linguistic observations have so far been correlated with gross locus of brain lesion in quantitative, more than in qualitative fashion. For instance, Blumstein's Broca's and Wernicke's aphasics showed a nearly identical percentage of substitutions that involved unmarking (63% and 66% respectively, 1973a:53). However, in quantitative terms, Broca's aphasics made about nine times as many errors as Wernicke's aphasics made over roughly the same number of words uttered. Blumstein's classifications of aphasic syndromes were based on neurological findings and the Goodglass and Kaplan (1972) aphasia test.

In a similar vein, patients with both of these aphasic syndromes have been found to make environmentally motivated substitutions. For instance, Lecours and Lhermitte (1969) based their work on the substitutions of French-speaking Wernicke's aphasics (Lecours 1972, personal communication). In my own sample of primarily Broca's patients (as determined by the Western Aphasia Battery [Kertesz and Poole 1974]), environmentally motivated substitutions were comparatively rare. Nevertheless, the fact that they did occur further substantiates the notion that gross linguistic pathologies may very well be found as a result of lesions in a variety of areas, while their frequencies of occurrence differ greatly from one locus to another.

Since the intent of this study is to characterize aphasic vowel errors, it is best to concentrate on the patients that commit this type of error the most frequently, anterior aphasics. A further systematic demonstration that the qualitative tendencies determined here do not differ from syndrome to syndrome was considered outside the scope of this study.[3]

D. Successive Approximations

Since we can work with the assumption that target words are semantically well-specified[4], the phonological breakdown of anterior aphasics is open to a comparison of presumed target with perceived output. Anterior patients often attempt a target several times, a phenomenon termed "successive approximations". For instance, patient AB, of the present study, said [maʔm, mmæ:m, mm^{1}ænɪm, mænɪm], which are four approximations for the word 'madam' (Appendix II). The context unambiguously delineated the target even though it was never actually achieved. In the complete sample of this study, the desired target vowel was uttered at the end of about every third successive approximation.[5]

Some question arises in all studies of this type as to whether it is reasonable to assume a specific target when it is actually never uttered. For instance, in the above example, is the [ɪ] in [m^{1}ænɪm] indeed a substitution for the assumed [ə] of [m^{1}ædəm]? Given its unstressed nature, it would be easy to assume that the vowel was misperceived in the transcription process. Fortunately, the phonological system of most patients is still sufficiently intact for a transcriber to abstract a complete phonological system which makes identification of substitutions possible[6]. In the present sample, for instance, only 6.6% of all vowel targets were subjects to substitutions (Chapter III, below). Thus it was with reasonable confidence that the anomalous use of unstressed [ɩ] in the above example was judged to be a substitution vowel.

Segmental phonological errors fall into three major types: substitution, deletion and addition.[7] In [ta^{ɩ}m] → [ta^{ɩ}n] 'time', the substitution consonant [n] replaced the target [m]. The deletion [frɛnč] → [fɛnč] 'French' shows a loss of [r], while [papa] → [papra] demonstrates an addition of the same consonant. Blumstein (1973a:46) reports that substitution errors were the most frequent in her sample, followed by deletion errors, and least frequent were addition errors.

E. Aphasic vs. Dysarthric Syndromes

Dysarthria is typically defined as a set of syndromes involving motor speech problems which are caused by lesions in the efferent motor pathways, the brain stem and/or the cerebellum. Phenomenologically, Darley et al. (1969) distinguished symptoms in pitch, loudness, vocal quality, respiration, prosody, and articulation of phonemes (p.248). This latter category is of particular interest, especially in a study on vowels, as Darley et al. report "vowel distortion" in five of their seven clinical dysarthric syndromes. Could it then be that vowel errors are purely dysarthric, rather than aphasic, in nature?

In fact all of the patients interviewed for this study were deficient in some of the 38 subcategories listed by Darley et al., especially in the major category of articulation of phonemes (*imprecise conso-*

nants, phonemes prolonged, phonemes repeated, irregular articulatory breakdown and *vowels distorted*). Yet at the same time, these patients have also frequently substituted very dissimilar vowels for intended targets, such as [a] for [ɩ] in [kɩdz] → [kadz] 'kids'. It is doubtful that the term "vowel distortion" can be extended to cover this phenomenon, and the frequent occurrence of such distinct substitutions may indeed be one of the few clear articulatory features that distinguish anterior aphasics from dysarthrics.

It will therefore have to be examined whether the data collected from the present set of patients show further qualitative articulatory differences from the findings reported for dysarthrics in the literature. But even if more differences can be substantiated, it will remain difficult to decide on the basis of behavioural examinations of articulation whether a patient shows an exclusive aphasic difficulty of manipulating linguistic units (features, phonemes, etc.), or whether his impairment is entirely due to a more peripheral and dysarthric neuromuscular disorder. Although anterior aphasia and dysarthria are generally regarded as separate disorders, the dividing line between them may not be all that precise.

F. On Correlating Acoustic and Articulatory Data

Since the mid-sixties, dysarthric speech has been investigated spectrographically (Tikofsky 1965, Lehiste 1965, Kent and Netsell 1975). The tacit assumption in the first two studies appears to have been that the Formant_1 vs. Formant_2 (F_1 vs. F_2 hereafter) plot for mid-vowel frequencies corresponds at least roughly to the articulatory position of the tongue. This notion was first articulated by Joos (1948:49-59) as the correlation *plot:tongue height* and then refined by Delattre (1951:228) into *plot:oral constriction width*, or in Delattre's terminology, *opening*.

Delattre insisted on the narrowest constriction between tongue and palate because of measurements made on X-ray photographs. But his argument appears to be valid on the basis of another consideration: it is this constriction, rather than some absolute tongue height, which is likely to be crucial in the formation of the acoustic vowel sound frequencies (cf. Stevens and Hause 1955:35, Fujimura 1972:120).

Since part of this study is devoted to a F_1 by F_2 analysis of aphasic vowels, such a correlation merits some further delineation.

One of the problems in the early studies was that the X-ray measurements of vocal tract constriction and their spectrograms were based on held vowels, rather than vowels in running speech. This procedure was necessitated by the limitations of the X-ray photography of the early fifties. More recent studies have used cineradiography on 16 mm film (Perkell 1969, Gay 1974) and have sometimes succeeded in doing without any artifacts such as lead pellets or barium paste (Ondráčková 1973). Nevertheless, the data base has remained somewhat sparse, and it will be a few years before detailed studies on the correlation between acoustic and articulatory measurements become available.[8] It will then be possible to judge more accurately just how reliable spectrographic evidence is for articulatory movements.

From the available evidence, however, it appears that a gross correlation does exist. For reasons that will become evident in Chapter III, the discussion of this correlation will be limited to observations about F_1 and oral vocal tract constriction.

If the closest point of constriction between the tongue and the palate in Perkell (1969:55, bottom) is measured, one arrives at the vowel series ū < ī < ι < ʊ < ɛ < æ < a (where [ū] shows the narrowest constriction). Lehiste and Peterson (1961:229) report the vowel series ī < ū < e$^{\iota}$ < ι < ʊ < o^{u} < ɔ < ɛ < ə < æ < a (where [ī] is the sound with the lowest average frequency for F_1) on the basis of 1263 words. The Spearman r for the seven attested vowel pairs is .964 (significant, $p < .01$). The same procedure applied to the French vowels reported in Brichler-Labaeye (1970:250) and Delattre (1948:238) yields an r_s of .973 ($p < .01$).

These high positive correlations are nevertheless to be viewed with circumspection. Perkell's data are those of a single subject, and Lehiste and Peterson's data obviously derive from a different subject. The same is the case for the French data, where Delattre's vowels were furthermore held vowels. It should also be noted that recently, Ouellon and Lindfelt (1973) have expressed some serious doubts about the way the Kay Sonograph computes formant values, especially in the case of F_1.

Despite all these caveats, it seems reasonable to assume that in some rough degree, spectrographically measured F_1 values reflect degrees of vocal tract constriction. The same case has not been made, however, for the dimension of variability. Greater variability in spectrogram measurements may or may not reflect greater variability in vocal tract constriction.[9] While it is thus defensible to state spectrographic findings for averaged values of F_1 in articulatory terms, the variability found for those values will have to be stated primarily in acoustic terms.

FOOTNOTES TO CHAPTER I

[1]In most patients, that is. Most anatomy texts show the two divisions (e.g. Gray and Goss 1973:597, Schaeffer 1942:636); this is in accordance with the most common clinical findings (Mohr 1972). However, Netter (1953:37) draws a middle cerebral artery with a number of equal-size branches that extend from a long central trunk, and Gray (1901:511) has a middle cerebral artery that abruptly branches into four major divisions.

[2]Other authors use "receptive" or "sensory aphasia" for what I call here posterior aphasias, and "expressive" or "motor aphasia" for one specific, or all of the anterior syndromes. Another very common term for the latter is "apraxia" or "verbal apraxia". I prefer to reserve the term apraxia for disorders of non-verbal behaviour (cf. Hécaen and Angelergues 1965:189, Goodglass and Kaplan 1963:105, Geschwind 1975).

[3]Nor did any difference show up on any of the measures applied to the data (cf. Chapter III). This judgement is tentative in view of the small number of vowel substitutions gathered from patients with non-Broca's aphasic syndromes.

[4]For all practical purposes, especially in a spontaneous speech or repetition task. For an investigation of a limitation in the semantic specification, see Zurif et al. (1974).

[5]Exact figures: 39.2% of the time on stressed vowels and 26.0% of the time on unstressed vowels. Interestingly enough, anterior patients did a bit better than posterior patients; on stressed vowels, anteriors reached the correct

target 39.5%, posteriors 37.1% of the time. On unstressed vowels the effect was greater: anteriors 26.7%, posteriors 19.4% of the time. Number of targets: anteriors 1160, posteriors 132.

[6]For a relevant acoustic experiment on this point of issue, cf. Ladefoged and Broadbent (1957).

[7]This terminological distinction between "error" and "substitution" will be observed throughout this study.

[8]A very extensive project using 35 mm cineradiographic film of French and English speech (without artifacts) is being undertaken at Laval University, Québec, at present. A newly developed real-time spectrograph that projects onto 35 mm film is being used to analyze the recordings acoustically (Ouellon and Lindfelt 1973).

[9]Gay's (1974:265) arguments against such a correlation are not satisfactory. He reports that [ī] and [ū] are articulatorily less variable than [a], while all three vowels show comparable variability in spectrogram measurements. However, it appears that Gay measures tongue height and not vocal tract constriction (p.256). Since [a] involves moving the jaw far more than is the case for either [ī] or [ū], it is easy to see how cineradiographic measurements for [a] will vary greatly, depending on what the combined effects of tongue height and jaw opening will be. With [ī] and [ū] one can assume relatively stable maxillary and jaw positions, so tongue height will reflect constriction levels more closely.

II. THE PATIENTS AND THE DATA

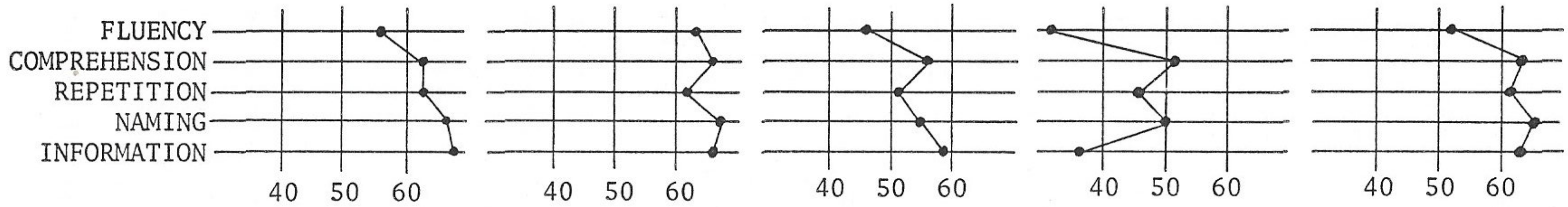
A. The Patients

1. Aphasia Battery Scores and Neurological Deficits

Ten right-handed aphasic patients who frequently produced successive approximations on vowels were included in the sample. Eight of them were tested with the Western Aphasia Battery (Kertesz and Poole 1974), one (AB) with the Schuell Aphasia Examination (Schuell 1957), and one (RGMS) was given a number of batteries on all of which she scored 100%. To obtain comparable battery scores for all ten patients, AB was rescored on the Western Aphasia Battery by converting the Schuell scores to appropriate and weighted Western Aphasia Battery scores, and RGMS was rescored as having attained 100% on each of the subtests of the Western Aphasia Battery. The scores of the various subtests are presented in standardized form as T-scores in Appendix I; the same information appears in graphic form in Figure 2. The various neurological deficits for each patient are noted below the scores.

Inspection of Figure 2 reveals that seven patients (AB, AW, BW, DH, EL, GP and ID) scored lower on fluency than on comprehension. In contrast, patients JR and TK performed nearly equally well on these two subtests. They did, however, show notable deficits in repetition. The first type of composite score corresponds to the syndrome of an anterior, or Broca's, aphasia, while the latter fits the description of a posterior syndrome called conduction aphasia[1].

Though the aphasia batteries were uninformative on RGMS's deficit, autopsy revealed in that case a small



AB.*

1. suspect CVA
2. none
3. none
4. none
5. none

AW.

1. suspect CVA
2. slight R
3. slight R
4. R finger, leg
5. none

BW.

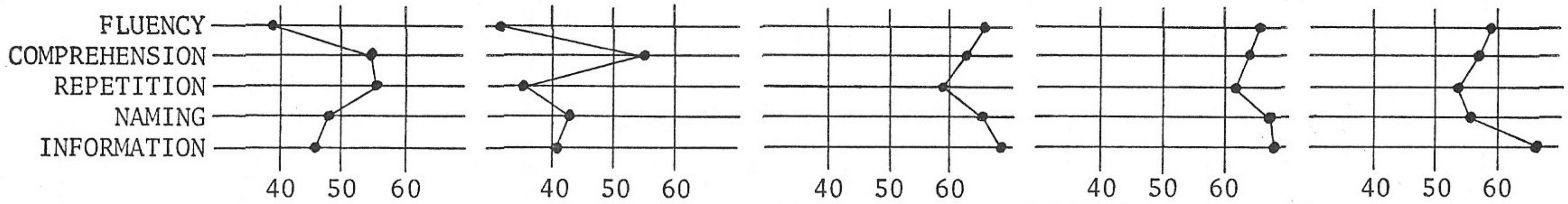
1. suspect CVA
2. severe R
3. severe R
4. none
5. none

DH.

1. suspect CVA
2. severe R
3. R
4. R arm, leg
5. none

EL.

1. suspect CVA
2. severe R
3. slight R
4. R trunk
5. none



GP.

1. suspect CVA
2. severe R
3. none
4. none
5. none

ID.

1. suspect CVA
2. severe R
3. none
4. R arm
5. none

JR.

1. CVA
2. none
3. none
4. R face
5. scan: incr- eased uptake in L posterior-pa- rietal region

RGMS.*

1. subdural hematoma
2. none
3. none
4. none
5. autopsy: pri- marily L supramar- ginal gyrus

TK.

1. aneurism, hematoma
2. none
3. slight R
4. none
5. operative: aneurism in L sylvian fissure

Figure 2. T-scores (mean=50, sd=10) for the ten patients of the sample, as measured on the Western Aphasia Battery (WAB). The graphs of the starred patients were obtained by rescoring (see text, p. 16). All patients except TK were tested six months or more after insult (TK: 5 weeks). 1, etiology; 2, hemiplegia; 3, hemianopia; 4, sensory loss; 5, localization data.

circumscribed lesion affecting all six layers of the supramarginal gyrus cortex and very minor secondary lesions in the temporal and parietal lobes (Kehoe and Whitaker 1972). Since such lesions are generally associated with posterior aphasic syndromes, RGMS was grouped with the posterior patients JR and TK. As a result, the sample of ten patients may be divided into a group of seven anterior and a group of three posterior patients.

For the seven aphasics with an anterior syndrome, neurological localization information was unfortunately not available. Their deficits were judged either so slight that arteriograms or brain scans were not considered (AW and BW), or these techniques did not reveal any abnormalities. However, the presence of other neurological deficits, such as hemiplegia, hemianopia and sensory loss in all patients but one (AB), would seem to indicate that for most of these cases, cortical tissue was probably affected over a larger area than the classical anterior areas, i.e. Broca's area and the portion of the motor cortex most directly involved in articulation. The term "anterior aphasia" is thus for the time being to be understood primarily as characterizing the syndrome, rather than the extent, or even the focus, of the lesion.

2. Socio-economic and Language Backgrounds

A variety of socio-economic and language backgrounds were represented in the sample. Three patients were in blue-collar jobs, four were in white-collar jobs and three were professionals (Table 1).

After insult, seven patients were informally judged to be typical southern Ontario speakers, one patient spoke

TABLE 1:

PERSONAL INFORMATION ABOUT THE PATIENTS OF THE SAMPLE

	INITIAL	SEX	AGE*	PROFESSION	NATIVE LANGUAGE	MAIN LANGUAGE AT INSULT
ANTERIOR PATIENTS	AB	M	50	shipper, chef	French (France)	English (New England)
	AW	M	62	marketing researcher	English (Midwest U.S.)	English (Westrn U.S.)
	BW	M	50	schoolbus driver	English (south. Engld.)	English (south. Ont.)
	DH	M	60	electronics researcher	English (south. Engld.)	English (south. Ont.)
	EL	F	68	telephone operator	English (south. Ont.)	English (south. Ont.)
	GP	M	54	quality control inspector	French (Québec)	English (south. Ont.)
	ID	M	72	cement pourer	English (south. Ont.)	English (south. Ont.)
POSTERIOR PATIENTS	JR	F	52	housewife	English (south. Ont.)	English (south. Ont.)
	RGMS	F	20	biology teacher	English (upstate N.Y.)	English (upstate N.Y.)
	TK	M	49	purchaser	English (south. Ont.)	English (south. Ont.)

**Mean age for the sample was 53.7.*

a New England dialect, one an upstate New York, and one a Western United States dialect with traces of Upper Middle Western speech (cf. Reed 1967).

Though all patients spoke English as their main language at the time of the cerebral insult, two of the patients had French as their native language. Patient AB, originally from France, learned English in his early teens, and patient GP learned it as a child in a bilingual section of Québec. At the time of the interviews, both showed comprehension for French (as tested informally) yet productively, they were all but incapable of using French. Nevertheless, at various points in the analysis of the results, it became necessary to treat their results separately from those of the eight unilingual patients (see Chapter III, below).

B. The Data

1. The Various Projects

The Aphasic Running Speech Sample

An initial project in the area of aphasic vowel errors should undertake a minimal characterization of the phenomenon before investigating its relevant parameters. For this purpose, an aphasic running speech sample was compiled. Six patients provided 1½ minutes each of running text chosen from various places in the same recordings that served as the basis of the Vowel Substitution Sample (see below). On the basis of these nine minutes of text, the frequency of vowel errors could be compared to the frequency of all vowels, to the frequency of consonant errors, and to time. The Aphasic Running Speech Sample was transcribed *in toto* (see Appendix II), while the Vowel Substitution Sample was merely scanned aurally for vowel substitutions which were subsequently transcribed. Since the listening and transcription process must necessarily be far more exacting for a total transcription than for the selective transcription of errors, this sample helped check how many errors were missed in the Vowel Substitution Sample (see "Completeness of the Substitution Sample", below).

The Vowel Substitution Sample

This, the main sample, is based on over 30 hours of recorded speech. Patients were given the three following tasks:

1. Spontaneous Speech. Patients were engaged in conversation, if possible. Six patients were capable of substantial spontaneous speech with vowel errors. Three (ID, GP and DH) were too severely, and one (RGMS) was too slightly, impaired for this task.

2. Repetition. Tasks were titrated to the patients' levels of speaking competence by using stimulus words of varying length and familiarity. For instance, one patient (ID) was only capable of monosyllabic words. For him, high frequency monosyllabics were selected from the Howes list (Howes 1966). At the other extreme was patient AW for whom only the longest and least frequent polysyllabics from the same list evoked any vowel errors. As a consequence, it was impossible to control for frequency of vowel and word occurrence, word length, and linguistic complexity. Nevertheless, this titration procedure did not appear to affect the similarity of results from the different patients (cf. for instance patients AW and ID on p. 62). As in the Spontaneous Speech task, RGMS did not contribute any errors to this task.

3. Reading. Tasks were titrated to the patients' reading competence. EL and BW were given high frequency bisyllabics, while RGMS was given a special list, reproduced in Schnitzer (1972). AW was given this same list, plus high frequency polysyllabics from the Howes list. Frequency of vowel occurrence was not controlled. No other patient was capable of performing in extended reading-aloud tasks.

Insofar as this is the first extended aphasic vowel error sample to be compiled, the purpose was to concentrate on the spontaneous speech and repetition output of anterior aphasics while at the same time to insure that a few potentially diverse elements, such as bilingualism, posterior aphasia, and reading tasks be included in the sample. The first type of data was to be used to formulate and test a number of hypotheses, while the latter would serve this and other investigators as indicators of probable areas where the results obtained through the first type of data might differ. At no time was a systematic comparison of unilingual vs. bilingual, spontaneous speech/repetition vs. reading, or anterior vs. posterior data intended.

Thus the breakdown of the total of 1566 substitutions that were collected is as follows: unilingual 79%, bilingual 21%; spontaneous speech/repetition 82%, reading 18%; anterior patient errors 91%, posterior 9%. Diphthongs are excluded from these figures. Full details are found in Tables 2 and 3.

The Spectrographic Sample

Because many of the results of this study are stated in terms of formant frequencies, a subsample of the Vowel Substitution Sample was analyzed on a Kay Electric Company Sonograph. 100 substitutions were recorded and analyzed on four displays: 1. wide band spectrogram, 2. wide band amplitude, 3. wide band and 4. narrow band cross-sections through the nuclei of the substitution and target vowels. Formant values were derived from these displays using the calibration provided by the Sonograph.

Selection of the substitutions was constrained by two factors: first, the substitution had to occur within 2.4 seconds of the target so that both could be measured on the same set of displays, and secondly, only substitutions where the correct target was actually uttered could be included. All substitutions of this type from patients

TABLE 2:

SUMMARY OF VOWEL SUBSTITUTION SAMPLE

	ANTERIOR PATIENTS							*POSTERIOR PATIENTS*			
	AB*	AW	BW	DH	EL	GP*	ID	JR	RGMS	TK	TOTAL
APPROXIMATIONS	132	209	195	19	194	84	66	21	70	16	1006
SUBSTITUTIONS ON VOWEL NUCLEI	189	378	281	31	276	138	129	29	95	20	1566
SUBSTITUTIONS ON DIPHTHONGS**	18	28	27	3	46	45	37	6	4	1	215
TOTAL OF SUBSTITUTIONS	207	406	308	34	322	183	166	35	99	21	1781

**bilingual patients.*

***diphthongal substitutions were listed for the Vowel Substitution Sample, but they were not used in any of the analyses.*

TABLE 3:
OVERVIEW OF ERROR TYPES

	NUMBER OF ERRORS*	PERCENTAGE	TOTAL OF ERRORS*
MONOLINGUAL PATIENT ERRORS	1239	79.1%	1566
BILINGUAL PATIENT ERRORS	327	20.9%	
SPONTANEOUS SPEECH AND REPETITION ERRORS	1276	81.5%	1566
READING ERRORS	290	18.5%	
ANTERIOR PATIENT ERRORS	1422	90.8%	1566
POSTERIOR PATIENT ERRORS	144	9.2%	

**only errors on vowel nuclei are included.*

DH, GP, ID, JR, BW and TK were included in this sample, with the remaining 63 substitutions distributed equally among AB, AW and EL.

The Normal Running Speech Sample

The Vowel Substitution Sample did not control for frequency of vowel types, but was assembled with the assumption that a sufficiently large sample would reflect the frequencies found in the language. That assumption can however only be maintained

(a) if the Vowel Error Sample and the sample underlying the normal vowel frequency count were transcribed using the same subdivisions into vowel types and stress levels, and

(b) if the two samples are based on comparable linguistic material with reference to age, dialect and social class, as well as spontaneity of production.

The two major modern vowel frequency counts are those of Denes (1963) and Roberts (1965). Neither of them satisfied both conditions. Denes's count was based on phonetic readers used to teach British received pronunciation and Roberts used a transcription system substantially different from that used here[2].

Hence, a normal running speech sample of 9½ minutes of a Canadian Broadcasting Corporation radio broadcast was transcribed *in toto*. Ten native speakers from a Southern Ontario town gave their opinions about life in their community. As judged from the content of their contributions, their age range appeared to correspond well with that of the aphasic sample.

French, Carter and Koenig (1930) found that in telephone conversations, 20% of their sample of words consisted of half-completed utterances, and of interjections such as "uh" and "ah". However, none of the substitutions in the Vowel Substitution Sample involved interjections like "uh" and "ah". All occurrences of this type of interjection in the Normal Running Speech Sample were therefore eliminated.[3] Half-completed utterances were counted. The results of the Normal Running Speech Sample are summarized in Appendix III.

As a measure of reliability in estimating the population of vowels from the present sample, frequencies on eleven vowel types in stressed and unstressed condition (a total of 22 scores) in the first half of the sample were correlated with the corresponding frequencies in the second half. The resulting value was $r = .980$ ($z = 10.02$, $p < .001$). The correlation between the total sample and the results of the Denes count was .880 ($z = 6.00$, $p < .001$), which suggests that despite an over-all correlation, vowel frequencies may indeed be somewhat influenced by dialect and spontaneity of production (condition [b], above).

2. The Recording Process

Six patients were recorded during the summer of 1974 in the Metropolitan Toronto area (AW, BW, EL, GP, and ID). In addition, three patients were made available on tape by other researchers in the field[4] (AB, JR, and TK), and a full list of RGMS's errors is found in Schnitzer (1972).

The Toronto patients were recorded in quiet surroundings, using UHER Report 4200 equipment at 7½ inches per second (19 cm per second), and a Shure microphone with an essentially flat response between 90 and 15,000 Hz. The recordings of one patient (AB) were passed through a band filter which enhanced the 8,000 Hz range, and cut off below 30 Hz and above 15,000 Hz. The comparatively high interjudgmental agreement on this particular patient (see below) suggests that this might be a valuable procedure for general application.

3. The Transcription System

The various transcription systems in use for English do not differ substantially in their consonants. However, the way vowels are transcribed often reflects a difference in the theoretical assumptions of the user. For instance, in the Trager and Smith system advocated by Gleason (1961) the word 'see' is transcribed as /siy/, while Pike (1947) writes it [si], and Chomsky and Halle (1968) prefer the transcription [sī]. All such transcription issues were resolved with reference to the specific needs of aphasic speech, or of the analysis of the results.

<u>Vowels with offglides and diphthongs</u>

Vowels with offglides (e.g. [eᶥ] and [oᵘ]) and the diphthongs were both initially grouped with vowel nuclei, since aphasics sometimes substituted them for the latter (e.g. [b<u>ʊ</u>kīpɩŋ] → [g<u>oᵘ</u>kīpən] 'bookkeeping' and [<u>ɩ</u>nǰoᶥ] → [<u>aᶥ</u>nǰoᶥ] 'enjoy').

In the analysis of the results, however, the diphthongs behaved quite differently from the vowels with offglides in respect to formant parameters (see Chapter III). For this reason, the vowels with offglides were grouped together with the vowel nuclei, and the diphthongs were excluded from analysis. The resulting line-up of vowels and diphthongs thus corresponds to the use in Pike (1947) and Lehiste and Peterson (1961).

Individual sounds

[ə]: Such sounds as [ɩ], [a] and [ʋ] are typically reduced to schwa-like sounds in unstressed position. However, such sounds were only transcribed as [ə] if they were perceived as being completely neutralized, in other words, if they were auditorily indistinguishable from the underlined sounds in an unemphatic pronunciation of 'banana', 'bird', or 'collect'. Rigid enforcement of this criterion ensured relatively better interjudgmental agreement on transcriptions of this type of sound.

[r] and [l]: Since the syllabic use of those sounds was not very common in the sample, and in the interest of keeping the number of vowels to a manageable minimum, they were transcribed as [ər] and [əl], respectively, when they occurred in syllabic position. The aphasics of this sample did not clearly treat them as separate vowels. Thus we have [kaᵘnsələr] → [tɔhnsədɪ̄r] 'councillor', where a substitution has occurred on the schwa-sound alone (among the vowels), but we also find, in the speech of the same patient, [peᶥpər] → [teᶥpɪ̄] 'paper', where [ɪ̄] replaces the whole sequence [ər].

[a]: This vowel shows great phonetic variation, both across speakers and across allophones in use with the same speaker. Among non-aphasic older speakers in Southern Ontario, 'father' was heard with a fronted version of the sound, approaching [æ], while younger speakers of the same community used a sound much closer to the [a] in 'car'. Also, the variants of the sound [a] in 'but' or 'mustard' can occasionally be found with a phonetic quality very different from that of [a] in 'car'. However, in running text this difference has proven exceedingly hard to perceive, except for those cases where the vowel was

sufficiently reduced to warrant a transcription as [ə]. All other variants of this sound were grouped with [a].

Stress

Only two levels of stress were distinguished and marked, primary stress ("stressed") and all other levels ("unstressed"). This insured a high level of inter-judgmental agreement (see below).

4. The Transcription Process

Transcription and Correction

Three linguistics students from the University of Toronto and Carleton University in Ottawa made the original transcriptions from tape.[5] This investigator went over various passages together with the transcribers to explain the criteria of transcription, and corrected the entire data base with reference to the tapes before it was committed to punched cards. After the keypunched data were listed by the computer, the data base was verified, again with reference to the tapes. The only portion of the sample not verified in this way was the vowel errors in the Aphasic Running Speech Sample which were re-corrected by the original transcriber (LM). Those errors were used as part of the sample which was tested for inter-judgmental agreement (see below).

Inclusion of Errors in the Vowel Substitution Sample

Only approximations involving substitutions were transcribed. Those involving addition or deletion of an element (e.g. [swɩčbord] → [swɩtə̲bo] 'switchboard', or [ɪ̲lɛktɩd] → [lɛktɩd] 'elected') were excluded because by their very nature they would be relevant to a syntagmatic, rather than a paradigmatic study. If an approximation involved substitutions as well as additions or deletions, the whole approximation was transcribed; however, the computer program was set to ignore all but substitution errors.

Approximations where the transcription of either the intended target or the substitution vowel was in doubt were excluded. Dialect variants, such as [ə] instead of [ɛ] in the Upper Middle Western pronunciation of 'very', or the lengthened [a] in the New England pronunciation of 'car', were transcribed as perceived.

Vowel substitutions associated with errors of a primarily semantic nature ([čɛr] → [teˡb] 'chair' → 'table', for instance) were excluded, but those found in substitutions of a morphological nature (e.g. [fɛl] → [fɔl] 'fell') were included. In the first one the intended target differs from the word chosen as a substitution, while in the second one, the two may be the same, since even random generations of substitutions by computer create a certain percentage of this latter type of substitution (Lecours, Deloche and Lhermitte 1973). Not more than ten such morphological-phonological substitutes occurred throughout the sample.

Alignment of Errors

Often more vowels are found in the target than in the substitution (e.g. [yɛloᵘ] → [lə] 'yellow'). The question then arises, which target vowel is involved in the substitution. The consonantal environment was the clue in the overwhelming number of cases (such as in the above example where [ə] is counted as a substitution of [oᵘ]. Sometimes the consonantal environment itself was defective (e.g. [dīsɛmbər] → [əz] 'December'); then the error was aligned in such a way that the consonantal environment was matched for as many features as possible.[6] Thus [ə] is seen as a substitute for [ī] in this example. This is in line with the finding of many researchers using a variety of feature systems that most consonant errors differ by a single feature, regardless of the type of aphasia (Lecours and Lhermitte 1969:78, Trost and Canter 1974:73, Martin and Rigrodsky 1974:336, Blumstein 1973a:49).

In the case of telescoping deletions the vowel was assumed to 'belong' with its succeeding consonant. In the example [ǰaŋkšən] → [ǰən] 'junction' for instance, there is no vowel substitution at all. This editorial judgement was based on the general principle that wherever possible, the alignment should minimize the error.

5. Completeness of the Vowel Substitution Sample

When going through tapes listening for vowel errors to be transcribed, many errors are missed. 17 out of the 35 vowel errors in the Aphasic Running Speech Sample were missed in the Vowel Substitution Sample. This is not a serious disadvantage as long as errors were not excluded systematically. To check for this possibility, this investigator went through three hours of tapes and noted down errors that had been missed by the first transcriber (JN). No pattern involving particular vowels or vowel groups were noted in this set of errors.

6. Computation

Computation of vowel frequencies in the two running speech counts, and the tabulation and the compilation of vowel substitutions in the Vowel Substitution Sample were done in three SPITBOL computer programs.

7. Interjudgmental Agreement

Aphasic speech is notoriously difficult to understand, even when relatively free of dysarthric effects. It was thus examined how much interjudgmental agreement there existed between the final computer print-out and a new transcription by a linguistics student who was not aware of the hypotheses to be tested in the study (LM).

She transcribed sections of speech involving about 35 vowel errors from each patient. This new transcription was checked with reference to the tapes, and those vowels that this investigator disagreed with were queried. In about one third of the cases, the second judge subsequently changed her original transcription. That transcription was then compared with the final print-out of the Vowel Substitution Sample. Table 4 lists the percentage of agreement for each patient.

There was total agreement on stress assignment. The weighted average percentage of agreement on vowel quality, based on the total of errors from each patient, was 76.9%.

An analysis of the 60 disagreements out of 323 sounds transcribed, indicated that most transcriptions differed relatively little from each other, especially as measured along the front-back axis ($Formant_2$). The disagreements are fully listed in Appendix IV. Moreover, this interjudgmental agreement figure compares favourably with Peterson and Barney's results (1952:177). In their study, 1520 CVC words from 76 normal speakers were presented to 70 listeners over loudspeakers. Unanimous agreement on the ten vowels that were tested was 54.3%. Nevertheless, these agreement figures pose at least two questions. Why are they so low and will they affect the results reported in

TABLE 4:

INTERJUDGMENTAL AGREEMENT ON TRANSCRIPTION OF VOWEL SUBSTITUTION SAMPLE

	AB	AW	BW	DH	EL	GP	ID	JR	TK	WEIGHTED AVERAGE*
PERCENT OF AGREEMENT ON VOWEL NUCLEI	83.3	80.8	63.3	83.3	82.5	78.9	70.8	68.4	81.3	76.9

**weighted by the total number of errors for each patient, as determined from the Vowel Substitution Sample.*

this study?

The primary cause of the relative difficulty in coming to interjudgmental agreement is probably the substitution vowel's lack of identifying context. In normal speech, the listener brings certain expectations to bear on the listening effort. When the listening task is artificially freed of clues for such expectations (such as in the Peterson and Barney study), the degree of agreement drops drastically. In aphasic substitutions it is, of course, impossible to predict which vowel will be chosen. It is therefore likely that the agreement figures can only be raised by the use of special filtering techniques and speech range extenders.

Interjudgmental disagreement will not affect the results of this study as long as the disagreements are not systematic. If they are, one should examine which transcriber introduced the systematicity.

From Appendix IV it appears that only [ɩ] was the source of considerable disagreement (the frequencies of [ʊ] and [ɔ] were too low to judge). 17 (or 57%) of the 30 sounds transcribed by the second judge as [ɩ] were not recorded with that symbol in the final computer print-out. This seemed to reflect a personal preference of that judge, since only seven (or 35%) of the 20 [ɩ] sounds in the print-out were not transcribed as such by the second judge. There is therefore no evidence that the transcription was systematically biased.

FOOTNOTES TO CHAPTER II

[1]The general classification "posterior syndrome" is also supported by neurological indicators. JR's brain scan showed an increased uptake in the left posterior parietal region and TK's condition necessitated a fronto-temporal craniotomy for an aneurism in the sylvian fissure.

[2]Roberts used the Trager and Smith system which optionally combines the vowels /i/, /e/, /æ/, /ə/, /a/, /u/, /o/ and /ɔ/ with the glides /y/, /w/ and /H/. This led to anomalies in the count because of instances such as the following: the sound [ī] (as in 'see') was rendered as /iy/, and in the computer count, the /i/ and /y/ were counted separately. This made later distinction of the offglide /y/ from the syllable-initial /y/ impossible, and made the count incompatible with my treatment of this type of vowel.

Moreover, Roberts unfortunately did not distinguish stressed and unstressed vowels in his otherwise meticulous study. The results of my sample (Appendix III) indicate that the frequencies differ greatly for the two conditions.

[3]Only 27 out of a total of 1844 vowels (1.5%) had to be eliminated from this edited radio sample.

[4]For list, see Acknowledgements, above.

[5]Aphasic Running Speech Sample: Linda Moran, Carleton University, Ottawa. Vowel Substitution Sample: Jane Naughton, The University of Toronto. Normal Running Speech Sample: Anne Greenwood, The University of Toronto.

[6]This assumes that the consonant did not change location either--a syntagmatic error of a type described by Lecours and Lhermitte (1969). In view of the relative rarity of syntagmatic vowel errors in this anterior sample,

it was reasonable to take such a risk.

III. RESULTS

A. Characterizing Vowel Substitutions in Aphasia

1. Analysis 1: Vocalic vs. Consonantal Substitutions in Aphasic Running Speech

The Aphasic Running Speech Sample was analyzed for the distribution of targets and substitutions among vowel nuclei and consonants (diphthongs excluded). In this manner, the degree of intactness of the patients' phonological system could be ascertained with reference to vowels and consonants. The results of this analysis are presented in Table 5.[1]

There were roughly twice as many consonant targets as there were vowel targets. Nevertheless, the number of substitutions for the two conditions was of the same order (52 and 47, respectively). This is surprising in view of the clinical finding that patients with frequent vowel substitutions are seen relatively rarely (cf. Trost and Canter 1974:69[2]). For both anterior and posterior patients, the percent of targets subject to substitutions out of all targets was somewhat greater for vowel nuclei than for consonants. This means that unlike the patients of many other studies (e.g. Fry 1959, Shankweiler and Harris 1966), these patients were characterized by a high frequency of vowel errors. Nevertheless, it should be noted that consonant errors were also in frequent evidence.

Still, only a small proportion of vowel targets are ever subject to being substituted. On the average, five times a minute (6.6% of 75.4/min), aphasics of this sample erred on a vowel target, and then for this target, they usually produced several substitutions which averaged out to 6.5 a minute. This indicates that by and large, the phonological system was still intact, and that erroneous sounds were the exception, rather than the rule, in the speech of these patients.

As expected, the disfluent anterior type of patient produced substitutions more commonly (7.6 times a minute) than the fluent posterior type of aphasic (4.7 times a minute). This is mirrored in consonantal substitutions, a fact documented in Blumstein (1973a:46).

TABLE 5: TARGETS AND SUBSTITUTIONS
IN APHASIC RUNNING SPEECH SAMPLE

		ALL TARGETS		SUBSTITUTIONS		TARGETS SUBJECT TO SUBSTITUTIONS	
		n	n/min*	n	n/min*	n	% of all targets
VOWEL NUCLEI	Anterior patients	275	61.8	34	7.6	26	9.5%
	Posterior patients	268	97.5	13	4.7	10	3.7%
	Combined	543	75.4	47	6.5	36	6.6%
CONSONANTS	Anterior patients	549	123.4	44	9.9	37	6.7%
	Posterior patients	477	173.5	8	2.9	8	1.7%
	Combined	1026	142.5	52	7.2	45	4.4%
	TOTAL	1569	217.9	99	13.8	81	5.2%

* *For this calculation, all pauses were removed. Total length of sample: 7.2 minutes.*

2. Analysis 2: Vowel Occurrences in Aphasia

The vowel frequencies of the Aphasic Running Speech Sample were compared to those of the Normal Running Speech Sample. As in the latter, occurrences of filled hesitations, such as "uh", were removed (36 instances).[3] The aphasic vowel frequencies are presented in Table 6.

Vowels used by these aphasics are similar in their distribution to those used by normals (see Figure 3). The Pearson product-moment correlation is .933 (significant with $z = 7.33$, $p < .001$), and the χ^2_{21} of 29.5 indicates no significant difference ($\alpha = .05$).

The vowel nuclei distributions for the anterior and posterior patients were correlated separately with the vowel distributions of the Normal Running Speech Sample, and similar high figures were attained: anterior patients, $r = .928$ ($z = 7.2$, $p < .001$) and posterior patients, $r = .907$ ($z = 6.6$, $p < .001$). It is apparent that vowels used by aphasic patients and those used by normal persons are similarly distributed, a finding that is basic for the analysis of the larger vowel substitution sample because all its analyses are grounded in this assumption. It also corresponds with the results reported for consonants by Blumstein (1973a:41).

3. Analysis 3: Syntagmatic vs. Paradigmatic Substitutions

Since this study set out to analyze vowel substitutions along the paradigmatic axis, an attempt was made to weed out the most obvious syntagmatic errors.[4]

Syntagmatic errors were excluded from the sample according to the following criteria:

(a) any error whose substitution vowel was identical to the immediately preceding or immediately following

TABLE 6: VOWEL NUCLEI FREQUENCIES
IN THE APHASIC RUNNING SPEECH SAMPLE

	STRESSED		UNSTRESSED		TOTAL	
	n	%	n	%	n	%
[ī]	18	10.8	49	10.0	67	10.2
[ɩ]	11	6.6	59	12.0	70	10.7
[e^ɩ]	16	9.6	17	3.5	33	5.0
[ɛ]	22	13.3	52	10.6	74	11.3
[æ]	23	13.9	52	10.6	75	11.4
[ə]	10	6.0	160	32.7	170	25.9
[ū]	9	5.4	13	2.7	22	3.4
[ʊ]	3	1.8	5	1.0	8	1.2
[o^u]	16	9.6	34	6.9	50	7.6
[ɔ]	9	5.4	6	1.2	15	2.3
[a]	29	17.5	43	8.8	72	11.0
TOTAL	166	100	490	100	656	100

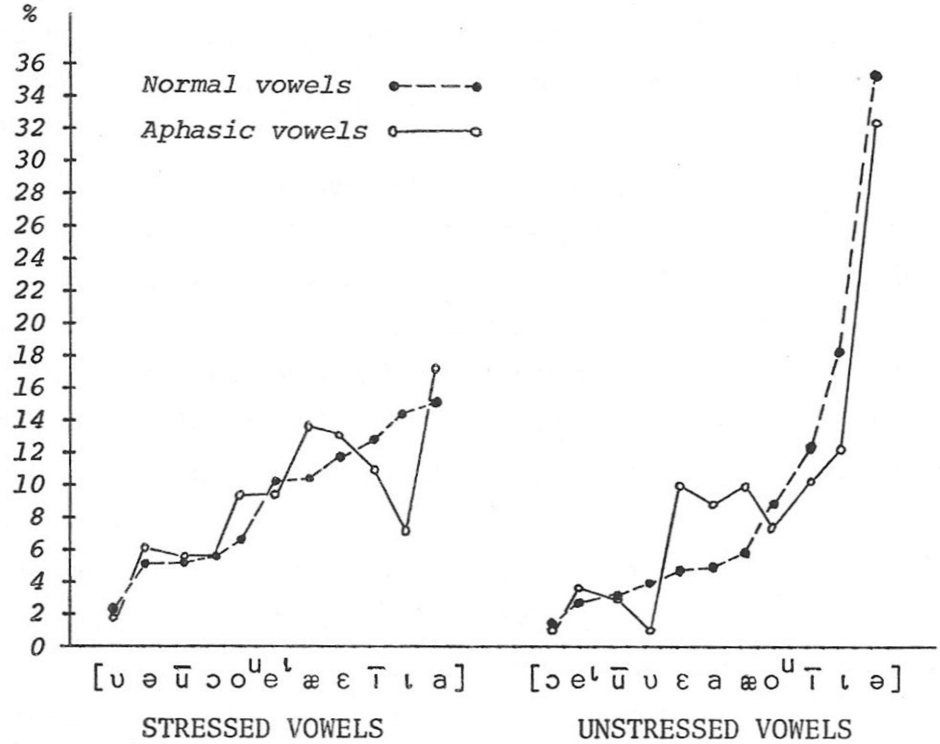


Figure 3. Vowel frequency distribution.

target vowel (e.g. [bækyard] → [bakyard] 'backyard' or [əlūmənəm] → [ələmənəm] 'aluminum',

(b) any error whose substitution vowel was stressed and identical to the immediately preceding or immediatly following stressed target vowel (e.g. [wɩmənz kalɩy̌ hāspɩtəl] → [wamənz kalɩy̌ hāspɩtəl] 'Women's College Hospital').

The two criteria applied both within and across word boundaries. They were applied with the assumption that identical vowels in the two stated environmental positions would exert the greatest syntagmatic influence on the substitution vowel.

While the remaining substitutions will henceforth be referred to as "paradigmatic errors", it is not suggested that the syntagmatic axis was eliminated entirely by this procedure. The substitution vowel may still:

--resemble an adjoining vowel, but not be identical with it (e.g. [rīmɛmbər] → [reᶦmɛmbər] 'remember'),

--resemble, or be identical with a vowel in the more remote environment, especially if that vowel is surrounded by a consonantal context strongly reminiscent of the target context (e.g. [yū kən ɩmæǰən] → [yū kən yūmæǰən] 'you can imagine'),[5]

--or, be correlated with the occurrence of certain consonants or groups of consonants surrounding the target vowel.[6]

Nevertheless, it is suggested that the remaining errors are homogeneous enough for the further analyses of this study. The homogeneous results that emerged from Analyses 4-8, summarized on pp. 75-6, would indicate so.

The percentages of substitutions classified as "syntagmatic" under the two above criteria (a and b), and of remaining "paradigmatic" substitutions are given in Table 7. The bulk of the syntagmatic substitutions were classified under criterion (a), and only five instances of criterion (b) were noted. Moreover, by far most syntagmatic substitutions occurred inside word boundaries. Only

TABLE 7:
SUBSTITUTIONS ON VOWEL NUCLEI*

	SYNTAGMATIC SUBSTITUTIONS		PARADIGMATIC SUBSTITUTIONS		TOTAL	
	n	%	n	%	n	%
Spontaneous Speech	73	4.7	427	27.3	500	31.9
Repetition	118	7.5	658	42.0	776	49.6
Reading	60	3.8	230	14.7	290	18.5
TOTAL	251	16.0	1315	84.0	1566	100.0

**Source: Vowel Substitution Sample.*

25 instances, or 10% of the total of syntagmatic substitutions, were found to extend across word boundaries.

The remainder of the study will be concerned with the paradigmatic axis, and thus will be based on the 1315 paradigmatic substitutions collected in the Vowel Substitution Sample.

B. Spectrographic Analyses

1. Analysis 4: The Variability of Formant Frequencies in Aphasia, Normal Speech, and Dysarthria

In comparing formant frequencies of aphasics with those of normals and dysarthrics, use will be made of the results reported in Tikofsky (1965) for normals and a variety of dysarthrics. That study uses the same transcription system as the present one, and reports both means and standard deviations of formant positions.[7] Tikofsky's sample consisted of nine clinically defined dysarthrics and nine normals approximately matched for age, education and occupational status. The major dialectal differences to be expected between Tikofsky's Upper Middle Western (Ann Arbor, Michigan) sample and the predominantly southern Ontario sample of this study were examined. Some fell into the area of diphthongs[8] and were not of interest, and others did not appear to affect the results.[9]

The means and standard deviations of F_1 and F_2 are given in Table 8 and plotted in Figures 4 and 5. Aphasic formants derived from targets and substitutions were combined, since they did not differ significantly (t_{10}=.547 for F_1 and .409 for F_2, $p > .05$).

A later analysis, Analysis 5, will be concerned with a comparison of the mean frequencies. Here, we will

TABLE 8: MEANS AND STANDARD DEVIATIONS
FOR $FORMANT_1$ AND $FORMANT_2$ OF NORMALS, DYSARTHRICS AND APHASICS
(N = 9 IN EACH CASE)*

		NORMALS			APHASICS			DYSARTHRICS		
		mean	sd.	n	mean	sd.	n	mean	sd.	n
[ī]	F_1	366	16.7	10	448	103	20	343	9.6	10
	F_2	2133	74.4		2287	256		1908	71.2	
[ι]	F_1	403	33.5	18	523	92	20	434	29.5	18
	F_2	1736	95.3		1955	155		1635	97.4	
[e$^{\iota}$]	F_1	409	42.0	15	583	75	15	413	33.9	15
	F_2	1982	88.4		2057	337		1800	44.5	
[ε]	F_1	548	52.7	23	630	104	22	528	35.4	23
	F_2	1623	117.0		1841	252		1511	130.0	
[æ]	F_1	628	96.4	20	664	103	11	603	10.2	20
	F_2	1691	124.0		1632	311		1525	82.5	
[ə]	F_1	619	44.2	18	588	98	28	596	21.7	18
	F_2	1183	65.0		1450	254		1175	85.8	
[a]	F_1	665	40.5	22	685	107	37	633	69.9	22
	F_2	1200	36.9		1295	221		1163	40.8	
[ɔ]	F_1	517	75.0	20	607	128	14	537	44.8	20
	F_2	953	94.4		1164	233		968	71.8	
[o^{u}]	F_1	426	35.2	10	540	84	14	465	26.0	10
	F_2	832	37.6		957	311		891	41.7	
[υ]	F_1	427	21.2	6	513	85	4	438	17.1	6
	F_2	1063	78.7		1275	323		975	65.1	
[ū]	F_1	397	26.9	11	473	75	13	388	15.9	11
	F_2	996	178.3		992	162		925	90.4	

* *Comparative data for normals and dysarthrics taken from Tikofsky (1965:34).*
Mean and standard deviation values are in hertz.

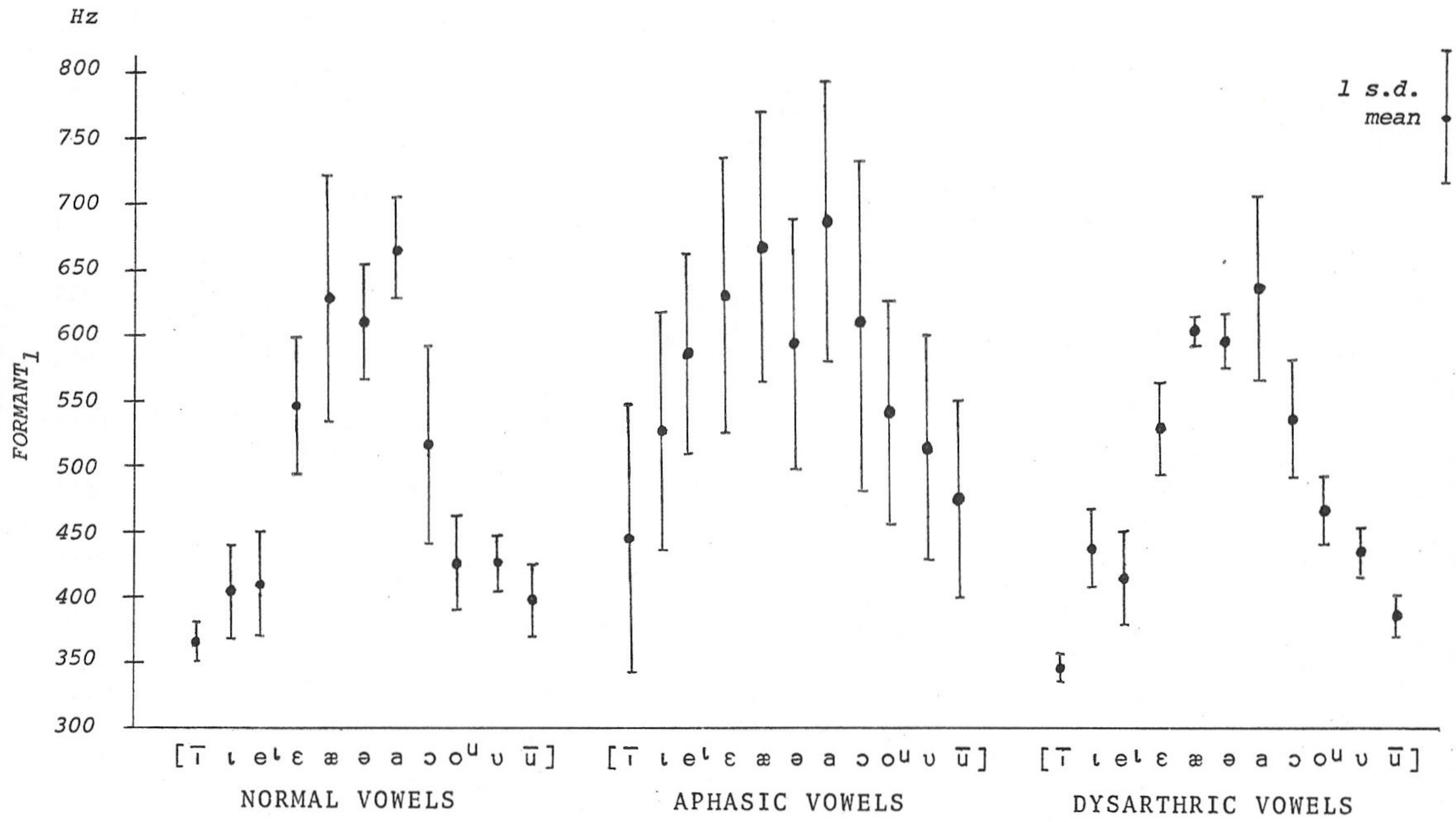


Figure 4. Means and standard deviations of $Formant_1$ in normal, aphasic, and dysarthric vowels. Normal and dysarthric data from Tikofsky (1965:34).

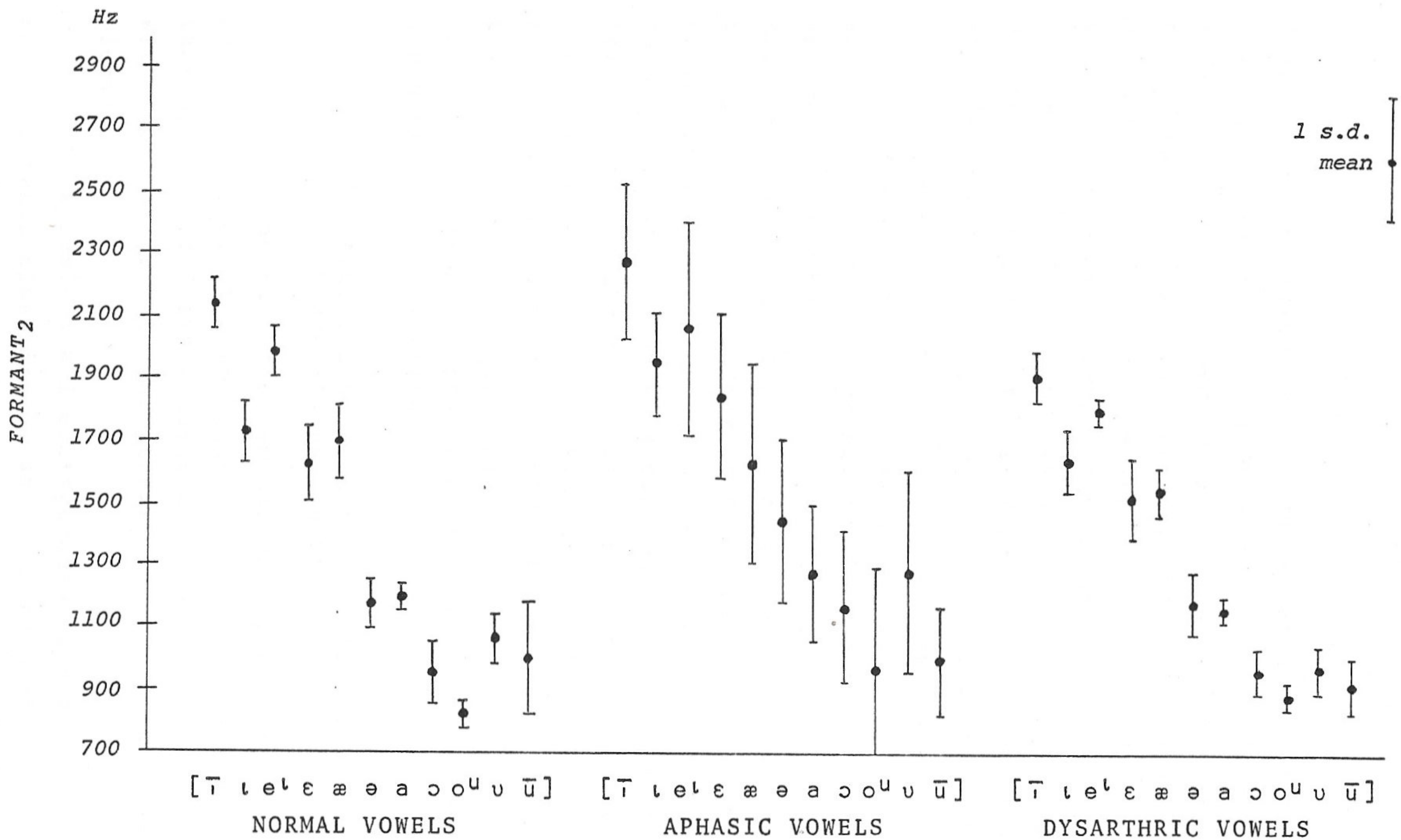


Figure 5. Means and standard deviations of $Formant_2$ in normal, aphasic, and dysarthric vowels. Normal and dysarthric data from Tikofsky (1965:34).

first note the differences in the variability of formants. For F_1, as well as for F_2, measured frequencies are far more variable in aphasia than in dysarthria or normal speech. 20 out of the 22 differences between normal and aphasic variances were significant ($p < .025$). All differences in variances between dysarthrics and aphasics were significant at $\alpha = .05$. This variability was also documented for single vowels of individual patients (Table 9). 16 out of 18 of the single cells of that table show significant differences from the standard deviations of normal subjects.

Inasmuch as this result can be taken to reflect an empirical measure and not merely the vagaries of formant analysis,[10] it supports the notion that there is a measurable difference in the articulations of anterior aphasics and dysarthrics. Dysarthrics typically articulate with reduced speed and range of excursion in their vocal tract movements, and also show muscle weakness. In contrast, anterior aphasics articulate with considerable variability in vocal tract movements, as evidenced by sound substitutions both accross and within phonemic categories. If the variability in formant frequencies indeed reflects a variability in articulatory movements, the present result supports such a behavioural distinction.

2. Analysis 5: Mean Formant Positions in Aphasic and Normal Speech

The mean values of normal and aphasic speech formants were replotted in Figure 6.[11] Tikofsky (1965) shows that dysarthric formant means are generally in agreement with those of normals, and therefore, those values were not plotted.

The aphasic vowel configuration appears to be somewhat flattened along the F_1 axis, in comparison to the normal configuration. With the exception of [ə], aphasic

TABLE 9: FORMANT VARIABILITY
IN ALL SINGLE CELLS WITH N ≥ 5

PATIENT	VOWEL	N	FORMANT	APHASIC STANDARD DEVIATION	NORMAL STANDARD DEVIATION*	PROBABILITY ($\alpha = .05$)
AB	[ə]	7	F_1	113.4	44.2	< .025
			F_2	228.9	65.0	< .005
	[a]	8	F_1	74.4	40.5	< .05
			F_2	156.8	36.9	< .001
AW	[ī]	5	F_1	89.4	16.7	< .001
			F_2	125.5	74.4	n.s.
	[ɩ]	8	F_1	77.6	33.5	< .005
			F_2	176.8	95.3	< .025
	[eɩ]	6	F_1	63.2	42.0	n.s.
			F_2	206.0	88.4	< .05
	[a]	7	F_1	144.7	40.5	< .005
			F_2	234.0	36.9	< .001
EL	[ī]	5	F_1	86.0	16.7	< .025
			F_2	156.5	74.4	< .05
	[ə]	11	F_1	90.2	44.2	< .025
			F_2	223.8	65.0	< .001
	[a]	7	F_1	140.6	40.5	< .001
			F_2	241.3	36.9	< .001

**n* for normal vowels is to be found in Table 8, p. 45. Data for normals from Tikofsky (1965:34). Standard deviation values are in hertz.*

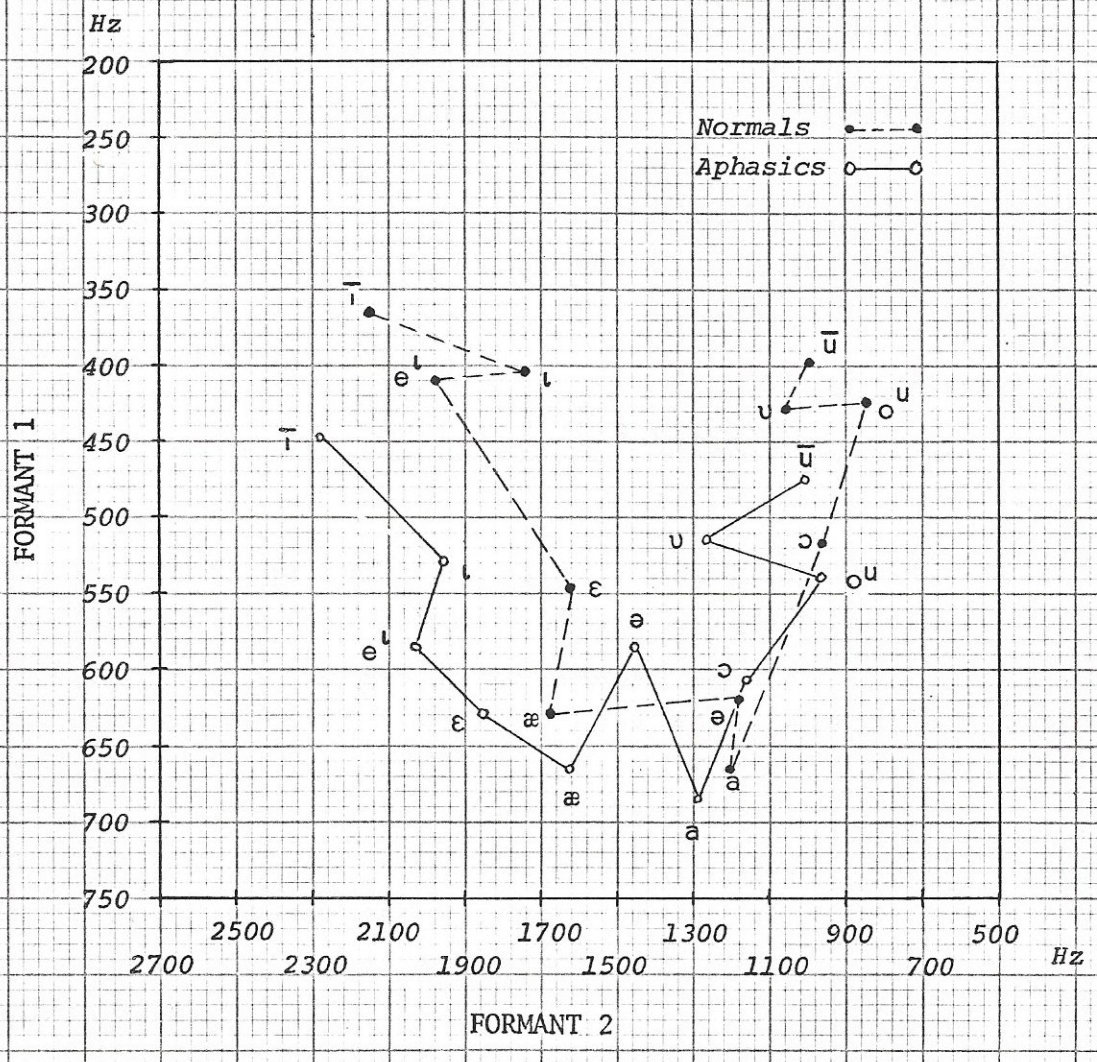


Figure 6. Mean formant values for normal and aphasic vowels.

vowels have a higher F_1 than normal vowels (significant at $\alpha = .05$, $t = 2.17$). The difference in frequency means is least with vowels [a] and [ɵ], the two that appear at the bottom of the configuration, which gives it the flattened appearance. Table 10 lists these differences between aphasic and normal vowel means.

To the extent that F_1 can be correlated with various levels of vocal tract constriction, these figures suggest that in aphasics, vocal tract configurations are generally less constricted than in normals.

C. The Results of the Vowel Substitution Sample

1. An overview

The frequencies of the various types of possible vowel substitutions are given in the matrices tabulated in Appendix V. Vowels are arranged along F_1, as it was derived for aphasic vowels in Analysis 4 (Table 8, p.45). The results are reported separately for 1. unilinguals on the tasks of spontaneous speech and repetition (Tables 1 and 2, Appendix V), 2. unilinguals on the reading task (Tables 3 and 4, Appendix V), and 3. bilinguals on spontaneous speech and repetition (Tables 5 and 6, Appendix V).

Since vowels occur with unequal frequency, and since the Vowel Substitution Sample was collected without constraint on vowel occurrence, the results for each target vowel must first be adjusted for chance of occurrence. This was accomplished by multiplying the frequency of each target vowel by a constant. It was derived by dividing the frequency of the least frequent vowel in the Normal Running Speech Sample (Appendix III) by the frequency of the particular vowel. The constants are

TABLE 10: F_1 FREQUENCY DIFFERENCES
BETWEEN APHASIC AND NORMAL VOWEL MEANS (IN HZ)*

[eᶥ]	[ɩ]	[oᵘ]	[ɔ]	[ʊ]	
174	120	114	90	86	
[ī]	[ɛ]	[ū]	[æ]	[ə]	[a]
82	82	76	36	31	20

**Normal data from Tikofsky (1965:34).*

given in Table 11.

Equalized figures appear in italics below each substitution type in Appendix V. The following analyses will be on either substitution frequencies or equalized equivalents, whichever is appropriate.

At the time of this writing it appeared that a more immediately useful set of constants would have added up to 11, the number of vowels. In that way any equalized frequency would have been readily comparable to the observed frequency. The reader can derive such a comparable figure by multiplying the equalized number by 2.93 in the case of stressed vowels, and 2.89 in the case of unstressed vowels. A conversion chart is given in Figure 7.

Figures 8 and 9 show the most prominent substitutions made by unilinguals in spontaneous speech and repetition tasks. Only the substitutions that were most common (as measured in equalized figures) were graphed.

In both conditions of stress a tendency to substitute lower vowels for higher ones can be noted, or in acoustic terms, a tendency towards a raising of F_1. This possibility will be examined in Analysis 6.

The vowel [a] appears to be a common choice for substitutions, as is [ə]. The question whether some vowels are more commonly chosen as substitutions than others is considered in Analysis 7.

Some additional phonetic features, such as ROUND and TENSE, are studied within the whole of the vocalic feature framework in Analysis 8. Closely associated is Analysis 9 which examines substitutions in terms of markedness theory.

TABLE 11: CONSTANTS USED IN EQUALIZING THE RESULTS OF THE VOWEL SUBSTITUTION SAMPLE

STRESSED										
[ī]	[ū]	[ʊ]	[ɩ]	[o^u]	[e^{ι}]	[ə]	[ɔ]	[ɛ]	[æ]	[a]
.169	.440	1.000	.157	.354	.224	.458	.407	.190	.207	.147
UNSTRESSED										
[ī]	[ū]	[ʊ]	[ɩ]	[o^u]	[e^{ι}]	[ə]	[ɔ]	[ɛ]	[æ]	[a]
.123	.514	.400	.083	.173	.545	.042	1.000	.340	.257	.327

Stressed vowels: equalized number	Stressed vowels: comparable number	Unstressed vowels: equalized number	Unstressed vowels: comparable number
10.0	29.30	10.0	28.92
9.5	27.84	9.5	27.47
9.0	26.37	9.0	26.03
8.5	24.91	8.5	24.58
8.0	23.44	8.0	23.13
7.5	21.98	7.5	21.69
7.0	20.51	7.0	20.24
6.5	19.05	6.5	18.80
6.0	17.58	6.0	17.35
5.5	16.12	5.5	15.90
5.0	14.65	5.0	14.46
4.5	13.19	4.5	13.01
4.0	11.72	4.0	11.57
3.5	10.26	3.5	10.12
3.0	8.79	3.0	8.68
2.5	7.33	2.5	7.23
2.0	5.86	2.0	5.78
1.5	4.40	1.5	4.34
1.0	2.93	1.0	2.89
0.5	1.47	0.5	1.45
0.0	0.00	0.0	0.00

STRESSED VOWELS — UNSTRESSED VOWELS

Figure 7. Chart for conversion from equalized to comparable frequency (see text, p. 53).

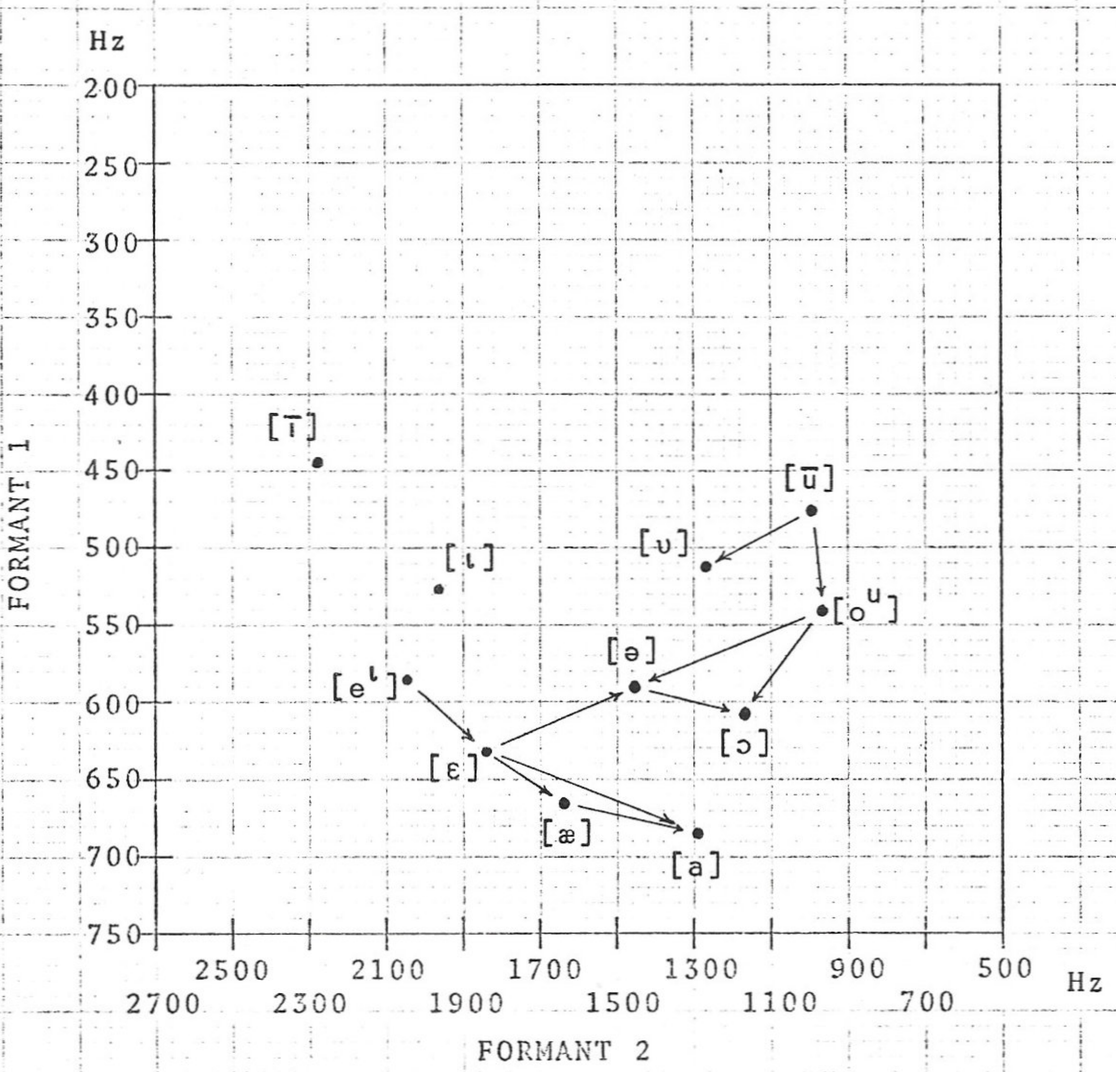


Figure 8. The most prominent substitutions (>3.0 in equalized figures); unilinguals, spontaneous speech and repetition, stressed vowels.

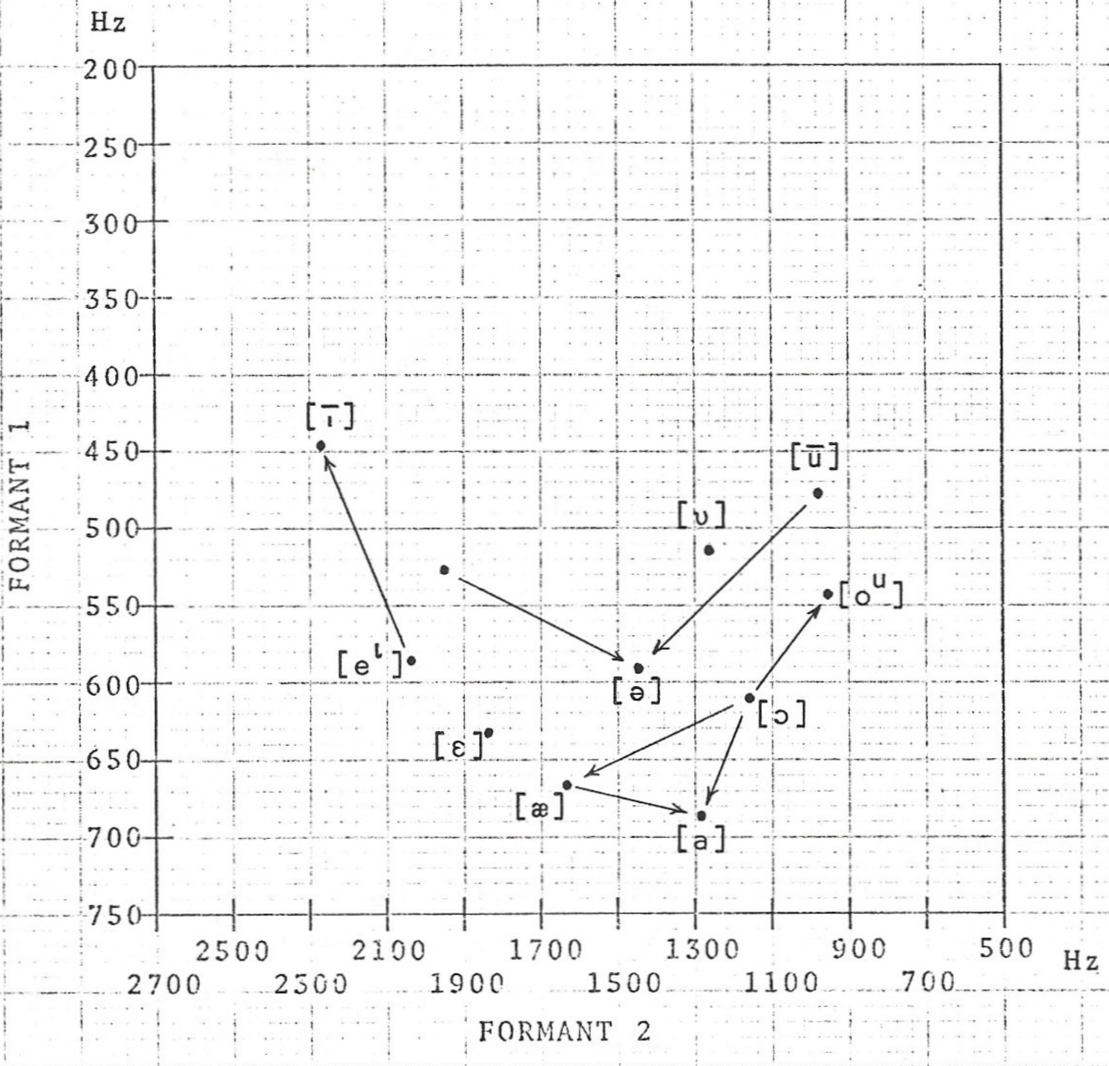


Figure 9. The most prominent substitutions (>2.0 in equalized figures); unilinguals, spontaneous speech and repetition, unstressed vowels.

2. Analysis 6: Substitutions along the Frequency Axes of F_1 and F_2.

If vowels are arranged according to their mean frequencies on F_1, a substitution matrix will reveal whether substitutions are predominantly higher in F_1 frequency (and articulatorily lower) than their targets. Similarly, arranged according to F_2, it will be possible to find out if substitutions have a consistent tendency towards higher F_2 values than their targets (and are thus further back articulatorily).

For these analyses it was assumed that the formant frequencies of the substitutions in the Vowel Substitution Sample for the most part reflect the mean frequencies of the Spectrographic Sample (Table 8, p.45). This will not always be the case, of course, because of the variability of aphasic vowel formant frequencies. It is possible to predict raising in F_1, for instance, on the basis of a perceived substitution [ɪ̄] → [eˡ], when in actual spectrographic measurements, this substitution turns out to be a case of F_1 lowering. This possibility was investigated on the 100 substitutions of the Spectrographic Sample. The predictions made on the basis of the perceived substitution agreed with formant measurements 81% of the time for F_1 and 88% of the time for F_2.

With this reservation in mind, the results of these analyses are presented in Tables 12 and 13.[12]

Unilingual aphasics in spontaneous speech and repetition show a very definite tendency to substitute vowels that are lower than the target vowels (or have a higher F_1). This tendency is evident in stressed as well as unstressed condition and can be noted among all unilingual patients. Moreover, there is great overlap between the

TABLE 12: SUBSTITUTIONS ANALYZED ACCORDING TO F_1

	STRESSED				UNSTRESSED			
	n*	% of F_1** ↑ or ↓	RESULT IN ARTICULATORY TERMS	PROBABILITY ($\alpha = .05$)	n*	% of F_1** ↑ or ↓	RESULT IN ARTICULATORY TERMS	PROBABILITY ($\alpha = .05$)
<u>Unilinguals:</u>								
Spontaneous Speech	145 *32.413*	61.5↑	LOWERING	$p < .01$	113 *21.673*	62.1↑	LOWERING	$p < .01$
Repetition	288 *84.303*	70.5↑	LOWERING	$p < .001$	243 *38.798*	67.8↑	LOWERING	$p < .001$
Combined	433 *119.548*	68.7↑	LOWERING	$p < .001$	356 *60.471*	65.8↑	LOWERING	$p < .001$
Reading	72 *17.326*	57.2↓	RAISING	not significant	158 *20.638*	65.9↑	LOWERING	$p < .001$
<u>Bilinguals:</u>								
Spontaneous Speech	110 *30.718*	60.5↑	LOWERING	$p < .025$	59 *14.192*	63.7↑	LOWERING	$p < .025$
Repetition	97 *26.469*	64.2↓	RAISING	$p < .01$	30 *3.762*	67.8↑	LOWERING	$p < .05$
Combined	207 *57.187*	56.3↓	RAISING	$p < .05$	89 *17.955*	64.5↑	LOWERING	$p < .01$

*top: observed frequency, bottom: equalized equivalent (see text, p. 51).
**i.e. percent of substitutions that show F_1 raising (↑) or lowering (↓).

TABLE 13: SUBSTITUTIONS ANALYZED ACCORDING TO F_2

	STRESSED				UNSTRESSED			
	n*	% of F_2** ↑ or ↓	RESULT IN ARTICULATORY TERMS	PROBABILITY ($\alpha = .05$)	n*	% of F_2** ↑ or ↓	RESULT IN ARTICULATORY TERMS	PROBABILITY ($\alpha = .05$)
<u>Unilinguals</u>:								
Spontaneous Speech	145 *32.413*	59.3↓	BACKING	$p < .025$	113 *21.673*	50.1↑	FRONTING	not significant
Repetition	288 *84.303*	55.1↓	BACKING	$p < .05$	243 *38.798*	55.1↑	FRONTING	not significant
Combined	433 *119.548*	56.4↓	BACKING	$p < .01$	356 *60.471*	53.8↑	FRONTING	not significant
Reading	72 *17.326*	60.6↑	FRONTING	$p < .05$	158 *20.638*	52.4↓	BACKING	not significant
<u>Bilinguals</u>:								
Spontaneous Speech	110 *30.718*	51.2↓	BACKING	not significant	59 *14.192*	86.0↑	FRONTING	$p < .001$
Repetition	97 *26.469*	66.7↑	FRONTING	$p < .01$	30 *3.762*	76.7↑	FRONTING	$p < .01$
Combined	207 *57.187*	57.1↑	FRONTING	$p < .025$	89 *17.955*	84.1↑	FRONTING	$p < .001$

*top: observed frequency, bottom: equalized equivalent (see text, p. 51).
**i.e. percent of substitutions that show F_2 raising (↑) or lowering (↓).

results on spontaneous speech and repetition. This was true of all substitution analyses. Henceforth, the results will therefore be reported in combined form. Table 14 lists the result of all those single cells of unilinguals (one patient, one task, one stress condition) that had over 40 substitutions. All seven cells are significant at least at $\alpha = .025$; the pattern of vowel lowering is thus general throughout patients, tasks and stress levels.

In reading, unilinguals also show lowering in unstressed vowels, while this tendency does not manifest itself in the stressed condition.

Similar circumstances prevail among bilingual patients. However, here a case of raising is observed in stressed repeated vowels.

A much less consistent picture is evident in the F_2 analysis. There is some tendency towards backing in stressed condition among unilinguals, but that is not supported in the reading task. Bilinguals on the other hand show considerable fronting under unstressed condition.

To sum up, the main axis of displacement appears to be along F_1. Unilinguals have a strong tendency to use lower vowels than are required for the target. The results for bilinguals and reading among unilinguals diverge; however, these are based on a much smaller sample of subjects and substitutions than are the main results.

3. Analysis 7: Predominant Target and Substitution Vowels--Contribution to the χ^2.

In a characterization of vowel substitutions it is useful to examine which target vowels are particularly prone or immune to substitutions. Likewise, substitutions can be examined to detect which vowels were more frequently,

TABLE 14: F_1 RAISING IN UNILINGUALS

(CELLS WITH OVER 40 SUBSTITUTIONS)

PATIENT	TASK	STRESS	n*	% OF F_1 RAISING	PROBABILITY ($\alpha = .05$)
AW	repetition	unstressed	94 *14.274*	70.4	$p < .001$
BW	repetition	stressed	92 *25.783*	85.5	$p < .001$
BW	repetition	unstressed	98 *16.019*	66.1	$p < .001$
EL	spontaneous speech	stressed	90 *22.333*	64.2	$p < .01$
EL	spontaneous speech	unstressed	63 *12.890*	64.3	$p < .025$
EL	repetition	stressed	42 *10.945*	72.1	$p < .01$
ID	repetition	stressed	123 *25.428*	67.9	$p < .001$

* top number: observed frequency, bottom number: equalized equivalent (see text, p. 51).

and which were less frequently used than expected.

As noted in Analysis 2 (p.39), aphasics use vowels with a similar frequency distribution to that of normals. By comparing the observed frequency of targets with the expected frequency, we can derive χ^2 values, an index of the difference. Individual vowels will make different degrees of contribution to this value; thus an examination of the contribution to the χ^2 will determine which vowels are unusually frequent or infrequent. Table 15 lists the χ^2 values, and the contributions of the various vowels, for targets.

Among unilinguals in spontaneous speech and repetition, two values stand out, those for stressed [ə] and [a]. [ə] is unusually prone (47 instead of an expected 21.3 targets of this type) and [a] is unusually immune to being involved in substitutions (24, with an expected frequency of 66.5). None of the other values of Table 15 are worth mentioning here, given the sample size associated with many of them.

Among substitutions, some particularly high contributions to the χ^2 are noted (Table 16). Unilinguals in spontaneous speech and repetition used stressed [ə] and [ɔ], and unstressed [ɛ] and [a] much more often than would be expected if substitutions were randomly distributed according to the frequency distribution of normal persons. This is also represented in the top graph of Figure 10. Conversely, stressed [ī] and [ɩ] and unstressed [ə] occur considerably less frequently than expected.

Expressed in terms of substitution raising or lowering, we then find a strong tendency towards lower vowels and away from higher ones, within each condition of stress.

In reading, very similar circumstances prevail for unstressed vowels. However, in stressed condition, the

TABLE 15: CONTRIBUTION TO THE χ^2: TARGETS

		[ῑ]	[ū]	[ʊ]	[ɩ]	[o^u]	[e^ɩ]	[ə]	[ɔ]	[ε]	[æ]	[a]	χ^2 and PROBABILITY (10 degr. of fr.)
STRESSED	Unilinguals:												
	Spontaneous Speech and Repetition	2.8	7.4	0.5	0.4	5.7	5.5	31.0	9.3	7.5	1.4	27.2	98.7 $p < .001$
	Reading	0.3	0.8	1.6	2.7	0.1	0.2	12.1	2.3	0.2	4.9	0.1	25.3 $p < .01$
	Bilinguals:												
	Spontaneous Speech and Repetition	5.8	0.0	1.1	0.0	0.3	4.6	11.4	3.7	0.1	0.9	0.2	28.1 $p < .01$
UNSTRESSED	Unilinguals:												
	Spontaneous Speech and Repetition	1.6	0.6	5.2	7.8	0.5	1.0	0.0	14.3	0.0	0.4	7.8	39.2 $p < .001$
	Reading	0.9	0.4	0.6	1.9	10.0	1.2	7.2	0.1	0.1	0.5	3.8	26.7 $p < .01$
	Bilinguals:												
	Spontaneous Speech and Repetition	0.7	27.1	6.7	4.1	0.0	2.4	0.1	0.1	0.2	0.3	0.2	41.9 $p < .001$

TABLE 16: CONTRIBUTION TO THE χ^2: SUBSTITUTIONS

		[ī]	[ū]	[ʊ]	[ɩ]	[oᵘ]	[eᶥ]	[ə]	[ɔ]	[ɛ]	[æ]	[a]	χ^2 and PROBABILITY (10 degr. of fr.)
STRESSED	Unilinguals:												
	Spontaneous Speech and Repetition	10.6	7.8	10.6	15.6	0.1	11.6	77.8	33.0	0.8	4.2	7.0	179.1 $p < .001$
	Reading	0.6	0.1	1.2	0.2	1.3	0.1	3.5	0.3	0.7	0.1	0.4	8.5, not significant
	Bilinguals:												
	Spontaneous Speech and Repetition	0.2	0.0	8.4	8.3	3.6	0.2	24.5	3.7	2.9	10.7	1.9	64.4 $p < .001$
UNSTRESSED	Unilinguals:												
	Spontaneous Speech and Repetition	7.7	0.0	4.0	4.2	12.7	8.6	29.4	21.6	83.9	0.4	298.0	470.5 $p < .001$
	Reading	0.0	0.6	2.6	5.6	1.6	0.4	28.5	13.1	1.3	0.4	387.2	441.3 $p < .001$
	Bilinguals:												
	Spontaneous Speech and Repetition	0.1	0.1	2.2	0.3	0.9	2.8	7.6	5.6	66.5	2.0	1.1	89.2 $p < .001$

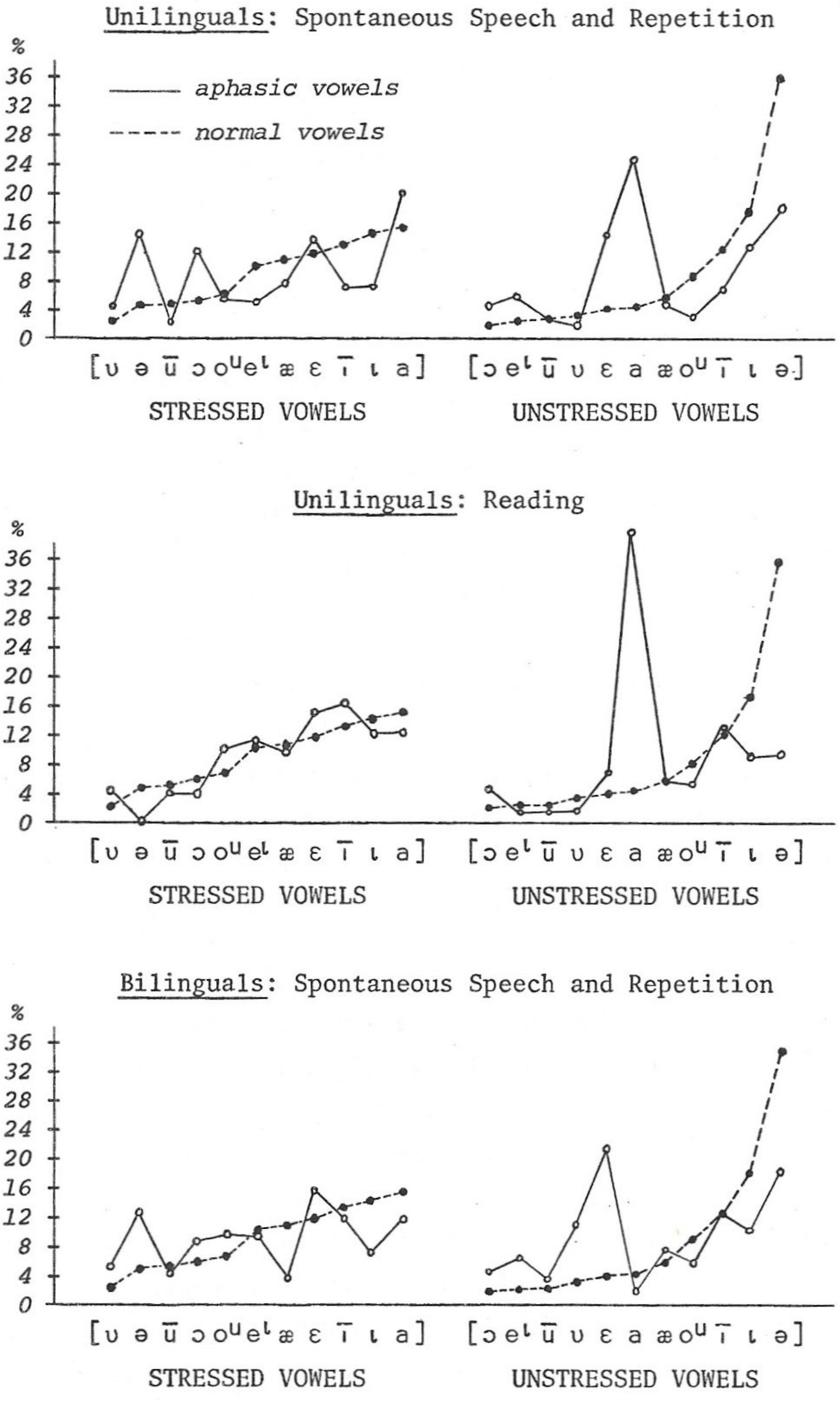


Figure 10: Frequency distribution of substitutions.

frequency distribution is roughly parallel to the expected normal one (χ^2 not significant at $\alpha = .05$). This suggests that in stressed vowels of a reading task, a different effect may be at work than in the stressed vowels of spontaneous speech and repetition tasks.

Only two vowels are prominent in the bilingual sample, stressed [ə] and unstressed [ɛ]. Their high frequencies, together with the conspicuous absence of an elevated [a] frequency, throw some light on the divergent results noted for bilinguals in the formant analysis (Analysis 6, p. 58).

Blumstein (1973a:43), in a very similar analysis of consonants, finds that the least frequent consonants of the language (such as [š] , [č] and [ž]), are proportionally more prone to substitution than the more frequent consonants (such as [t], [n] and [s]). This pattern apparently does not generalize to vowel substitutions. For instance, in the unilingual results, stressed [a] and unstressed [ə] are very frequent substitution vowels and they also occur frequently in the language. Conversely, [ū], in both stress conditions, is a rare sound, in language use as well as in substitutions.

4. Analysis 8: Changes in Feature Values

Several aspects of vowel production, such as degree of rounding and tensing, have so far been left unexamined. They are most easily studied by a feature analysis; its results will incidentally also serve to check the findings of the formant analysis, Analysis 6. The feature system to be used here will be that of Chomsky and Halle (1968).

There is a major drawback to feature analysis in comparison to formant analysis. Every vowel differs from every other vowel in its mean formant frequencies. Thus a substitution can always be described in terms of an increase or decrease in the (probable) frequencies of the formant concerned. Since two vowels may have the same value in the particular feature under study, only a subsample of the total sample ever differs in any one feature, though, of course each vowel is different from each other by at least one feature. For instance, [ā] and [ɔ̄] differ in the feature ROUND, but not in HIGH, BACK, LOW and TENSE. Thus a substitution [lɔ̄] → [lā] 'law' cannot contribute to an investigation of lowering and raising tendencies within a feature analysis. A formant analysis, on the other hand, would have recorded this substitution as a case of lowering. In stressed vowels, an average of only 33.1% of substitutions contributed to the feature analysis. The figure drops to 19.3% for unstressed vowels. This means that for bilingual patients, for instance, the sample of unstressed vowels contributing to the feature analysis has shrunk to perhaps 17 substitutions (19.3% of 89 substitutions).

Not all features were equally likely to be involved in substitutions. The feature TENSE was most likely to be involved in a substitution, ROUND least likely, and HIGH, LOW and BACK generally took intermediate positions.

Tables 17 to 19 present the results of the feature analysis.[12] Among unilinguals in spontaneous speech and repetition, the pattern of lowering is supported in stressed vowels; the results are inconclusive for unstressed vowels in these tasks, but there is again lowering in unstressed vowels in reading. Bilinguals once more show some divergence from the unilingual patterns with a slight tendency towards raising.

The unilingual results on the feature BACK are consistent: backing is found in all three tasks under both conditions of stress, but as in the formant analysis, the results are statistically much weaker in unstressed than in stressed vowels. Bilinguals show a strong tendency for fronting.

TABLE 17: FEATURE CHANGES IN SUBSTITUTIONS

(UNILINGUALS: SPONTANEOUS SPEECH AND REPETITION)

FEATURE	STRESSED				UNSTRESSED			
	n*	% of sub-stitutions + or -**	RESULT	PROBABILITY ($\alpha = .05$)	n*	% of sub-stitutions + or -**	RESULT	PROBABILITY ($\alpha = .05$)
HIGH	133 *33.656*	74.2-	LOWERING	$p < .001$	92 *16.252*	50.6+	RAISING	not significant
LOW	143 *34.744*	81.5+	LOWERING	$p < .001$	70 *18.063*	55.9+	LOWERING	not significant
BACK	132 *29.350*	64.7+	BACKING	$p < .001$	74 *19.970*	52.7+	BACKING	not significant
ROUND	74 *22.100*	66.9-	UNROUNDING	$p < .01$	45 *18.858*	81.8-	UNROUNDING	$p < .001$
TENSE	164 *40.610*	63.1+	TENSING	$p < .001$	92 *21.368*	55.3-	LAXING	not significant
TOTAL POSSIBLE N	433 *119.548*				356 *60.471*			

**n* = *those substitutions that underwent a change for the feature concerned. Top number: substitutions, bottom number: equalized equivalent.*

***+ indicates [- → +] (gain of feature), and - indicates [+ → -] (loss of feature).*

TABLE 18: FEATURE CHANGES IN SUBSTITUTIONS
(UNILINGUALS: READING)

FEATURE	STRESSED				UNSTRESSED			
	n*	% of substitutions + or -**	RESULT	PROBABILITY (α = .05)	n*	% of substitutions + or -**	RESULT	PROBABILITY (α = .05)
HIGH	28 *5.381*	58.4+	RAISING	not significant	38 *6.736*	68.1-	LOWERING	$p < .025$
LOW	31 *6.190*	55.3-	RAISING	not significant	32 *6.219*	85.4+	LOWERING	$p < .001$
BACK	15 *3.428*	58.9+	BACKING	not significant	26 *4.673*	71.9+	BACKING	$p < .025$
ROUND	18 *3.983*	52.1+	ROUNDING	not significant	18 *7.142*	78.4-	UNROUNDING	$p < .01$
TENSE	37 *7.565*	51.8+	TENSING	not significant	40 *6.889*	85.7+	TENSING	$p < .001$
TOTAL POSSIBLE N	72 *17.326*				158 *20.638*			

**n = those substitutions that underwent a change for the feature concerned. Top number: substitutions, bottom number: equalized equivalent.*

***+ indicates [- → +] (gain of feature), and - indicates [+ → -] (loss of feature).*

TABLE 19: FEATURE CHANGES IN SUBSTITUTIONS

(BILINGUALS: SPONTANEOUS SPEECH AND REPETITION)

FEATURE	STRESSED				UNSTRESSED			
	n*	% of substitutions + or -**	RESULT	PROBABILITY (α = .05)	n*	% of substitutions + or -**	RESULT	PROBABILITY (α = .05)
HIGH	62 *15.898*	57.7+	RAISING	not significant	19 *4.197*	59.5-	LOWERING	not significant
LOW	70 *17.116*	66.9-	RAISING	$p < .01$	9 *2.388*	73.4-	RAISING	not significant
BACK	73 *19.799*	64.5-	FRONTING	$p < .01$	16 *6.043*	91.0-	FRONTING	$p < .001$
ROUND	56 *17.739*	70.7-	UNROUNDING	$p < .001$	15 *6.062*	91.0-	UNROUNDING	$p < .001$
TENSE	89 *22.161*	58.8+	TENSING	$p < .05$	19 *5.562*	77.6-	LAXING	$p < .01$
TOTAL POSSIBLE N	207 *57.187*				89 *17.955*			

**n* = *those substitutions that underwent a change for the feature concerned. Top number: substitutions, bottom number: equalized equivalent.*

**+ *indicates [- → +] (gain of feature), and - indicates [+ → -] (loss of feature).*

There is very consistent unrounding in all tasks and conditions, except in stressed vowels of reading where a statistically insignificant percentage of rounding is reported (*p* > .05).

In the feature TENSE, substitutions are generally tenser than their targets; there was one case of laxing in the bilingual sample, yet that is based on a very small sample of 19 substitutions. Given the vagaries of the equalization procedure within a substitution matrix, this figure cannot be given very much credit.

5. Analysis 9: Changes in Markedness Complexity

It was examined whether the vowel substitutions follow the same pattern in markedness complexity as Blumstein (1973a:52) reports for consonants. For vowels, the rules of Chomsky and Halle (1968:405) were used to derive a complexity index, graphically represented in Figure 11.

The sound [a] has the index 0, [ī] and [ū] have the index 1, [ɩ], [$e^{ɩ}$}, [o^{u}] and [ʊ] have the index 2, and [ɛ], [æ] and [ɔ] the index 3. [ə] is left out of this scheme because it is generally derived for surface representation by the rule of REDUCTION, after which it can take on dialect-specific feature representation (Chomsky and Halle 1968:110).

Table 20 reports the results of this analysis.[12] The results for stressed vowels are generally inconclusive. Only bilinguals show something of a trend towards unmarking.

In unstressed vowels, some considerable unmarking is reported for unilinguals in all tasks, while marking appears in bilinguals.

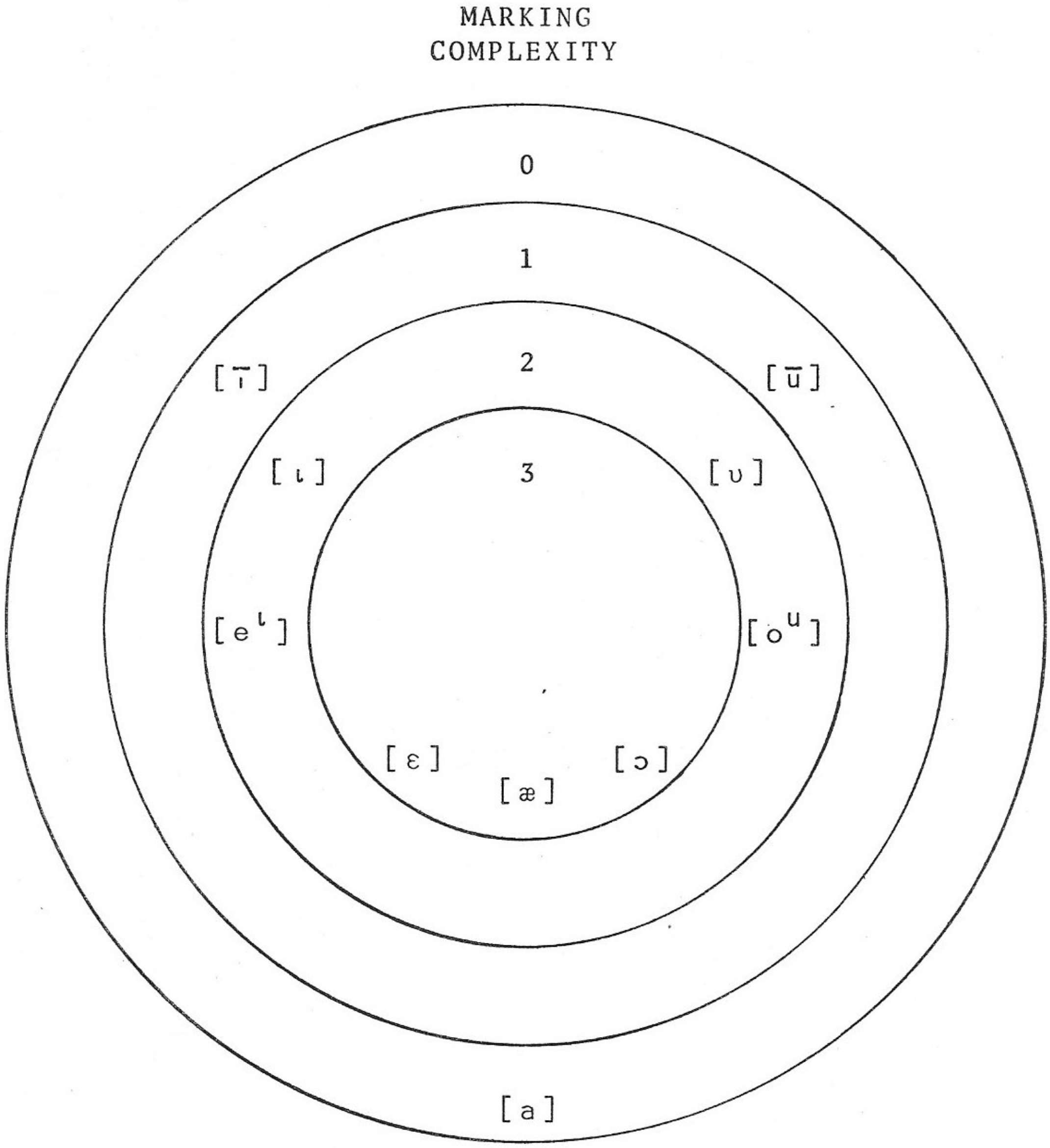


Figure 11: Marking Complexity Index for Vowels.

TABLE 20 : MARKING CHANGES IN SUBSTITUTIONS

	STRESSED				UNSTRESSED			
	TOTAL POSSIBLE N*	n**	% OF SUBSTITUTIONS ↑ OR ↓***	RESULT and PROBABILITY ($\alpha = .05$)	TOTAL POSSIBLE N*	n**	% OF SUBSTITUTIONS ↑ OR ↓***	RESULT and PROBABILITY ($\alpha = .05$)
<u>Unilinguals</u>:								
Spontaneous Speech and Repetition	433 *119.548*	255 *65.119*	54.5↑	MARKING not significant	356 *60.471*	131 *32.078*	73.3↓	UNMARKING $p < .001$
Reading	72 *17.326*	54 *11.041*	51.0↓	UNMARKING not significant	158 *20.638*	62 *13.386*	75.1↓	UNMARKING $p < .001$
<u>Bilinguals</u>:								
Spontaneous Speech and Repetition	207 *57.187*	132 *31.978*	60.5↓	UNMARKING $p < .01$	89 *17.955*	29 *8.434*	71.0↑	MARKING $p < .025$

**top number: observed frequencies, bottom number: equalized equivalent.*

***those substitutions that underwent a change in marking; top number: observed frequencies, bottom number: equalized equivalent.*

****i.e. ↑ indicates an increase in the markedness index, ↓ a decrease.*

These results can be illuminated by referring back to the χ^2 analysis (p.61). It was reported there that in unstressed vowels unilinguals were much more likely to use [a] as a substitution vowel than any other. It will be recalled that [a] has the marking complexity index 0. This would account for the tendency of unmarking in unilinguals. In bilinguals, a predilection for the substitution vowel [ɛ] was demonstrated, which, with an index of 3, contributes heavily to marking.

However, the marking pattern does not generalize to other crucial vowels. For instance, with a marking index of 1, the vowels [ī] and [ū] should be predominant choices as substitutions in unilinguals. However, Figure 10 shows that these two vowels are either below or at average values. In bilingual substitutions as well, other highly marked vowels are not prominent substitution vowels (cf. for instance, [ɔ] or [æ]). The concept of markedness complexity seems to have little to contribute to a search for a unifying principle behind the vowel substitutions of this sample.

D. Summary

A number of major tendencies in vowels and vowel substitutions of English-speaking unilingual aphasics have crystallized through the application of a variety of analytical techniques. The results are summarized here and their implications will be discussed in Chapter IV.

1. Aphasic vowels vary considerably in their formant frequencies for the same perceived vowel. This can perhaps be interpreted as greater variability in vocal tract configurations than normals or dysarthrics exhibit.

2. Aphasics have generally higher mean $Formant_1$ values than normals or dysarthrics do for the same vowels.

This is least the case for [a]. This tendency can be seen as a trend towards relatively wider vocal tract constrictions among aphasics.

3. In substitutions, higher vowels (those with lower F_1 values) have a very consistent tendency to be replaced by lower vowels (or those with relatively higher F_1 values). This can be interpreted to support the above tentative conclusion that aphasics have a proneness towards relatively wider vocal tract constrictions.

4. The vowel with the widest oral vocal tract constriction, [a], is used as an unstressed substitute vowel far more frequently than it would naturally occur in language. Conversely, some of the more constricted unstressed vowels, such as [ɪ̄], [ɩ] and [ə], occur relatively infrequently.

5. Aphasics tend to substitute unrounded vowels for rounded ones, as well as tenser vowels for laxer ones.

6. A circumscribed sample of bilingual (natively French-speaking) aphasic speech in English revealed somewhat divergent tendencies in the choice of substitution vowels. [ε], rather than [a], was the predominant choice, another sound with a relatively wide vocal tract constriction. This tendency was, however, compounded by an additional tendency towards fronting.

7. Another limited sample of unilingual aphasic speech in reading tasks revealed some similarities to spontaneous or repeated speech in unstressed vowels, but clearly divergent and inconsistent tendencies in stressed vowels.

8. An examination of changes in the feature marking indices of substitution vowels did not disclose any generalizable marking patterns.

FOOTNOTES TO CHAPTER III

[1]For this analysis, [w], [y] and [h], used in the computer print-out as consonants as well as glides, were separated manually.

[2]Two of their ten patients accounted for most vowel errors. Since these two patients were among the most severely impaired patients, they suggest that the presence of vocalic errors, in addition to consonantal errors, may be a severity indicator of this type of aphasia. However, the presence in this sample of quite a number of patients with slight impairment (AB, AW, EL, JR and RGMS) would seem to indicate that this is unlikely.

[3]With this exception the frequencies comprise all vowels that occurred: targets and substitutions, and their respective repetitions, as well as additions.

[4]Arguing that all substitutions can be analyzed both syntagmatically and paradigmatically, it was at first decided to subject the entire data base to analyses 7 and 9. However, when the result turned out to be rather weak and inconsistent, it was decided to separate out those substitutions that had apparently undergone the most influence along the syntagmatic axis.

[5]Incidentally, Victoria Fromkin's (1971:251) data for slips of the tongue in normals are most frequently of this type. However, only very few such errors were observed among the aphasics reported here.

[6]This possibility was investigated for consonants preceding and succeeding those instances where a substitution had occurred for the vowels [ī], [ə] and [ū]. Assuming that consonantal correlation would manifest itself

most readily in place features, it was expected that [ī] would be surrounded predominantly by anterior consonants, [ū] by velars, and [ə] by a mixture of both. However, no such pattern emerged. Trost and Canter (1974:69) proposed the possibility that vowels "were misarticulated in relation to articulatory difficulty on contiguous consonants". But assuming that their patients and the present ones are comparable, it now appears that vowel substitutions have "a life of their own", independent of consonantal difficulties.

The reverse possibility, that vowels influence the substitutions occurring among consonants, is suggested in Cohen et al. (1963:173). This fascinating possibility merits exploration on a wider scale.

[7]The acoustic analysis for that study was done by Ilse Lehiste. It is not entirely clear how far her sample in Tikofsky (1965) differed from that of Lehiste (1965)--there appears to be considerable, but not total, overlap. In any case, the two sources are consistent in the means and standard deviations of formant positions of dysarthrics.

[8]e.g. Canadian raising (Joos 1942:141, Chambers 1973:113), where Canadian [hə^{u}s] corresponds to Upper Middle Western [ha^{u}s] 'house'.

[9]e.g. the difference between the two dialects on the pronunciation of the word 'fog'. Even though the Upper Middle Western pronunciation is often judged to be closer to the sound [a] than the Southern Ontario variant, this difference between dialects was not reflected in the spectrographic mean plots (p. 50).

[10]Among these can be counted disagreements between the three displays (the spectrogram, the wide and the

narrow band cross-sections), additional unexplained formants, and the limitations of the measuring process. Some of these limitations are being overcome by new, real-time computer assisted formant analysis (cf. Ouellon and Lindfelt 1973).

[11]Most two-dimensional formant plots are made on a logarithmic scale. This practice was not adopted here in order to facilitate visual comparison of distances between normal and aphasic plotting points.

[12]The percentages reported here are based on the equalized figures. Probabilities were determined by means of the variant of the binomial test reported in Glass and Stanley (1970:323).

IV. DISCUSSION

A. Possible Unifying Hypotheses

In the previous two chapters, two prominent linguistic concepts were discounted as possible unifying hypotheses for the results of this study. The first concept is that of environmental phonetic influence on the substitution sound. Only 16 percent of the substitutions of the present sample of aphasics had potentially undergone such environmental influence; in addition, the results reported on pp. 75-6 are based on the remaining 84 percent of substitutions. If phonetic environment had been the only cause of those vowel errors, the results would not have been as systematic as they were. The second concept is markedness which distinguishes various degrees of "naturalness" within a sound system. When sounds were ranked according to their degree of markedness, no clear and pervasive patterns were established.

In this chapter a third hypothesis will be considered. Since articulation can be viewed as a motor system, it should be possible to speculate on the neuromuscular events of articulatory breakdown. The expectation is that these events would be similar to the neuromuscular events that have been described for the breakdown of other motor systems which, like aphasia, result from cerebral lesions. Accordingly, there follows first a description of likely neuromuscular events in articulation, and then, a characterization of how these events are altered in the case of certain brain lesions.

B. Anatomy of the Tongue and Electromyographic Measurements

All vowels are formed with the tongue bunched into nearly the same rounded form (Perkell 1969:63). Therefore, the intrinsic tongue musculature can for the most part be left out of consideration here; by and large, the body of the tongue is moved into its various typical positions by three extrinsic muscles: the *genioglossus* which runs along most of the middle of the underside of the tongue and connects it to the front inside of the jaw, the *hyoglossus* which connects the sides of the tongue with the hyoid bone, and the *styloglossus* which runs from the side of the tongue to the two styloid processes below the ear openings of the skull (Figure 12).

Other muscle groups are active in the oral articulation of vowels, such as those that activate the jaw, the lip muscles, those that lower and raise the hyoid bone, a few intrinsic muscles of the tongue, and perhaps one more extrinsic muscle, the *palatoglossus*. However, for expository simplicity, it will be assumed here that a rough sketch of tongue muscle activity is possible in terms of the above-mentioned three main muscles.

One of the main findings of this study is that higher vowels have a consistent tendency to be replaced by lower vowels. In terms of extrinsic tongue muscle action, what distinguishes higher from lower vowels? This question has been examined empirically by an electromyographic study done by Mac Neilage and Sholes in 1964. For each vowel they recorded at least 20 artifact-free tracings from thirteen points along the surface of the tongue of a single subject as he pronounced vowels in a [p]V[p] series ([pīp], [peᶥp], etc.). Two suction micro-electrodes were attached

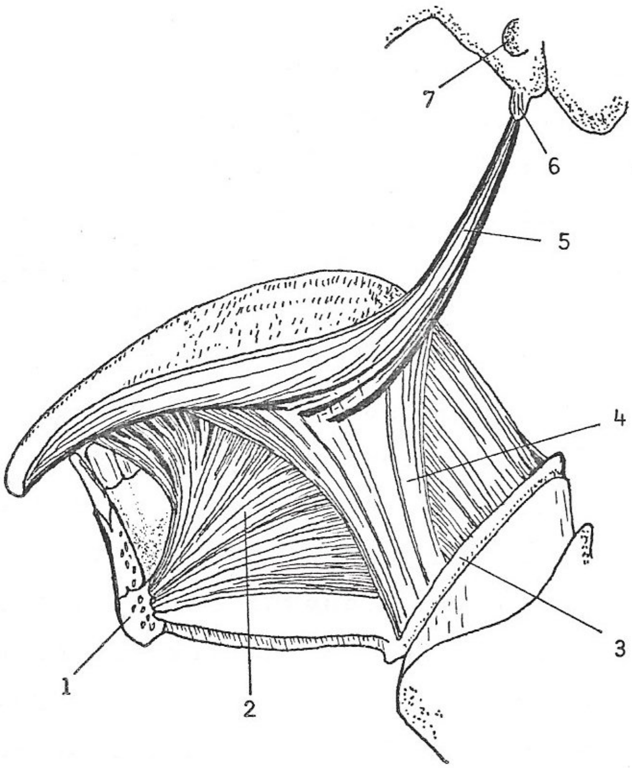


Figure 12. The main extrinsic tongue muscles. 1, jaw; 2, genioglossus; 3, hyoid bone; 4, hyoglossus; 5, styloglossus; 6, styloid process; 7, ear opening. Based on Gray and Goss, 1973.

to the tip of the tongue, three to the blade, four to the back, and four to the root of the tongue. Mac Neilage and Sholes report their data separately for each electrode; however, for this summary, their tracings were averaged and are reported for the main areas of the tongue just indicated.

Figure 13 gives a summary of the averaged peaks found in eight of the eleven vowels examined for this study. [ə] was left out because Mac Neilage and Sholes did not include it in their study, and the two vowels [ɩ] and [ʊ] paralleled [ī] and [ū] respectively in their electromyographic profiles, save for somewhat attenuated peak levels. [ī], [ū], [oᵘ] and [eᶥ] were chosen as high vowels, and [ɔ], [ɛ], [æ] and [a] as low vowels--which corresponds to their status on the F_1 measurements.

We can see from the graphs of Figure 13 that high vowels have rather elevated activation levels at one or the other extreme of the tongue. In contrast, low vowels have fairly even activation levels over the whole surface of the tongue. Interpreted in terms of muscle contractions, the values at the root of the tongue probably represent genioglossus activation and those at the blade presumably represent the innervation to the styloglossus and/or the hyoglossus. As a result, for [ī], the genioglossus would have to contract very acutely to accomplish the considerable forward movement required for this vowel. The simultaneous high activity at the tip probably represents the activity of an intrinsic muscle which has the effect of retracting the tip so as to keep it from touching the teeth as the tongue advances. [ū], on the other hand, has high activity levels at the blade and the tip which is best interpreted as styloglossus contraction. [eᶥ] and

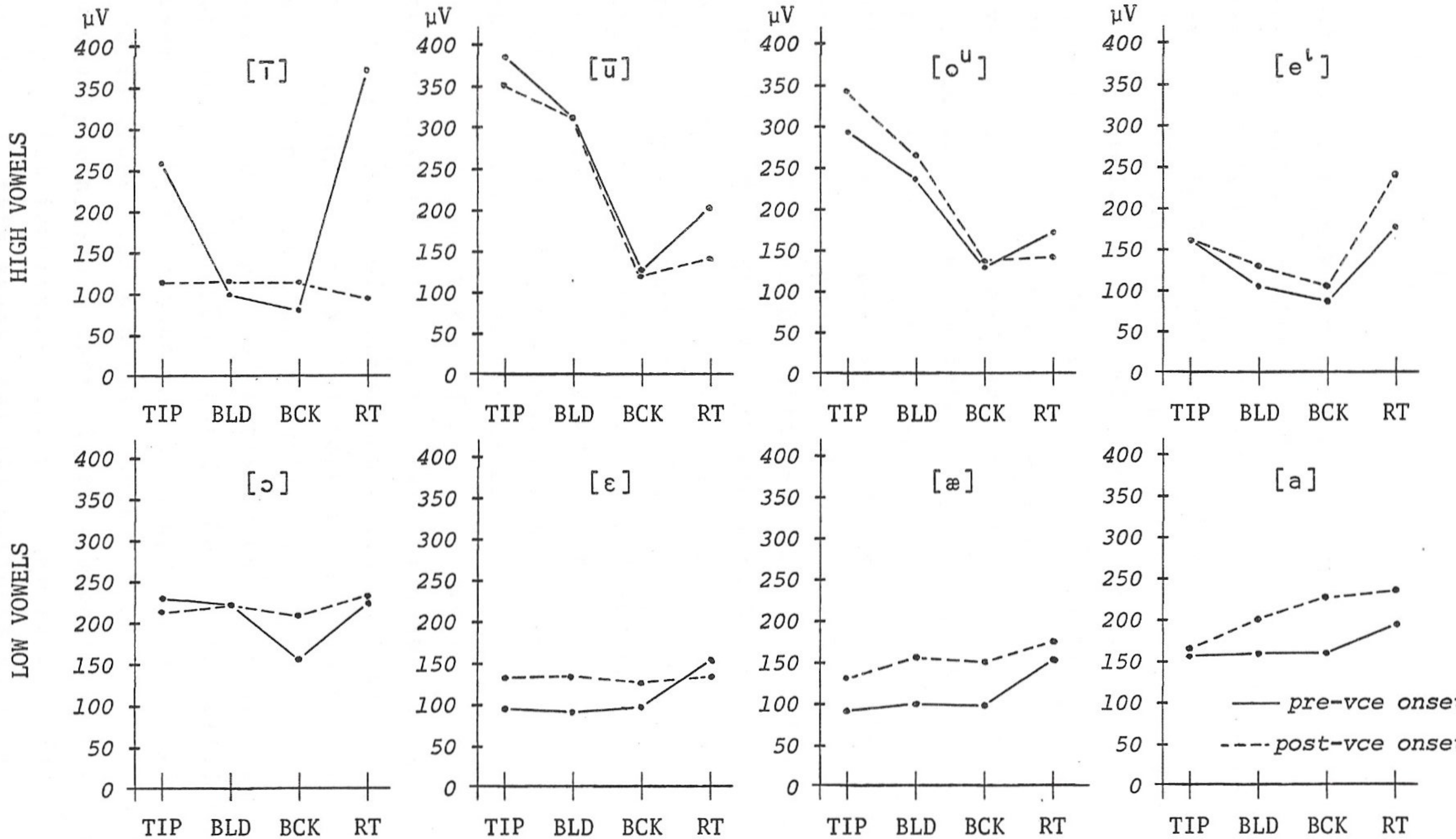


Figure 13. Averaged peaks of electromyographic measurements of the tongue during articulation. Based on data from Mac Neilage and Sholes, 1964. BLD, blade; BCK, back; RT, root.

[o^{u}] exhibit peak activity that is similar to that of their articulatorily related vowels: like [$\bar{\imath}$], [e^{ι}] shows probable genioglossus contraction, and [o^{u}], like [$\bar{u}$], has peak activity that lets us conclude considerable styloglossus activity (Mac Neilage and Sholes 1964:214-7).

The low vowels, with their far more evenly distributed activation levels, would seem to depend on a contraction of the two lower muscles, the genioglossus and hyoglossus. For these vowels, the activity levels at the tip and the blade are relatively low, probably reflecting the relaxation of the opposing styloglossus muscle. This accomplishes the goal of moving the tongue downwards and away from the position that it would occupy if the muscles were totally relaxed. This representation of articulatory events is of course grossly simplified. For one thing, the environment is held constant in a [p]V[p] sequence which means that co-articulation effects are eliminated. Nevertheless, for the purposes of this description, the preceding deductions are probably useful. The reader is referred to the original article and to Mac Neilage (1972) for an elucidation of the detail.

Stated in terms of neural activity innervating the tongue muscles, it appears that for lower vowels there is a similar level of activation throughout the tongue musculature, while with higher vowels there is differential activation of particular muscle groups. For example, a very pronounced peak of activity was recorded at the front of the tongue for [$\bar{u}$]. But for [a], peak activity extends over the whole surface of the tongue (Figure 13). If we can conclude from a normal subject upon aphasics (which we probably can, since there is no reason to assume a pathology in the innervation and musculature of this sample of aphasics), this means that the patients of this study could very well have received motor impulses that were less selective than they should have been. Instead of a selective activation of individual muscles, there could have been a more generalized activation of all tongue muscles. The tongue would have been lowered as a result, and a vowel substitution would have been produced. This would account for the lowering tendency reported in the analyses of the substitution sounds of this study.

This schema can also account for the finding that the aphasics of this sample probably articulated the same perceived vowels with wider vocal tract configurations than normal subjects did. Such pathological lowering of the tongue could be sufficient to show up on spectrograms, but not in a perceived vowel substitution. Even considerable changes in the vocal tract configurations do not necessarily prevent a vowel from being perceived as the intended vowel; as Stevens and House (1955:41) demonstrated by means of a simulation study, the same perceived vowel can be formed with greatly varying vocal tract constrictions.

A number of other results of the study are also illuminated if we can assume loss in the selectivity of neural commands. Lip rounding, a contraction of the orbicularis oris muscle, is only successful when its synergistic partners for lip spreading (such as the risorius and the triangularis muscles) extend simultaneously. It will be recalled that the aphasics of this sample had a tendency to substitute unrounded vowels for rounded ones; this can then be interpreted as another instance of insufficient synergistic selectivity in neural commands.

Tense sounds, in Chomsky and Halle's (1968:324) feature system, "involve considerable muscular effort" over the entire articulatory tract. A patient who lacks selective control over his musculature is likely to redouble his efforts, which will result in heightened muscle tonus throughout the phonation apparatus. It is thus not surprising that the patients of this sample tended to substitute tense for lax vowels.

C. Lack of Selectivity as a Cortical Dysfunction

As may be recalled from Chapter I (p. 2), Alajouanine et al. (1939:118) ventured a description of articulatory movement disturbances in neurological terms. They felt that articulatory movements, and especially the production of vowels, had a synkinetic character. Synkinesis is "an unintentional movement accompanying a volitional movement" (Dorland 1965), such as the inevitable partial flexing of the ring finger that accompanies a full flexion of the middle finger. In pathological cases, synkinesis is clearly a loss in neural muscle selectivity, analogous to the state that was deduced for impulses to the tongue in the previous section.

Pathological synkinesis as a result of a cortical lesion is not unique. Luria (1966:179), reporting on the work of Foerster (1936), notes that in many cases of lesions that lie posterior to the Rolandic fissure (Brodmann's areas 3, 1, 2 and 5--see Figure 14), limb muscles had defects which were due to a loss of selectivity of the motor impulse. As a result, both partners of the synergistic muscle pair would contract diffusely. He also describes a case of almost total loss of selectivity from his own laboratory; this patient had lost the ability to alternatively extend and flex all fingers by means of the muscle pair flexor carpi radialis/extensor carpi radialis. Electromyograms of the two muscles documented this lack

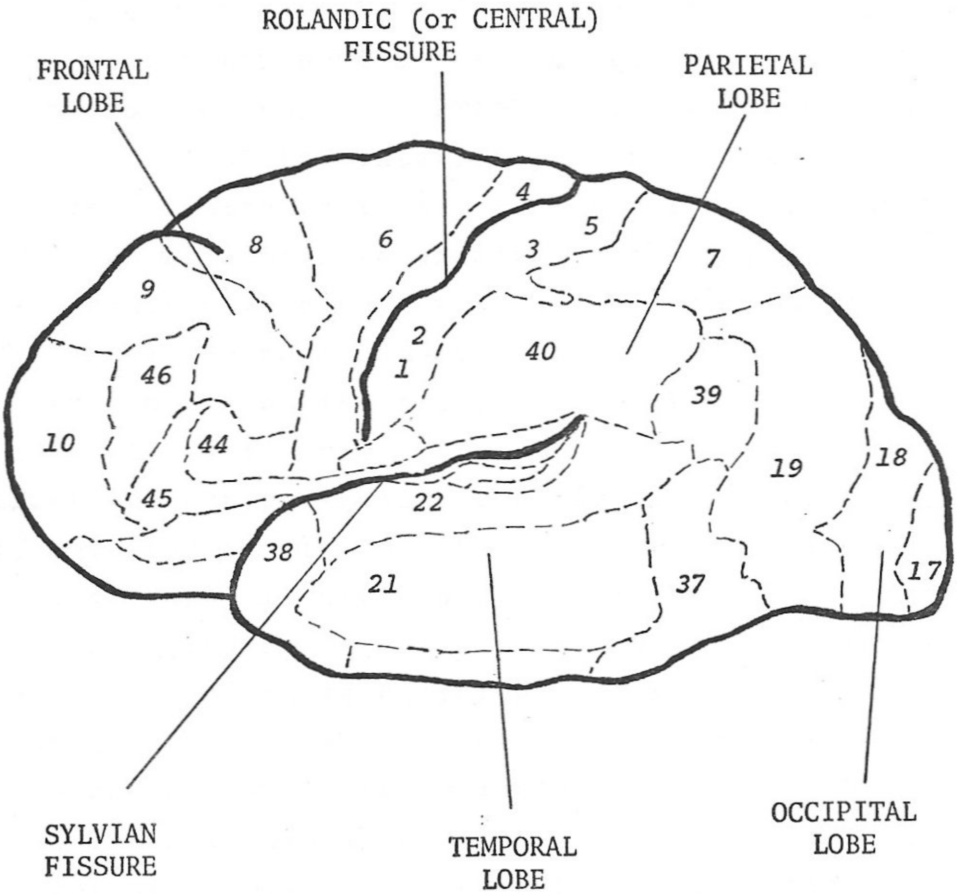


Figure 14. Cytoarchitectonic areas of the left hemisphere (after Gray and Goss, 1973)

of selectivity in graphic form (Figure 15).

However, the sensory-motor area that lies posterior to the Rolandic, or central, fissure is only one of several cortical areas directly concerned with movement. All of these areas lie in the irrigation area of the upper division of the middle cerebral artery and are thus ready targets for an embolic infarct. Prima facie, we thus have no reason to assume that the anterior patients of this sample must all have a lesion that lies exclusively in the sensory-motor area. We will have to examine whether lesions in the other areas could have caused the observed symptomatology.

The so-called motor areas are bands of cytoarchitectonically similar neural tissue lying parallel to and adjoining the central fissure. Posterior to the central fissure lies the sensory-motor area (Brodmann's areas 3, 1, 2 and 5), anterior to it lies the motor-sensory area (Brodmann's area 4), and situated in front of the latter is the pre-motor area (Brodmann's areas 6, 8 and 44) (see Figure 14). Those parts of these different areas which lie adjacent to the sylvian fissure contain cells directly concerned with movements of the articulatory organs. The *postcentral articulatory area* contains predominantly cells that register proprioceptive feedback from the articulators. The *precentral articulatory area*, on the other hand, contains pyramidal cells which conduct motor impulses into the upper vocal tract. And anterior to that lies Brodmann's area 44, or part of *Broca's area*, an area distinguished from its cytoarchitectonic relative, area 6, by the fact that cell layer III forms an unusually dense associative network (Luria 1966:206). It is this area that has been implicated in the majority of those cases of the anterior aphasic syndrome where localization was attempted.

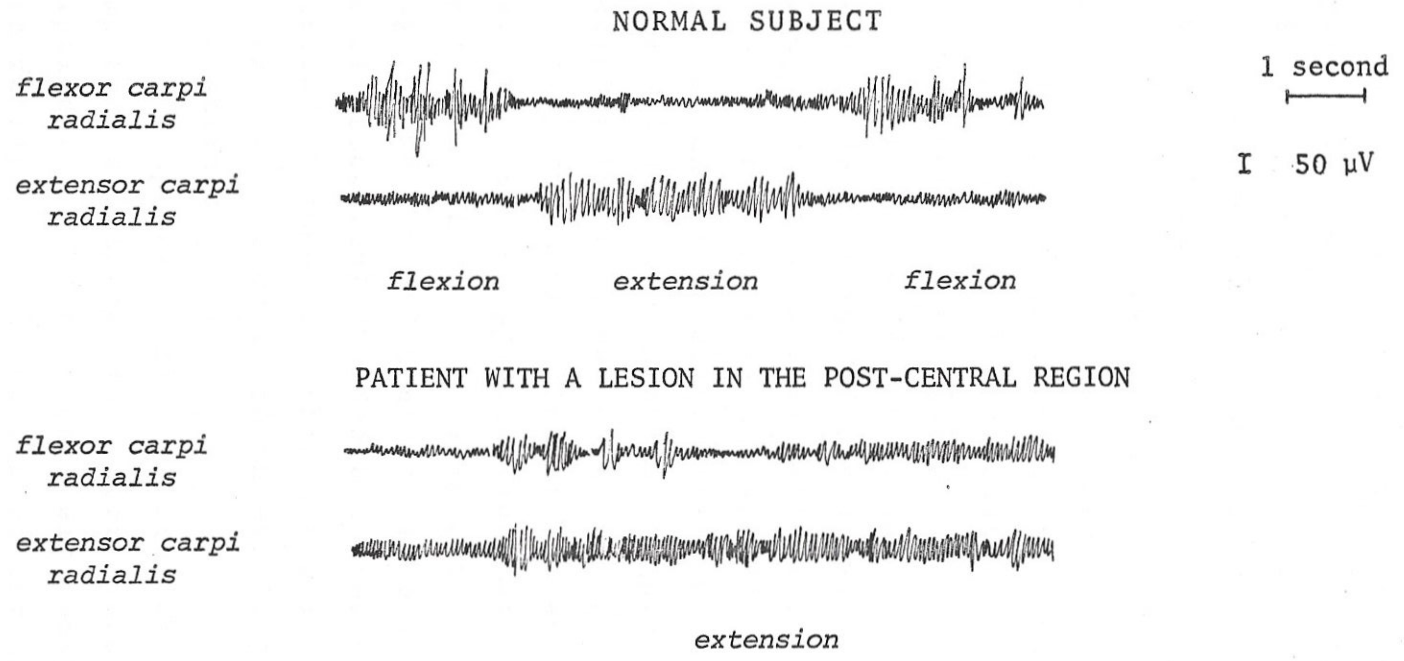


Figure 15. Electromyograms of muscular action involved in flexing and extending the hand (adapted from Luria, 1966:181).

What are the characteristic symptoms associated with lesions that are exclusive to these areas? Luria (1966:187) reports that patients with lesions in the inferior portion of the postcentral region do not generally show anterior aphasia as an isolated syndrome. Rather, they show an incapacity for quick and concentration-free articulation, and "the innervation of articulatory actions has lost its usual selectivity". One result noted by Luria is that the patient has troubles assuming the correct positions of the tongue and lips. This is reminiscent of the first symptom listed by Alajouanine et al. (Chapter I, p.2).

Luria is also one of the few modern writers who attempts a description of exclusive damage to Broca's area. Basing himself on his sizeable investigations of traumatic cases of premotor (Areas 6 and 44) injury, he notes that such patients have difficulties with the concatenation of movements and the inhibition of preceding movements. Articulatorily, in area 44, this results in difficulties in stringing together syllables and words into whole sentences. Successive approximations are the result (Luria 1966:207). This set of symptoms is supported by the findings of Hécaen and Consoli (1973:384ff.). For their sample of precentral and Broca's area patients (predominantly affected by tumours), they noted an articulatory as well as sensory difficulty in integrating linguistic units into whole strings.

It appears that the anterior patients of the present sample have symptoms that correspond to both preceding descriptions. It is thus entirely possible that these patients have fairly generalized damage throughout the motor areas. However, they were selected for the study because in addition to showing the stated symptoms of precentral injury, they also made frequent vowel errors. They appear to be part of a subgroup of anterior patients because of this feature (Trost and Canter 1974:69). Vowel errors of the type reported here could thus be an indication that these patients had a lesion which extended into the postcentral area, since their symptoms match those reported by Luria. Anterior patients without such frequent vowel errors could, according to this reasoning, have lesions that respect this area.

This attempt at localizing the injury of vowel error producing patients raises the question of why two posterior aphasics contributed qualitatively indistinguishable substitutions in their spontaneous speech and repetition tasks (the third posterior patient only made reading errors). A re-examination of the localization data available for these patients is illustrative. Patient TK recovered very rapidly from a left fronto-temporal craniotomy for a large left hemispheric middle cerebral artery aneurism that had formed in the sylvian fissure. He only made 17 paradigmatic vowel substitutions in the first aphasia test which took 45 minutes and was administered five weeks after surgery. A few weeks later, his interviews were devoid of vowel errors. The postcentral inferior parietal cortex could thus still have been affected by post-operative swelling at the time of the first interview.

Patient JR likewise is well-documented. Her angiogram showed left-sided thickening of the arteries, the brain scan registered an area of increased uptake in the left posterior parietal region extending from the periphery toward the midline, and the EEG picked up a prominent focus of slow activity in the left post-frontal area. It would seem that a lesion reaching into the inferior postcentral parietal area from a midparietal focus is a definite possibility.

But whatever the impact of these observations on localization may ultimately prove to be, of much more central interest is the neurological argument presented above. It can lead to a set of productive research hypotheses for further investigation of the motor aspects of aphasia.

To summarize the main points of the argument, first, Mac Neilage and Sholes (1964) showed that in normal subjects, the production of lower vowels required a less selective activation of tongue muscles than in the case of higher vowels. Second, Luria (1966) correlated postcentral injury with a loss of selectivity of muscle activation for alternating movements. And third, the present study demonstrated that wider vocal tract configurations tend to replace narrower configurations. It now follows that research with tongue electromyographs of aphasics with vowel errors should reveal whether the preceding argument has been correct. The hypothesis which follows from the argument would predict that the tongue would be prevented from moving into the full extreme positions required for high vowels through concurrent activation of agonist and antagonist muscles. As a result, electromyography would show high levels of neural activation close to the points of insertion of both types of muscles.

However, alternative hypotheses are also possible. The present results can for instance be interpreted to reflect a weakness of the tongue musculature. Under this hypothesis, the tongue remains in a lower-than-required vocalic position because of insufficient activation of the agonist muscles. If this were the case, reduced levels of innervation to the relevant muscles would be registered by electromyography.

But if neither hypothesis can be supported, the present results would likely have to be considered to be impairments at a more central level of linguistic organization. If that were the case, it would have to be examined which role these substitution tendencies could play in a characterization of internal linguistic processing.

D. Bilingual Patients

So far the discussion has focussed on the main results of unilingual speakers. A small sample of substitutions was collected from two native speakers of French who premorbidly had been excellent speakers of English. Their results were reported separately in Chapter III. They showed a similar tendency towards wider vocal tract constrictions; however, that tendency was compounded by an additional tendency towards fronted vowels. The lowering tendency could again be relegated to a state of partial synkinesis. On the other hand, the fronting tendency possibly had its roots in the patients' bilingualism.

French and French Canadian vowels are known to be further front than their North American English counterparts. To substantiate this commonly-heard statement, Brichler-Labaeye's (1970:250) cineradiograph tracings were compared to those of Perkell (1969:55). After adjustments for differences in the overall sizes of the tracings, Brichler-Labaeye's tongue positions for [ī], [ū], [ɛ] and [a] were an average of 22% further front than Perkell's American English counterparts. The distance measured was the horizontal line between an ordinate, sectioning the dento-alveolar juncture and the tongue at the point of its closest constriction with the palate. Similar measurements of tongue positions were made for the two comparable Canadian French vowels [ɛ] and [a] in Charbonneau (1971:332pp.).

The two vowels were respectively 24% and 8% further front than Perkell's counterparts. All of these measurements, however, are based on the tracings of cineradiographic pictures of the vocal tracts of single speakers. There is considerable variation in the tracings of the vocal tracts of different speakers while the same vowel is articulated, or of different articulations of the same vowel by the same speaker. This argument will thus remain a rather speculative one until larger numbers of tracings from normals and aphasics can be studied. But if further evidence supports the above observations, an argument can be made that bilingual patiens were indeed showing signs of regression to an earlier state of language competence.

E. Substitutions in the Reading Task

Another subsample of substitutions was collected from four unilingual English-speaking aphasics on a reading task. The purpose of collecting this sample was to investigate if the substitution tendencies in this task were congruent with those from the other tasks. The implication was that if that was the case, a neuromuscular account of peripheral motor action in articulation would then also account for the aberrant behaviour on the visuo-motor task of reading. In other words, if all the results in reading fell into the same categories as those collected from other articulation tasks, brain processes associated with the visual capacity could then be considered to be unaffected by the cerebral injury of the present group of aphasics. The results from this task were therefore reported separately throughout Chapter III.

The findings were intriguing. On unstressed vowels, the pattern followed closely that of the spontaneous speech and repetition tasks: there was considerable lowering, unrounding and tensing in the vocal tract. But in stressed vowels, no really significant tendencies emerged on the feature analysis, or any other analysis. However, an inspection of the stressed substitutions revealed a great many errors of the type [r̲æ̲dɩkəl] → [re̲ʲdɩkəl] 'ra̲dical', or [mænəǰɩ̲rɪ̄əl] → [mænəǰɛ̲rəkəl] 'manage̲rial'. These are substitution pronunciations which are common variants for the spelled letters that were being attempted. In the first example, for instance, [eʲ] is a common pronunciation of the letter *a*, witness words like *nation, radial* and the like.

One patient who showed a particularly high proportion of this type of error (84%) is RGMS. This patient also differed from the others in another respect. Fully 53% of her vowel substitutions involved incorrect changes in stress placement (e.g. [kə̀nsɩ́st] → [kánsɩ̀st] 'consist'), while only a single error of this type was noted among the remaining three patients. Both of the tendencies of this patient were analyzed in depth in terms of the generative phonology framework by Schnitzer (1972). His linguistic account may explain the tendencies in the stressed substitutions of the other patients of this sample as well.

But just as in the case of the bilingual sample, the conclusions reached on the basis of this subsample of substitutions must remain very tentative. It is possible that unstressed vowel substitutions can be accounted for solely in terms of the main neuromuscular hypothesis sketched above. In the stressed condition however, the patients' visual associations with spelling variants could have interfered with their choice of the correct vowels to be articulated. If this was the case, those reading substitutions fall outside the narrow neuromuscular hypothesis advanced above, and may have to be subsumed by a larger hypothesis which can account for interactions between visual processing and the neuromuscular processes of articulation.

F. Summary

Neural activation is selective for particular extrinsic tongue muscles with high vowels, and more generalized for lower vowels. The tendency towards wider constriction levels in the vowels and substitutions of the aphasics of this study has thus been interpreted as a loss in the selectivity of neural activation. This concept can also account for the observed tendency towards unrounding and tensing. Loss of selectivity of neural activation is a common result of lesions in the postcentral cortex. This finding leads to the speculation that patients with frequent vowel substitutions have lesions that extend into the postcentral cortex, while those who do not, have lesions which respect this area. The vowel deficits of bilinguals appear to be compounded by tendencies of regression towards an earlier state of language competence. Reading errors on stressed vowels show signs of interference from the patients' visual associations with spelling pronunciation variants.

APPENDIX I

T-SCORES FOR STANDARDIZED SUBGROUPS OF THE WESTERN APHASIA BATTERY (WAB)

		FLUENCY	COMPRH.	REPET.	NAMING	INFORM.	MEAN
ANTERIOR PATIENTS	AB	(56.3)	(62.8)	(62.4)	(67.3)	(68.8)	(63.52)
	AW	62.7	64.8	61.8	66.4	65.6	64.26
	BW	46.0	57.2	51.8	55.2	59.4	53.92
	DH	32.7	51.4	46.6	50.0	37.5	43.64
	EL	52.7	63.1	62.4	66.7	65.6	62.10
	GP	39.3	54.4	55.3	48.5	46.9	48.88
	ID	32.7	56.2	36.8	42.7	40.6	41.80
POSTERIOR PATIENTS	JR	66.0	63.8	59.5	65.8	68.8	64.78
	RGMS	(66.0)	(64.8)	(62.4)	(68.5)	(68.8)	(66.10)
	TK	59.3	58.3	54.2	56.1	65.6	58.70
Anterior patients		46.06	58.56	53.87	56.69	54.91	54.02
Posterior patients		63.77	62.30	58.70	63.47	67.73	63.19
All patients		51.37	59.68	55.32	58.72	58.76	56.77

Notes: 1) These T-scores have a mean of 50 and a standard deviation of 10; standardized for a population of 150 aphasics (Kertesz and Poole 1974).

2) Bracketed figures were obtained by rescoring (cf. Chapter II, p. 16).

3) COMPR. = comprehension; REPET. = repetition; INFORM. = amount of information conveyed by spontaneous speech.

APHASIC RUNNING SPEECH SAMPLE

ANTERIOR PATIENTS

```
AB
   9__                                           9__WHY DON'T YOU TELL ME THE
                                                 STORY OF MADAM BUTTERFLY?
00 3__*OW BOY, Y|ES, AY K|UHD+NT, AY             3__*OH BOY, YES, I COULDN'T, I
   K|UHD+N, AY K|EHN, AY KEN, <DHE, DH+>         COULDN'T, I CAN, I CAN, <THE>
15 <MA?M, MM@HM, *MM|@NIM, M|@NIM>,              *<MADAM>,
   SHIY H|@HD <DH+, DH+, DH+> B|EYBIY            SHE HAD <THE> BABY
30 @HND, +H, SHIY AD|OHLT+D*...                  AND, UH, SHE ADOPTED*...
   9__                                           9__ADOPTED...
   3__NOW?, YES, FOR W|AHN, @N DH|IS             3__NO, YES, FOR ONE, AND THIS
   <MA?, M|ADH+H>, SH|IY, |OW BOY, <YUW?,        <MOTHER>, SHE, OH BOY, <YOU>
45 YUW> NOW, YUW NOW*, DH|IS IS MM...            KNOW, YOU KNOW*, THIS IS HMM...
   <|OHL DH+ B?, DH+ WO?, DH+, ?+,               <ALL THE
   AY, LAY?, |OHL DH+? W|AYIL> DH@T              WHILE> THAT
60 <DH+ *GOW?, DH+? RIH, DH+ B|EYBIY Z           <THE BABY IS *GROWING>
   DH+ B|EYBIY IZ ROW?WOWRINGY+>
75 AP, *DHIS, HM? <?IY, H?, HIY> T|EL M+...      UP, *THIS, HMM <HE> TELLS HER...
90 NOW, NOW @N <|ENIYDEY, *|ENIYDEY>...          NO, NO AND <ANYWAY>*...

AW
00 1__*+, AY <(M+?) WIL (M-MUY, M|EYK)>          1__*UH, I <WILL MAKE>
   N|OWTS @N DHEN D|IKTEYT F+R DHIY?,            NOTES AND THEN DICTATE FOR THE,
   FOR DHIY <?, PR+PR, A, A, PRIY, E,            FOR THE
15 PRIY, +NOW, *RIYP|OHRTS> +N THINGS            <*REPORTS> AND THINGS
   LAYK DH|@T.                                   LIKE THAT.
   +N DHEN N|AW AY K@NT D|UW DH@HT @N            AN' THEN NOW I CAN'T DO THAT AND
   <WEN AY, W+ A POYN, AY R|AYT>, AY,            <WHEN I WRITE>, I,
   ?+, AY @HM V|+RIY SL|OW @N AY KEN D|UW        UH, I AM VERY SLOW AND I CAN DO
   DH@T F- M|EYBIY FOR T|UW AW+RZ +N DHEN        THAT F- MAYBE FOR TWO HOURS AND THEN
30 *AY GET, AY DES|INTRITREYT.                   *I GET, I DISINTEGRATE.
   2__                                           2__YOU DISINTEGRATE?
   1__YEHS.                                      1__YES.
   2__                                           2__YOU WANNA SAY THAT?
   1__AY...                                      1__I...
   2__                                           2__DIS...
   1__<(?IZINT), +, (DIS|INT+RGREYT)>.           1__<DISINTEGRATE>.
   2__                                           2__GOOD.
45 1__@ND + DHEN AY K@HN *R|AYT +                1__AND UH THEN I CAN'T *WRITE UH
   W|EHL DH|EN.                                  WELL THEN.
   2__                                           2__UHUH. RIGHT.
   1__IF AY RIYD AWT L|AWD, +H, AY GGET          1__IF I READ OUT LOUD, UH, I GET
   T|AY+RD V|+RIY F@HST...                       TIRED VERY FAST..
```

	2__	2__RIGHT. I SEE.
60	1__...BAT + IN DH? *|IYV+NIK,	1__..BUT UH IN THE *EVENING,
	IF AY RIYD SL|AYL+NTLIY, AY K@NT	IF I READ SILENTLY, I CAN'T
	RIYD V|+RIY L|OHNG. MAY |AYZ WOWNT	READ VERY LONG. MY EYES WON'T
	D|UW +T.	DO IT.
	2__	2__I SEE.
	1__ A?+ <?EH, +, ITS> N|AHT DH+ AYZ	1__UH <IT'S> NOT THE EYES
75	BIYK+Z +H* <(AYT), +, (AY)> W|ENT TUW	BECAUSE UH* <I> WENT TO
	DHIY +, +, SP|ESH+LAYST <+, +G|EN>	THE UH, UH SPECIALIST <AGAIN>
	FOR DHIY |AYZ. @HND + WIY +? H|@HV	FOR THE EYES. AND UH WE UH HAVE
	NUW GL|@HSIZ + NAW T|UW...	NEW GLASSES UH NOW TOO...
	2__	2__UHUH..
90	1__EN DH|@TS*...	1__AND THAT'S*...
RW 00	2__*	2__ *HOW ARE YOU FEELING TODAY?
	4__ F|AYN.	4__ FINE.
	2__	2__OKAY. UH, HAVE I TESTED
		YOU BEFORE?
	4__Y|A?.	4__YEAH.
	...	...
15	2__*	2__UHUH. AND *WHAT IS YOUR ADDRESS?
	4__W+?, S|ITIYBUK H|@SPIDL.	4__WELL, SUNNYBROOKE HOSPITAL.
	2__	2__UHUH. SUNNYBROOKE HOSPITAL.
		AND WHAT KIND OF WORK DID YOU DO
		BEFORE YOU BECAME ILL?
30	4__+H, *B|AS DRAYV+R	4__UH, *BUS DRIVER.
	2__	2__GOOD, OKAY. UH, CAN YOU TELL ME
		A LITTLE BIT ABOUT WHY YOU'RE HERE?
	4__F|AYV YIYRZ N + H|@HF.	4__FIVE YEARS AND A HALF.
	2__	2__YEAH? WHAT ABOUT FIVE YEARS
		AND A HALF... FIVE YEARS AND A HALF?
	4__Y@?.	4__YEAH.
	2__	2__YOU CAME HERE?
	4__Y@.	4__YEAH.
45	2__*	2__AGO, *AND UH WHY?
	4__T-P|UWS+N +T TUW MANTS, P|UWZ+N	4__BOOZIN' IT TOO MUCH, BOOZIN'
	TUW MAC.	TOO MUCH.
	2__	2__PUSHIN TOO MUCH?
	4__|AHLDI?H|AHLIK.	4__ALCOHOLIC.

60 2__ *
2__*I, I HAVE DIFFICULTIES
UNDERSTANDING.

4__@HM, H|@PIYKH|AHLIK.
2__
4__UHM, ALCOHOLIC.
2__CAN YOU WRITE IT DOWN? OKAY.
... IT'S ALCOHOLIC.

75 4__*Y@?.
4__*YEAH.

2__
2__THAT'S IT. OKAY, NOW I'VE
UNDERSTOOD. I'M SOMETIMES
A BIT SLOW.

90 4__Y@H, B+T, +, N|AYS, Y+ NOW.*
4__YEAH, BUT, UH, NICE, YOU KNOW.*

EL
00 2__*
2__*SO LET ME SEE, SO YOU WERE IN
THE WOMEN'S COLLEGE HOSPITAL?

5__H|AHSPIDL D@HTS...
2__
5__HOSPITAL, THAT'S...
2__RIGHT? AND WAS IT A NICE
HOSPITAL?

5__+Y|@HS, L|AVLIY, AY H@D T|UW
WAN+RF+L D@HTURS @H, B+T AY
15 W+D, +, <BED, B|@DLIY> *|ENJ+RJ.
@HM, DIS, +,
C|IYK+BOWN W+D D+ W|EY D|AWN H|IYR.
5__YES, LOVELY, I HAD TWO
WONDERFUL DOCTORS UH, BUT I
WAS, UH, <BADLY> *INJURED.
UHM, THIS, UH,
CHEEKBONE WAS A WAY DOWN HERE.

2__
5__DI C|IYKBOWN <W+D D+? WOMIN H|IY@H,
30 W+D D+ *W|EY D|AWN H|IYR>...
2__
2__I'M SORRY?
5__THIS CHEEKBONE <WAS A
*WAY DOWN HERE>...
2__YEAH...

5__..@ND, D+, DEY
H@D DUW |AHP+R+HT AP H|IYR,
DAMST IT, Y+ SIY, @H, DEN,
DEN, <NE?, N@ N|EYG> W+T+
45 AHL TW|IST+D @N EY H@D TUW *S|OW
D|@HT |AP...
5__...AND, UH, THEY
HAD TO OPERATE UP HERE,
(DAMAGED) IT, YOU SEE, UH, THEN,
THE, <A LEG> WAS
ALL TWISTED AND THEY HAD TO *SEW
THAT UP...

2__
5__...LEG, Y@H...
2__UH, WHAT WAS? THE LEG?
5__...LEG, YEAH...

2__
5__+N, @N EY H@D TUW
<K, C+, KUW, SHC|OW> |IT |AP
@ND +M, OHL +W|AWND, AY W+Z +
K+MPL|IYT, NOW, AY
60 W+Z + K+MPL|IYT *N|ES.
2__YOUR LEG WAS ALL TWISTED.
5__AND, AND THEY HAD TO
<SEW> IT UP
AND UHM, ALL AROUND, I WAS A
COMPLETE, NO, I
WAS A COMPLETE *MESS.

	2__	2__YOU CAN LAUGH ALL RIGHT.
		OH DEAR. BUT...SO... BUT
		THEY FIXED YOU UP ALL RIGHT?
75	5__DHEY DID, YEZ*.	5__THEY DID, YES*.
	2__	2__OH, YES. WELL, THAT'S GOOD.
		THAT'S GOOD. AND THEN...
	5__@N DHEN, DHEN, DH+? W|AN D|EY WHAN	5__AND THEN, THEN, THE ONE DAY WHEN
	AY WANT <W+?, AWT> <ST|API, SH|OHPING>	I WENT <OUT> <SHOPPING>
	AY W+D |AN M+Y B+Y B|@HK T+	I WAS ON MY WAY BACK TO
90	<D+, DHEYE, Y+?> *...	<THE>* (APARTMENT)...

POSTERIOR PATIENTS

JR		
00	8__*	8__*OKAY, I WANT YOU TO LOOK AT THIS
		PICTURE AND DESCRIBE AS MUCH AS YOU
		CAN ABOUT WHAT'S HAPPENING IN IT.
	6__<A FLOYK, + D|AK>, + LID+L G|+RL, A	6__<A DUCK>, A LITTLE GIRL, A
15	*B|OY, <+ TO, + D|OHG> +H, +H, OW, +H,	*BOY, <A DOG>, UH, UH, OH, UH,
30	+HM, *HM?, J|EY, |ES, |EM, |AY, T|IY,	UHM, *HMM, J. S. M. I. T.
45	|ES, +H <*MOH, MA?, MEYL, M|EY+L> EN,	S., A <*MAIL (BOX)> AND,
	+M, <+? TIY?, TIYR, + TR|IY, + TR|IY>...	UHM, <A TREE>...
	8__	8__GOOD.
60	6__...EN + <ANANA, *AN|ADH+H>	6__...AND UH <*ANOTHER>
	<TAH, T, TA, T> M, HM, <T+?, TIY?, T>.	<TREE> MM, HM, <TREE>.
75	|ENIYWEY, AYNK+*, @N EN + LID+L	ANYWAY, I'M*, AND THEN A LITTLE
	B|OY, +N|ADH+H W|AN, EN +H,	BOY, ANOTHER ONE, AND A,
90	WAT+, *HM...	WHAT, *HM...
TK		
00	8__*	8__NOW, *CAN YOU TELL ME A LITTLE
		BIT ABOUT YOUR TROUBLES?
	7__DY+ WAM MIY T HOWLD DH@T...	D'YOU WANT ME TO HOLD THAT...
	8__	8__I CAN HOLD IT.
	7__WER AY W+Z W|+RKING IN DH+, DH+	7__WHERE I WAS WORKING IN THE, THE
	H|ASPIDL. @FT+R AY J|OYND DHIS +...	HOSPITAL? AFTER I JOINED THIS UH...
	8__	8__HOW DID YOU GET SICK?

7__<DH, DH|@TS> DH+ WAN DH+T +M
T|OHKING +B|AWT.
8__
7__AY W|+RKT, AY GAHT ST|ART+D T+
15 GET S|IK, DHEN* IN TWENIY S|EV+N,
TWENIY |EYT, TWENIY N|AYNTH OV
J|@NYUWERIY. @N W|AN M|ORNING AY W+Z
W|+RKING +T S|IKS TH|+RDY IN DH+
M|ORNIN @N AY WAZ, AY FELT <(HO?),
+, (H|OR+B+L)> RAYT AP +NT+L |EYT
+KL|OK IN DH+ M|ORNIN DH@T TAYM,
30 *SOW AY TOWLD
+M, AY SED, +?, DH+ WEY AY F|IYL,
AHL H@F TU GOW H|OWM, SOW WEN AY GAT
H|OWM, AY J+ST C|EYNJD,
T|OWLD MAY W|AYF
DH@T AY, +, DH+ WEY AY F|ELT @N AY
45 CEYNJD INT+ MAY, +H, MAY B|@THRUWMS*
<SHI, THINGZ> +N AY WENT DH|ER @N AY
JIST K|OHFT W|ANS, @N DH+ F|+RST
TAYM DH@T H|@P+ND
AY GOT AH, S|+MTHING
H|@P+ND FR+M H|IYR AP INT+ DH+ B@HK
+V DH+ H|ED. AN DHIS WAT MEYD
60 MIY F|IYL RAYD +W|EY, *+N DHEN AY
BENT DH|IS WEY +N DHEN AY <HE?, HELD>
AP |@FT+R WIDH MAY ?|ED AP.
IT WAZ D|AB+L. L|UKING THINGZ,
AY KUD S|IY EVRIYTHING D|AB+L.
SOW AY FIG+R, WEL AY BED+R GOW D+
B|ED +N AY TH|OHT, W+L |@FT+R AY WOWK
75 |AP, AYD FIYL BED+R* L|EYD+R.
DH@T WAZ F+R + <T+, FR|AYDIY>,
S|@D+RDIY AN THR|IY KW|ORD+RZ OV
<S|@N+, S@H>, T|UWSDIY, @V <S|ANDIY>
AN DHEN AY FELT, WEL AYV GOD+ GOW
90 T+M|OR+, M|ANDIY*...

WHAT HAPPENED?
7__<THAT'S> THE ONE THAT I'M
TALKING ABOUT.
8__HMHMM.
I WORKED, I GOT STARTED TO
GET SICK, THEN* IN TWENTY SEVENTH,
TWENTY EIGTH, TWENTY NINTH OF
JANUARY. AND ONE MORINING I WAS
WORKING AT SIX THIRTY IN THE
MORNING AND I WAS, I FELT
<HORRIBLE> RIGHT UP UNTIL EIGHT
O'CLOCK IN THE MORNING THAT TIME,
*SO I TOLD
THEM, I SAID, UH, THE WAY I FEEL,
I'LL HAVE TO GO HOME, SO WHEN I GOT
HOME, I JUST CHANGED,
TOLD MY WIFE
THAT I, UH, THE WAY I FELT AND I
CHANGED INTO MY, UH, MY BATHROOM*
<THINGS> AND I WENT THERE AND I
JUST COUGHED ONCE, AND THE FIRST
TIME THAT HAPPENED
I GOT A, SOMETHING
HAPPENED FROM HERE UP INTO THE BACK
OF THE HEAD. AND THAT'S WHAT MADE
ME FEEL RIGHT AWAY. *AND THEN I
BENT THIS WAY AND THEN I <HELD>
UP AFTER WITH MY HEAD UP.
IT WAS DOUBLE. LOOKING (AT) THINGS,
I COULD SEE EVERYTHING DOUBLE.
SO I FIGURE, WELL I BETTER GO TO
BED AND I THOUGHT, WELL AFTER I WOKE
UP, I'D FEEL BETTER* LATER.
THAT WAS FOR UH <FRIDAY>,
SATURDAY AND THREE QUARTERS OF
<SUNDAY>, TUESDAY, OF <SUNDAY>
AND THEN I FELT, WELL I'VE GOTTA GO
TOMORROW, MONDAY*...

APPENDIX III

VOWEL NUCLEI FREQUENCIES IN THE NORMAL RUNNING SPEECH SAMPLE

	STRESSED		UNSTRESSED		TOTAL	
	N	%	N	%	N	%
[ī]	65	13.3	146	12.1	211	12.5
[ι]	70	14.3	218	18.1	288	17.0
[e$^{\iota}$]	49	10.0	33	2.7	82	4.9
[ε]	58	11.9	53	4.4	111	6.6
[æ]	53	10.9	70	5.8	123	7.3
[ə]	24	4.9	425	35.4	449	26.6
[ū]	25	5.1	35	2.9	60	3.6
[υ]	11	2.3	45	3.7	56	3.3
[o^{u}]	31	6.4	104	8.7	135	8.0
[ɔ]	27	5.5	18	1.5	45	2.7
[a]	75	15.4	55	4.6	130	7.7
TOTAL	488	100	1202	100	1690	100

APPENDIX IV

DISAGREEMENTS BETWEEN THE FINAL PRINT-OUT OF THE VOWEL ERROR SAMPLE AND A RETRANSCRIPTION*

	[ī]	[e^{ι}]	[ι]	[ε]	[æ]	[ə]	[a]	[ʊ]	[ɔ]	[ū]	[o^{u}]	TOTAL
[ī]	39	1	4									44
[e^{ι}]		12		2								14
[ι]	2	1	13	2		1					1	20
[ε]		1	6	30	2	1						40
[æ]				1	26							27
[ə]			6	2	1	57	1			1	3	71
[a]					2	4	40		1			47
[ʊ]								2		3	1	6
[ɔ]								3	2		1	6
[ū]								1		18		19
[o^{u}]			1			1	1		2		24	29
TOTAL	41	15	30	37	31	64	42	6	5	22	30	323

**Both target and substitution sounds were sampled.*
Note: Sounds are arranged according to the front-back axis ($Formant_2$) of aphasics (Table 8, p. 45).

APPENDIX V

TABLE 1: VOWEL SUBSTITUTIONS OF UNILINGUALS IN SPONTANEOUS SPEECH AND REPETITION (STRESSED VOWELS)

TARGET	SUBSTITUTION											
	[ī]	[ū]	[ʊ]	[ɩ]	[o^{u}]	[e$^{\iota}$]	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
[ī]		2 *0.338*	2 *0.338*	8 *1.352*	2 *0.338*	7 *1.183*	6 *1.014*	2 *0.338*	10 *1.690*	2 *0.338*	4 *0.676*	45 *7.605*
[ū]	5 *2.200*		10 *4.400*	2 *0.880*	10 *4.400*		2 *0.880*	1 *0.440*			5 *2.200*	35 *15.400*
[ʊ]		2 *2.000*		2 *2.000*	3 *3.000*		2 *2.000*	3 *3.000*				12 *12.000*
[ɩ]	7 *1.099*		1 *0.157*			6 *0.942*	12 *1.884*	5 *0.785*	25 *3.925*	3 *0.471*	8 *1.256*	67 *10.519*
[o^{u}]	1 *0.354*	3 *1.062*		2 *0.708*			10 *3.540*	15 *5.310*	1 *0.354*	2 *0.708*	6 *2.124*	40 *14.160*
[e$^{\iota}$]	6 *1.344*	1 *0.224*	2 *0.448*	4 *0.896*	1 *0.224*		3 *0.672*	4 *0.896*	5 *1.120*		2 *0.448*	28 *6.272*
[ə]	6 *2.748*	1 *0.458*	3 *1.374*	5 *2.290*	6 *2.748*	3 *1.374*		9 *4.122*	6 *2.748*	2 *0.916*	6 *2.748*	47 *21.526*
[ɔ]	2 *0.814*				1 *0.407*						6 *2.442*	9 *3.663*
[ɛ]	1 *0.190*		2 *0.380*	1 *0.190*		2 *0.380*	16 *3.040*	6 *1.140*		20 *3.800*	23 *4.370*	71 *13.490*
[æ]	2 *0.414*			3 *0.621*	2 *0.414*	2 *0.414*	9 *1.863*	2 *0.414*	7 *1.449*		28 *5.796*	55 *11.385*
[a]	3 *0.441*			4 *0.588*	1 *0.147*	1 *0.147*	2 *0.294*	5 *0.735*	4 *0.588*	4 *0.588*		24 *3.528*
TOTAL	33 *9.604*	9 *4.082*	20 *7.097*	31 *9.525*	26 *11.678*	21 *4.440*	62 *15.187*	52 *17.180*	58 *11.874*	33 *6.821*	88 *22.060*	433 *119.548*

TABLE 2: VOWEL SUBSTITUTIONS OF UNILINGUALS IN SPONTANEOUS SPEECH AND REPETITION (UNSTRESSED VOWELS)

TARGET	SUBSTITUTION											
	[ī]	[ū]	[ʊ]	[ɩ]	$[o^{u}]$	$[e^{\iota}]$	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
[ī]		4 *0.492*		9 *1.107*		4 *0.492*	12 *1.476*		5 *0.615*		1 *0.123*	35 *4.305*
[ū]				1 *0.514*		1 *0.514*	5 *2.570*				1 *0.514*	8 *4.112*
[ʊ]		1 *0.400*			1 *0.400*		1 *0.400*			1 *0.400*	1 *0.400*	5 *2.000*
[ɩ]	4 *0.332*		2 *0.166*			6 *0.498*	26 *2.158*	5 *0.415*	20 *1.660*	1 *0.083*	23 *1.909*	87 *7.221*
$[o^{u}]$	1 *0.173*	1 *0.173*	1 *0.173*	2 *0.346*		1 *0.173*	11 *1.903*	2 *0.346*	1 *0.173*	1 *0.173*	6 *1.038*	27 *4.671*
$[e^{\iota}]$	4 *2.180*		2 *1.090*	1 *0.545*			1 *0.545*		2 *1.090*		3 *1.635*	13 *7.085*
[ə]	14 *0.588*	3 *0.126*	1 *0.042*	28 *1.176*	8 *0.336*	6 *0.252*		6 *0.252*	19 *0.798*	9 *0.378*	34 *1.428*	128 *5.376*
[ɔ]				1 *1.000*	2 *2.000*	1 *1.000*	1 *1.000*		1 *1.000*	3 *3.000*	5 *5.000*	14 *14.000*
[ɛ]				2 *0.680*			5 *1.700*	3 *1.020*		2 *0.680*	4 *1.360*	16 *5.440*
[æ]	2 *0.514*	1 *0.257*		3 *0.771*			1 *0.257*		3 *0.771*		8 *2.056*	18 *4.626*
[a]				1 *0.327*			2 *0.654*		1 *0.327*	1 *0.327*		5 *1.635*
TOTAL	25 *3.787*	10 *1.448*	6 *1.471*	48 *6.466*	11 *2.736*	19 *2.929*	65 *12.663*	16 *2.033*	52 *6.434*	18 *5.041*	86 *15.463*	356 *60.471*

TABLE 3: VOWEL SUBSTITUTIONS OF UNILINGUALS IN READING (STRESSED VOWELS)

		SUBSTITUTION											
		[ī]	[ū]	[ʊ]	[ɩ]	[oᵘ]	[eᶥ]	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
TARGET	[ī]				2 *0.338*		1 *0.169*			5 *0.845*			8 *1.352*
	[ū]			1 *0.440*								1 *0.440*	2 *0.880*
	[ʊ]												0 *0.000*
	[ɩ]						2 *0.314*			3 *0.471*			5 *0.785*
	[oᵘ]	1 *0.354*							1 *0.354*	1 *0.354*		1 *0.354*	4 *1.416*
	[eᶥ]	3 *0.672*									3 *0.672*		6 *1.344*
	[ə]	4 *1.832*	1 *0.458*		3 *1.374*		1 *0.458*				1 *0.458*		10 *4.580*
	[ɔ]										1 *0.407*		1 *0.407*
	[ɛ]	3 *0.570*			1 *0.190*		1 *0.190*		1 *0.190*		2 *0.380*	2 *0.380*	10 *1.900*
	[æ]	1 *0.207*			2 *0.414*	1 *0.207*	3 *0.621*		1 *0.207*	1 *0.207*		5 *1.035*	14 *2.898*
	[a]		2 *0.294*	2 *0.294*	1 *0.147*	6 *0.882*				1 *0.147*			12 *1.764*
TOTAL		12 *3.635*	3 *0.752*	3 *0.734*	9 *2.463*	7 *1.089*	8 *1.752*	0 *0.000*	3 *0.751*	11 *2.024*	7 *1.917*	9 *2.209*	72 *17.326*

TABLE 4: VOWEL SUBSTITUTIONS OF UNILINGUALS IN READING (UNSTRESSED VOWELS)

	SUBSTITUTION											
TARGET	[ī]	[ū]	[ʊ]	[ɩ]	[o^{u}]	[e^{ɩ}]	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
[ī]				6 *0.738*			1 *0.123*	1 *0.123*	1 *0.123*	1 *0.123*	5 *0.615*	15 *1.845*
[ū]	1 *0.514*				1 *0.514*		1 *0.514*				3 *1.542*	6 *3.084*
[ʊ]	2 *0.800*							1 *0.400*			1 *0.400*	4 *1.600*
[ɩ]	7 *0.581*	1 *0.083*				1 *0.083*	10 *0.830*	1 *0.083*	4 *0.332*	3 *0.249*	9 *0.747*	36 *2.988*
[o^{u}]											2 *0.346*	2 *0.346*
[e^{ɩ}]	1 *0.545*						1 *0.545*					2 *1.090*
[ə]	6 *0.252*	1 *0.042*	2 *0.084*	9 *0.378*	7 *0.294*	2 *0.084*		3 *0.126*	5 *0.210*	7 *0.294*	34 *1.428*	76 *3.192*
[ɔ]											2 *2.000*	2 *2.000*
[ɛ]	3 *1.020*						1 *0.340*	1 *0.340*			1 *0.340*	6 *2.040*
[æ]				1 *0.257*			2 *0.514*	1 *0.257*			3 *0.771*	7 *1.799*
[a]		1 *0.327*			1 *0.327*							2 *0.654*
TOTAL	20 *3.712*	3 *0.452*	2 *0.084*	16 *1.373*	9 *1.135*	3 *0.167*	16 *2.866*	8 *1.329*	10 *0.665*	11 *0.666*	60 *8.189*	158 *20.638*

TABLE 5: VOWEL SUBSTITUTIONS OF BILINGUALS IN SPONTANEOUS SPEECH AND REPETITION (STRESSED VOWELS)

		SUBSTITUTION											
		[ī]	[ū]	[ʊ]	[ɩ]	$[o^{u}]$	$[e^{\iota}]$	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
TARGET	[ī]		1 *0.169*		3 *0.507*	1 *0.169*	3 *0.507*	1 *0.169*	1 *0.169*	4 *0.676*		1 *0.169*	15 *2.535*
	[ū]	4 *1.760*		3 *1.320*	1 *0.440*	1 *0.440*			1 *0.440*	1 *0.440*			11 *4.840*
	[ʊ]	2 *2.000*			1 *1.000*	1 *1.000*		2 *2.000*				1 *1.000*	7 *7.000*
	[ɩ]	5 *0.785*	2 *0.314*	1 *0.157*		1 *0.157*	5 *0.785*	5 *0.785*	2 *0.314*	6 *0.942*		2 *0.314*	29 *4.553*
	$[o^{u}]$	1 *0.354*	2 *0.708*	1 *0.354*			1 *0.354*	2 *0.708*	2 *0.708*	1 *0.354*	1 *0.354*		11 *3.894*
	$[e^{\iota}]$				1 *0.224*	1 *0.224*		3 *0.672*	1 *0.224*	3 *0.672*		2 *0.448*	11 *2.464*
	[ə]	1 *0.458*	2 *0.916*	2 *0.916*		4 *1.832*	1 *0.458*		4 *1.832*	4 *1.832*	1 *0.458*	2 *0.916*	21 *9.618*
	[ɔ]	4 *1.628*	1 *0.407*	1 *0.407*	2 *0.814*	3 *1.221*	1 *0.407*	2 *0.814*		1 *0.407*	1 *0.407*	2 *0.814*	18 *7.326*
	[ɛ]	4 *0.760*	1 *0.190*	1 *0.190*	3 *0.570*		4 *0.760*	2 *0.380*	1 *0.190*		1 *0.190*	6 *1.140*	23 *4.370*
	[æ]	2 *0.414*		1 *0.207*	2 *0.414*	3 *0.621*	3 *0.621*	2 *0.414*		6 *1.242*		8 *1.656*	27 *5.589*
	[a]	2 *0.294*	1 *0.147*	1 *0.147*	1 *0.147*	5 *0.735*	1 *0.147*	7 *1.029*	6 *0.882*	7 *1.029*	3 *0.441*		34 *4.998*
TOTAL		25 *8.453*	10 *2.851*	11 *3.698*	14 *4.116*	20 *6.399*	19 *4.039*	26 *6.971*	18 *4.759*	33 *7.594*	7 *1.850*	24 *6.457*	207 *57.187*

TABLE 6: VOWEL SUBSTITUTIONS OF BILINGUALS IN SPONTANEOUS SPEECH AND REPETITION (UNSTRESSED VOWELS)

		SUBSTITUTION											
		[ī]	[ū]	[ʊ]	[ɩ]	[o^u]	[$e^ɩ$]	[ə]	[ɔ]	[ɛ]	[æ]	[a]	TOTAL
TARGET	[ī]				2 *0.246*		2 *0.246*	3 *0.369*	1 *0.123*				8 *0.984*
	[ū]	2 *1.028*		3 *1.542*	2 *1.028*		1 *0.514*	3 *1.542*					11 *5.654*
	[ʊ]				2 *0.800*	1 *0.400*		3 *1.200*		2 *0.800*			8 *3.200*
	[ɩ]	2 *0.166*				1 *0.083*		1 *0.083*		4 *0.332*			8 *0.664*
	[o^u]	1 *0.173*	1 *0.173*	2 *0.346*				3 *0.519*			1 *0.173*		8 *1.384*
	[$e^ɩ$]												0 *0.000*
	[ə]	7 *0.294*	2 *0.084*	1 *0.042*	5 *0.210*	3 *0.126*	1 *0.042*		2 *0.084*	10 *0.420*	1 *0.042*	1 *0.042*	33 *1.386*
	[ɔ]											1 *1.000*	1 *1.000*
	[ɛ]				2 *0.680*				1 *0.340*				3 *1.020*
	[æ]						1 *0.257*	1 *0.257*		2 *0.514*			4 *1.028*
	[a]				1 *0.327*			2 *0.654*		2 *0.654*			5 *1.635*
	TOTAL	12 *1.661*	3 *0.257*	6 *1.930*	14 *3.291*	5 *0.609*	5 *1.059*	16 *4.624*	4 *0.547*	20 *2.720*	2 *0.215*	2 *1.042*	89 *17.955*

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GLOSSARY AND ABBREVIATIONS

afferent conveying (e.g. neural impulses) toward a nerve centre: *afferent pathways*

aneurism or aneurysm a sac formed through the dilation of a blood vessel as a result of internal pressure and a diseased vessel wall

angiogram an X-ray photograph showing the size and location of the arteries and veins

anomia a loss in the ability to recall the names of items or concepts

anterior aphasias a group of syndromes thought to result from lesions in the irrigation area of the upper division of the middle cerebral artery -*also* expressive aphasia, *sometimes* motor aphasia

apraxia a disorder of purposeful non-verbal behaviour

approximation see *successive approximation*

arteriogram an X-ray photograph showing the size and location of the arteries

ataxic aphasia see *motor aphasia*

BACK a distinctive feature used in generative phonology, specifying a retraction of the body of the tongue from its most relaxed position -*ant.* NONBACK

band in acoustic spectrography, a typical range of frequencies scanned for the presence of acoustic signals; in this study, wide band was 300 Hz and narrow band was 45 Hz.

barium paste a paste containing barium sulfate, used as a contrast medium in X-ray photography

Broca's aphasia an anterior aphasia thought to be due to a lesion focussing in Broca's area and marked by a deficit in fluency of verbal output

Broca's area [*P.P. Broca*, French surgeon, 1824-1880] the third frontal convolution of the brain (Brodmann's area 44, *cf.* Figure 14, p.88), involved in premotor processing of articulation -*cf. premotor cortex*

Brodmann's areas [*K. Brodmann*, German neurologist, 1868-1918] areas of cytoarchitectonically homogeneous brain tissue, identified by numbers

carotid artery the main ascending artery that supplies blood to the head -*specifically* internal carotid artery or arteria carotis interna the branch which supplies blood mainly to the brain

cell in statistics, the smallest subdivision of the data for which measurements are collected

cell layers in the cytoarchitecture of the grey matter of the brain, sheets of tissue that show homogeneous structure in neural cells; six layers are usually distinguished, layer I being the closest to the surface.

central fissure see *Rolandic fissure*

chi-square or χ^2 a statistical measure for the difference

GLOSSARY AND ABBREVIATIONS

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central fissure see *Rolandic fissure*

chi-square or χ^2 a statistical measure for the difference between a set of expected and observed values

cineradiography X-ray photography on film

conduction aphasia a posterior aphasia marked by a deficit in repetition

constriction see *oral vocal tract constriction*

correlation in statistics, a relationship between two sets or series, where the member of one is associated with a corresponding member in the other

craniotomy a removal of part of, or incision into, the skull, usually as a preliminary to brain surgery

cytoarchitecture the organization or structure of cells within tissue, especially neural cells in the central nervous system *-adj.* cytoarchitectonic

dento-alveolar juncture the surface on the inside of the oral cavity where the teeth issue from the alveolar process of the maxilla

distinctive feature in phonology, a specification of a sound along one of a number of parameters, such as height, backness, etc.

dysarthria a group of syndromes of motor speech disorders, characterized by imprecise articulation and a number of additional symptoms *-cf.* Darley et al. (1969)

efferent conveying (e.g. neural impulses) away from a nerve centre: *efferent pathways*

electroencephalogram or EEG a recording of the electrical activity of various areas of the brain, measurable at the scalp

electromyography the measuring of neuromuscular electrical activity

embolism the sudden blocking of a blood vessel by a clot or other particle *-adj.* embolic

error in this study, any deviation from the utterance form that is presumably desired by the speaker, including a substitution of a sound, a deletion or an addition

expressive aphasia see *anterior aphasias*

extensor carpi radialis see *flexor carpi radialis*

extrinsic muscles of the tongue those muscles that join the body of the tongue to various skeletal structures, such as the *genioglossus*, the *hyoglossus*, and the *styloglossus* (*cf.* Figure 12, p.82) *-cf. intrinsic muscles of the tongue*

feature see *distinctive feature*

flexor carpi radialis and extensor carpi radialis a pair of muscles responsible for the flexing and extending of the hand at the wrist

formant any of a number of prominent resonance bands determined through a frequency analysis of speech sounds, identified by numbers: *$Formant_1$* *-cf. spectrography* genioglossus or musculus genioglossus see *extrinsic muscles of the tongue*

hematoma a swelling or a tumor containing blood -subdural hematoma, such a swelling below the dura mater

hemianopia or hemianopsia a loss of visual capacity in half of the visual field; in the case of cortical origin, usually due to a unilateral lesion in the contralateral occipital lobe

hemiplegia paralysis on one side of the body; in the case of cortical origin, usually due to a unilateral lesion in the posterior portion of the contralateral frontal lobe

HIGH a distinctive feature used in generative phonology, specifying a raising of the body of the tongue above a midposition -*ant.* NONHIGH

homorganic in phonetics, produced with the same oral vocal tract configuration: [t] *is an anterior stop and* [n] *its homorganic nasal.*

hyoglossus or musculus hyoglossus see *extrinsic muscles of the tongue*

infarct a condition of insufficient blood supply; in the case of a cerebral infarct, such a condition causes a neural deficit in the area of irrigation of the deficient artery.

insult any attack or injury to the body

intrinsic muscles of the tongue muscles that serve to bunch the tongue body, or curl, twist, deflect and shorten it; they are situated within the tongue body. -*cf. extrinsic muscles of the tongue*

LOW a distinctive feature used in generative phonology, specifying a lowering of the body of the tongue below a midposition -*ant.* NONLOW

lowering see *oral vocal tract constriction*

markedness in linguistics, a specification of which aspects are more overtly signalled than others; for instance, the [ž] sound in 'measure' is very infrequent in English and acquired late in life. It is thus said to be a marked sound, while [a] does not stand out in such a way and is thus said to be unmarked, or less marked.

marking in linguistics, a change towards a more marked, or the marked, condition -*cf. markedness*

middle cerebral artery or arteria cerebri media a branch of the cerebral artery that supplies blood mainly to the frontal, parietal and temporal lobes of the brain; typical branches: upper and lower division temporal branch (*cf.* Figure 1, p.6)

monopitch a loss in variation of the intonational contour

motor aphasia an anterior aphasia, particularly one marked by articulatory deficits -*also* oral verbal apraxia, verbal apraxia, ataxic aphasia

motor-sensory cortex a band of cytoarchitectonically homogeneous neural tissue that lies anterior to the Rolandic fissure and contains cells that effect movement (Brodmann's area 4, Figure 14, p.88) -*also* precentral cortex

opening see *oral vocal tract constriction*

oral verbal apraxia see *motor aphasia*

oral vocal tract constriction in this study, the closest distance between the body of the tongue and the palate; usually, widening this distance involves lowering the tongue.

orbicularis oris muscle or orbicular muscle of the mouth a muscle encircling the mouth that rounds and protrudes the lips.

palatoglossus muscle or musculus palatoglossus a muscle between the sides of the tongue and the soft palate, forming the fauces; it may aid in elevating the tongue by constricting the fauces.

paradigmatic error in this study, an error which is most easily analyzed as a substitution that has not been subjected to obvious influences from preceding or succeeding sounds.

Pearson product-moment correlation coefficient or Pearson *r* [*K. Pearson,* British mathematician, 1857-1936] a statistical measure for the degree of correlation found in two series that show measurable degrees of the attribute(s) to be tested

postcentral articulatory area a section at the foot of the sensory-motor cortex most immediately concerned with proprioception from the oral vocal tract

posterior aphasias a group of syndromes thought to result from lesions in the irrigation area of the lower division of the middle cerebral artery -*also* receptive aphasia, sensory aphasia

precentral articulatory area a section at the foot of the motor-sensory cortex most immediately concerned with articulation

premorbid occurring before insult

premotor cortex a band of cytoarchitectonically similar neural tissue that lies anterior to the motor-sensory cortex and contains cells that are probably concerned with the integration and organization of movement (Brodmann's areas 6 and 44, Figure 14, p.88) -*cf. Broca's area*

proprioceptive feedback or proprioception information concerning the movements and position of various parts of the body.

pseudobulbar palsy a paralytic condition affecting facial muscles and control over vocal tract organs, thought to be due to a lesion of pyramidal motor cells.

pyramidal cells large pyramid-shaped neural cells

receptive aphasia see *posterior aphasias*

REDUCTION in generative phonology, a rule which substitutes a mid-central vowel for other vowels under specified conditions, including lack of stress

risorius muscle or musculus risorius a muscle that spreads the lips and moves the angle of the mouth laterally

Rolandic or central fissure or sulcus centralis [*L. Rolando* Italian anatomist, 1773-1831] a groove marking the boundary between the frontal and parietal lobes of the brain, extending from the top of the brain to the lateral midline -*cf.* Figure 14, p.88

ROUND a distinctive feature used in generative phonology, specifying a narrowing of the lip opening -*ant.* NONROUND

section or cross-section in spectrography, a display of the amplitudes at various frequencies at a particular point in time

segmental in phonology, concerned with small constituent parts of an utterance such as sounds and features -*ant.* suprasegmental extending over several such constituent parts, such as an intonation contour

sensory aphasia see *posterior aphasias*

sensory-motor cortex a band of cytoarchitectonically similar neural tissue that lies posterior to the Rolandic fissure and contains cells that register proprioceptive information (Brodmann's areas 3, 1, 2 and 5, Figure 14, p. 88) -*also* postcentral cortex

sonograph see *spectrography*

Spearman rank correlation coefficient or Spearman *r* [*C. Spearman*, British psychologist, 1863-1945] a statistical measure for the degree of correlation found in two series that can be ranked according to the attribute(s) to be tested

spectrography in acoustic phonetics, a method for dispersing the sound wave into a spectrum of acoustic frequencies, usually by means of a device called sonograph

speech range estender a device that slows down speech by inserting white noise into the speech signal at very rapid intervals

stress in linguistics, intensity of utterance given to a speech sound

styloglossus or musculus styloglossus see *extrinsic muscles of the tongue*

substitution in this study, an error that involves substituting a sound for a presumably desired target sound

successive approximation *(French: conduite d'approche)* a series of attempts, or approximations, made by an aphasic patient to articulate a desired utterance target

supramarginal gyrus or gyrus supramarginalis a convolution of the brain that curves around the posterior end of the sylvian fissure

sylvian fussure or sulcus lateralis cerebri [*F. de la Boe (Sylvius)*, French anatomist, 1614-1672, or *Jacobus Sylvius*, French anatomist, 1478-1555] a cleft separating the temporal and frontal lobes of the brain and extending posteriorly to the juncture of the temporal and parietal lobes -*cf.* Figure 14, p. 88

synkinesis an unintentional movement accompanying a volitional movement

syntagmatic error within this study, an error which is most easily analyzed within the context of influence from preceding or succeeding sounds

target in this study, the utterance form that is presumably desired by the speaker

TENSE a distinctive feature used in generative phonology, specifying a deliberate, accurate and maximally distinct gesture involving considerable muscular effort -*ant.* NONTENSE (LAX)

triangularis muscle or musculus depressor anguli oris a muscle that spreads the lips and pulls the angle of the mouth downward and sideways

unmarking in linguistics, a change towards a less marked, or the unmarked, condition -*cf. markedness*

verbal apraxia see *motor aphasia*

Wernicke's aphasia a posterior aphasia thought to be due to a lesion focussing in Wernicke's area and marked by a deficit in comprehension

Wernicke's area [*K. Wernicke*, German neurologist, 1848-1905] the superior temporal gyrus of the brain (Brodmann's area 22, *cf.* Figure 14, p.88), involved in auditory processing

α	a symbol in statistics; see Glass and Stanley. 1970. P.281.
ant.	antonym
χ^2	chi-square
CVA	cardiovascular accident
CVC	consonant-vowel-consonant
EEG	electroencephalogram
F_1	Formant 1
μV	microvolt
p	a symbol in statistics; see Glass and Stanley. 1970. P.218.
r	Pearson product-moment correlation coefficient
r_s	Spearman rank correlation coefficient
V	vowel
vce	voice
sd	standard deviation; see Glass and Stanley. 1970. P.82.
T-score	a standardized score in statistics; see Glass and Stanley. 1970. P.88.
z	a symbol in statistics; see Glass and Stanley. 1970. P.513.

Note: In the compilation of this glossary, use was made of a great many different sources; however, Dorland (1965) was referred to especially frequently.

PHONETIC SYMBOLS AND CONVENTIONS

Symbols

phonetic symbol	*computer equivalent*	*example*	*phonetic symbol*	*computer equivalent*	*example*
CONSONANTS:			[ɛ]	E	'bed'
[č]	C	'change'	[æ]	@	'cat'
[ǰ]	J	'George'	[ə]	+	'about'
[θ]	TH	'think'	[ū]	UW	'boot'
[ð]	DH	'those'	[ʊ]	U	'foot'
[š]	SH	'ship'	[oᵘ]	OW	'rote'
[ž]	ZH	'vision'	[ɔ]	O	'caught'
VOWELS:			[a]	A	'car'
[ῑ]	IY	'feet'	*DIPHTHONGS*		
[ι]	I	'fit'	[aᶥ]	AY	'kite'
[eᶥ]	EY	'late'	[aᵘ]	AW	'mouse'
			[oᶥ]	OY	'soil'

AS IN ENGLISH SPELLING

p, t, k, b, d, g, f, v, s, z, y, w, h, l, r, m, n

Bracketing Conventions for Computer Print-Out

(...) questionable utterances

< ... > successive approximations for a single target

<(   ) ... (   )> disjunctive sections of the same successive approximation, interrupted by extraneous comments

| marks primary stress on the succeeding vowel