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ABSTRACT

Two studies of adult aphasia, focusing on phonological disturbances, are presented. In the first study, subjects were 15 adults wit moderate aphasia and five age-matched controls. A variety of speech production and speech perception tests were administered, including tests of syllable discrimination, auditive word-picture matching, articulation, repetition of real words and non-words, naming, and picture description. Results of these tests are summarized and compared. In the second study, subjects were ten aphasic patients with a range of fluency and two controls. This research tested (1) the reliability of the clinical classification of aphasia into fluent and non-fluent types; and (2) the success of the two-stage view of speech production in predicting the nature of speaker errors. Two tests were used: one tested listener judgment of articulatory fluency, and an acoustic analysis of format frequencies and duration of eight Finnish vowel phonemes in the first (stressed) syllable. Results of these tests are also discussed. A 125-item bibliography is included. Appended materials include the tests, notes on Finnish phonology, materials related to the tests, and summarized test results. (MSE)

PIRKKO KUKKONEN

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Helsinki, March 1990 Pirkko Kukkonen

1 Introduction

Linguists are interested in the structure of natural language. Aphasia is of interest to the linguist because the ways in which language is disrupted by brain damage may provide additional information about the structure of the normal language system. The main aphasic syndromes observed seem to be relatively similar irrespective of the structure of the patient's language.

Roman Jakobson was a pioneer in linguistic studies of aphasia. He saw aphasia in a modular way: he defined aphasia syndromes as a result of a disturbance in the different grammatical components. This hypothesis, according to which the components of language can be disrupted selectively, is called functional modularity. At first, the components corresponded to the view of grammar that the European structuralists held (Jakobson, 1941-42). According to Jakobson, the disruption of the sound system in aphasics took place in the reverse order than the acquisition of the system by children. The phoneme oppositions that were most easily disturbed were those that were acquired late by children and that rarely occurred in the languages of the world. The oppositions of maximally different sounds were the most resistant to disturbances. This idea can be made more explicit by using the theory of distinctive features, as has been done both in connection with child language acquisition and adult aphasia (Blumstein, 1973, 1978; Caramazza and Zurif, eds., 1978).

Jakobson's basic idea of "linguistic modules" is still prevalent in the current linguistic literature. One of the modules is phonology. On the basis of the structure of the phonological component, one should be able to predict the structure of the phonological errors of aphasic patients. When Jakobson discussed phonology, no strict distinction was made between phonetics and phonology. By the development of instrumental techniques in phonetics, it became clear that speech is not only a mode of language expression, but also a motor skill. The first problem facing a student of phonological disturbances is the distinction between phonetic and phonological deficits. Several sets of distinctive criteria have been proposed, but none seem to work well (Miceli et al., 1980). There are very few patients who have both pure phoneme substitutions and no phonetic distortion in their speech. It seems even more unrealistic to look for patients with selective loss of some phonemes (Söderpalm, 1979).

Many studies of aphasia are essentially circular in that both the selection of the aphasic patients and the analysis of their errors are based on a linguistic theory and subsequent conclusions are drawn concerning the same theory. According to the psycholinguistic interpretation of generative grammar, the components of grammar

correspond to stages of language production and perception. For example, Garrett (1976, 1980) has proposed a model of this type. A direct application of this model to aphasia implies that stages correspond to aphasic syndromes. Caramazza and Berndt (1982) have proposed a classification of aphasia types into phonological, syntactic, lexical, and semantic divisions. Furthermore, a morphological deficit has been distinguished as separate from syntactic aphasia (Saffran, Schwartz, and Marin, 1980; Miceli, Mazzucchi, Menn, and Goodglass, 1983). One of the main questions is the homogeneity of such syndromes: is there only one type of phonological aphasia, or can different sub-types be distinguished?

There is empirical evidence to support the assumption that the problem the aphasic patient faces is essentially one of language use, i.e., the actualization of the linguistic knowledge which is stored in the memory. Several characteristics of the errors point to this direction: (1) their unsystematic nature, (2) the errors can be considered unsuccessful attempts at a correct target, and (3) the modality specificity of the deficits. Green (1986) accounts for such observations of bilingual aphasia by proposing that there are at least some cases in which language impairment following brain damage is not caused by the destruction or isolation of some functional subsystems, but is the result of a problem in regulating the activity of an intact system. According to the "distributed memory hypothesis", linguistic rules provide a structure for the memory of linguistic information (Allport, 1985). Such hypotheses give less direct predictions about the consequences of local brain damage than the functional modularity hypothesis.

In linguistically oriented studies, the existence of one linguistic system is usually taken for granted. Traditionally, however, aphasia syndromes have been divided along modalities: aphasia is either receptive or expressive. The aim of the present study is to examine the "phonological behaviors" of aphasics in various speech production and perception tests. A comparison of the tests is then made, with an attempt to distinguish between several types of deficits. It is assumed that the better the understanding of the nature of normal behavior, the better we can classify disorders, and vice versa. This does not necessarily mean that there are no differences between slips of the tongue and aphasic errors.

Chapter (2) provides information about the clinical background factors and a discussion of the necessary criteria for patient classification. Chapter (3.1) briefly summarizes the theories of normal speech perception and production that serve as a basis for the discussion of the disorders, and chapter (3.2) focuses on the problem of sound substitutions in aphasic speech. The objectives of the present study are formu-

lated in chapter (3.3). The data is presented in chapter (4). The results of the tests (speech perception, articulation, repetition, naming and picture description tests) are presented in chapter (5). The analysis was based on data transcribed by the author. Sub-samples of the data were subjected to a phonetic analysis: a listening experiment and an acoustic analysis of the first syllable vowels were performed. The experiments are explained in chapter (6). The findings are discussed in chapters (5.4) (a comparison of speech production and perception tests, and error types revealed by the phonemic analysis) and (6.4) (the role of phonetic factors in explaining sound substitutions, and the relation between phonetic distortion and phonemic errors). Problems of patient classification, and the linguistic implications of this classification, will be discussed in chapter (7).

2 Etiology and Clinical Classification

2.1 Etiology

Cerebrovascular accidents (CVA) are the most common causes of aphasia. Three major types of vascular pathology are traditionally recognized in cerebrovascular disorders: embolism, thrombosis, and hemorrhage. Blood is delivered to the brain through four main arteries: two large internal carotid arteries and the vertebral arteries. The internal carotid arteries divide into the anterior and middle cerebral arteries. The middle cerebral artery travels far into the Sylvian fissure and then divides into several cortical branches that supply the insula and the lateral surfaces of the frontal, parietal, temporal and occipital lobes. Any involvement of the left middle cerebral artery usually causes aphasia (Love and Webb, 1986). The infarcts caused by CVA do not necessarily involve the cortex, nor are they restricted to the cortex. Tumor, trauma, inflammation, poisoning, and drowning can also cause aphasia. However, the lesion caused by the preceding factors is less localized than a lesion caused by a CVA. The development of computerized brain imaging technology has made it possible to obtain reliable and exact information about the cortical and subcortical structures involved.

2.2 Methodological Considerations

Most aphasiologists are confident in their belief that the aphasia syndromes reflect the natural categories imposed by the common types of brain damage. Even so, it is often claimed that the classical taxonomic categories are profoundly unsuitable for the task of expressing, or helping to uncover, generalizations that are of interest to the neurolinguist (Caramazza, 1984; Schwartz, 1984). The classical aphasia categories are "polytypic", i.e. for each category, one cannot delineate an "essence" or idealized pattern which is invariant, and hence shared by all members of the group. As more patients have been studied with more sensitive test batteries, new characteristics have been discovered and added to the features which may, but not necessarily, be associated with the syndrome label. Thus, the classical aphasia categories have an increasingly empirical, atheoretical appearance. Overall, the groupings represent a majority of the shared characteristics. Within each group two members need not share attributes or patterns of attributes. Also, each attribute can appear in more than one category.

Schwartz (1984: 6) cites phonemic paraphasia as an example of a widespread symptom that can occur in several types of aphasia. However, it is possible that a more detailed linguistic analysis could reveal new differences between the symptoms. There may be several types of phonemic paraphasias, each of them associated with a certain the type of aphasia.

The neurolinguistic approach to patient classification attempts to be explanatory. An attempt is made to relate the various types of linguistic errors to normal language processing. Unlike clinically defined groupings (which are defined by a subject's performance in a wide range of tests), neurolinguistic classifications are established by the subject's performance in a single test or function. Patients are classified in groups if they produce a given type of error, regardless of other types of errors that they produce. In this approach, one patient may belong to several groups (c.f. Caplan, 1987: 153-4). As our knowledge of the normal processing system is limited, and the results obtained in neurolinguistics are preliminary, it is impossible to know how the neurolinguistic classification will relate to classic aphasia syndromes.

After the Second World War, when computerized tomography and exact lesion localizations were not yet available for the researcher, group studies were the preferred way of studying aphasia. Traditional clinical categories were used as independent variables. The occurrence of symptoms in different groups of patients were studied statistically. When more precise information about the lesion localization was made available, this information was used as an independent variable and the traditional categories became less attractive. In the research, precise qualitative information is often wished for, and it is not desirable to have patients with different lesion localizations in one group. The symptom dissociations observed in different patients are most interesting. Carefully prepared case descriptions can provide such information more readily than group studies, and case studies that once were popular in the nineteenth century are now becoming very common. One can also try to combine the two methodologies.

2.3 Clinical Classification

There are different hypotheses about the relation of speech production to perception and language processes. The controversy has its counterpart in clinical classification. In medical diagnoses dysarthria and aphasia are the two major classifications. In this classification no attention is paid to an articulatory deficit called apraxia of speech

that is sometimes considered to be a type of dysarthria (i.e. a motor speech production deficit), and sometimes a form of aphasia (i.e. a language deficit). First I will present the major divisions of dysarthria, and then I will discuss the different theories of speech apraxia. The final section of this chapter contains a classification of the different types of aphasia.

2.3.1 Dysarthria

Dysarthria is a cover term for various speech motor control disorders. Speech is certainly one of the most complex behaviors performed by human beings, requiring the action of major mechanisms at every significant motor integration level of the nervous system. Five major levels can be identified: (1) the cerebral cortex, (2) the subcortical nuclei of the cerebrum, (3) the brain stem, (4) the cerebellum, and (5) the spinal cord. For clinical purposes, the motor integration system of the brain for speech may be divided into three great motor subsystems: (1) the pyramidal system, (2) the extrapyramidal system, and (3) the cerebellar system (Love and Webb, 1986: 83). Spastic dysarthria is associated with a pyramidal lesion, dyskinetic dysarthria with an extrapyramidal lesion, and atactic dysarthria with a cerebellar lesion.

The pyramidal system is the primary controller of the voluntary muscle movements used for speech. The pyramidal tract descends from the bilateral motor cortices to the subcortical white matter in a fan-shaped distribution of fibers called corona radiata. The pyramidal system consists of three tracts of which the corticobulbar is the voluntary pathway for the movements of speech muscles, excluding those of respiration (Love and Webb, 1986: 117). In clinical neurology, the practice of dividing the motor system into upper and lower parts has proved useful. No upper motor neurons leave the neuraxis. Lower motor neurons are those neurons sending motor neurons into the peripheral nerves (Love and Webb, 1986: 88). A lesion of the upper motor neuron may accompany aphasia in many patients, and a more precise classification of such dysarthric symptoms can only be obtained by studying the nuclei involved. The nuclei of the cranial nerves that are important for speech production are situated at various points throughout the brain stem. The corticobulbar fibers descend through the genu of the internal capsule and pass through the midbrain in the cerebral peduncles and then synapse, either with the lower motor neuron directly, or indirectly through a chain of neurons situated between the primary afferent neuron and the final motor neuron (Love and Webb, 1986: 117).

The main nerves involved in speech production are: vagus, hypoglossal, trigeminal, glossopharyngeal and facial nerves (Love and Webb, 1986: 134-5; Hardcastle, 1976). There is bilateral innervation for all the cranial nerve motor nuclei except for portions of the trigeminal, facial, and hypoglossal fibers. This bilateral motor control provides smooth, symmetrical movement of the articulators - the lips, tongue, soft palate, and jaw. The principle of bilateral control of speech muscles suggests that serious involvement of speech muscles usually results from diseases that affect bilateral neurologic mechanisms. With unilateral damage to the nervous system, the effect on speech is generally less serious, and compensatory mechanisms are made available from the other side of the midline speech system (Love and Webb, 1986: 42).

The extrapyramidal system consists of a complex set of pathways that connect clusters of subcortical motor nuclei (Love and Webb, 1986: 96). The extrapyramidal system is concerned with coarse stereotyped movements. In addition to the extrapyramidal system (and basal ganglia in particular), the cerebellum and the cerebral cortex interact in a series of feedback loops suggesting complex interaction of motor subsystems to coordinate everyday speech motor performance (Love and Webb, 1986: 98-99). Auditory and tactile feedback also play a role in speech production. In the final analysis, the motor control of speech muscles, or any other musculature, is brought about by muscle contraction.

Every movement involves a multiplicity of neuromuscular events. As a result, speech physiologists have proposed underlying organizing principles to account for the human's control of these movements. They are discussed in detail e.g. by Kent (1976).

The most common clinical classification of dysarthrias is the one proposed by Darley, Aronson and Brown (1975: 13). There is no need to discuss the classification in this context. The major point is to stress the fact that the types of dysarthria that can be associated with aphasia are varied, and they should be taken into consideration when studying aphasic patients. There is some research done about the phonetic characteristics of different types of dysarthria (e.g. Lehiste, 1965; Tikofsky, 1965; McNeil, Rosenbek and Aronson, eds., 1984). However, the role of the different subcortical nuclei in speech motor control remains largely unknown.

2.3.2 Speech Apraxia

Darley, Aronson and Brown (1975) differentiate between dysarthria, apraxia of speech, and aphasia. They consider speech apraxia to be a non-linguistic disorder of motor speech production, whereas they consider aphasia to be a disorder in the processing of meaning-bearing language units. Aphasia is a cross-modality impairment.

It is most difficult for a patient with speech apraxia to correctly produce articulatory postures or sequences of these postures. Word-finding is not a problem in speech apraxia. In a series of trials the errors are highly variable. As subjects try to avoid articulatory error, they slow down, spacing their words and syllables evenly, and stressing them equally (Darley et al., 1975: 250). The errors of dysarthric and apractic patients are clearly different. For dysarthric patients, the most common error is the imprecise production of consonants, usually in the form of distortions and omissions. Patients displaying speech apraxia make relatively few of these simplification errors. For them, much more common is phoneme substitution, and frequently the substituted phonemes are unrelated. In addition, patients often add phonemes (for example, substituting consonant clusters for single consonants), repeat, and prolong phonemes (Darley et al., 1975: 251).

Blumstein, Cooper, Goodglass, Statlender, and Gottlieb (1980) have argued that speech apraxia (in Broca's aphasia) is, in fact, distinguishable from the phonological deficits. Apractic errors are caused by the false timing and lack of coordination between the independently moving articulators, such as the tongue and velum, or the tongue and larynx. Also Ryalls (1987) considers dysarthria and apraxia of speech to be phonetic rather than phonological disorders.

It seems to me that apraxia of speech as described by Darley et al. (1975) should not be considered identical with a phonetic deficit as described by e.g. Lecours and Lhermitte (1973) (c.f. chapter 3). Here phonetic disintegration is defined in terms of off-target articulations. In contrast, Darley et al. (1975) use the terms "phoneme" and "muscle movement" or "articulatory gesture" interchangeably in their description of speech apraxia. Most researchers do not consider this confusion of terms to be problematic as speech apraxia is considered to be the same as phonetic disintegration.

According to Love and Webb (1986: 199-200), apraxia of speech is the impaired ability to voluntarily execute appropriate articulatory movements in the absence of paralysis, weakness, or incoordination of speech musculature. Pure speech apraxia has been traditionally associated with the left frontal lobe, and it has been presumed that the lesion is localized specifically in Broca's area or in the underlying white matter.

Classic Broca's aphasia (with both speech apraxia and linguistic deficits) is caused by a lesion extending beyond Broca's area into regions other than the frontal lobe. The issue of lesion site continues to be controversial since other sites beyond Broca's area have also been suggested as contributing to speech apractic symptoms. Presented with a case that appears to be a pure speech apraxia, the speech pathologist must differentiate the speech apraxia from dysarthria. In speech apraxia, articulation is impaired by inconsistent initiation, selection and sequencing of articulatory movements; in dysarthria, articulatory movements are more consistent, with distortion errors predominating. Speech apraxics do not display consistent disturbances of phonation, respiration, and resonance, whereas dysarthrics consistently display those disturbances. Dysarthrics show impairment of non-speech musculature, including paralysis, weakness, involuntary movement, or ataxia. In contrast, speech apraxics do not have these neurologic oral musculature impairments.

The literature on speech apraxia is summarized by Mlcoch and Square (1984), where they claim that vowels are correctly articulated more often than other phonemes, and single consonants are produced correctly more often than are consonant clusters. In speech apraxia, clusters are often reduced. Fricatives and affricates are misarticulated more frequently than other phonemes. As for errors in the place of articulation, dentals seem to be the most difficult to produce. Consonants are misarticulated most often word-initially. Polysyllabic words tend to be misarticulated more frequently than monosyllabic words. According to Ziegler and von Cramon (1985), non-words are more difficult to produce than real words.

Kent (1983) and Hardcastle (1987) suggest hints for a theoretical (phonetic) explanation of error types. According to Kent (1983):

> "the apraxic errors in articulatory positioning and response sequencing might be explained by a theory of motor control of speech in which (1) temporal schemata ... regulate the sequencing of movements and (2) spatial targets are specified within a space coordinate system of the vocal tract. ... Initiation errors might be explained as a general failure of the schema to specify motor commands given the intended motor response, the current state of the articulators, and experience in meeting similar demands. Substitution errors perhaps represent a default motor execution in which preference is given to the best established schema. Schemata for alveolars should be well established by virtue of the high frequency of occurrence of alveolar sounds in English." (pp. 84-85)

Hardcastle (1987: 134) performed a physiological study, concluding from the results that impaired feedback monitoring in fluent aphasia is reflected in the lingual contact patterns. In apraxia of speech the errors can be interpreted in the following ways: (1) as a selection of an inappropriate articulatory gesture for a specific target phoneme, (2) as an incorrect serial ordering of articulatory gestures, and (3) as an inability to

achieve smooth transition between successive articulatory gestures. In dysarthria, component gestures would usually be distorted in their spatial configuration and be more consistently produced.

Mlcoch and Square (1984) have concluded that there are no speech perception disturbances in pure speech apraxia. However, Hardison, Marquardt and Peterson (1977) have proposed that speech production is affected by word position, word abstraction (meaning) and sentence voice.

There are some neurologists who do not separate speech apraxia from nonfluent aphasia, but instead classify it as merely one type of nonfluent aphasia that is recoverable (Love and Webb, 1986: 186, 200). The distinction between the two types of aphasia -- fluent and nonfluent -- is very common in aphasiology, yet the clinical diagnosis is usually based on the co-occurrence of a number of features. Grammatical criteria (length of utterance) and phonetic criteria (the presence or absence of speech distortion) have been studied in greatest detail.

We can conclude that the linguistic and motor control aspects of the syndrome of speech apraxia are controversial. Many studies that attempt to analyze the nature of the disturbances are complicated by the problem of recognizing patients with apraxia of speech. An additional problem is the lack of adequate definitions for the terms "motor" and "linguistic". Many authors (e.g. Kohn, Schönle and Hawkins, 1984; Mlcoch and Square, 1984; Ramsberger and Hillman, 1985) have questioned the claim that apraxia of speech is a unitary disorder -- they consider it highly possible that there are many different types of speech apraxia.

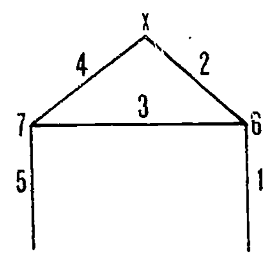
2.3.3 Aphasia

The most widely accepted of aphasia classifications is the system of dividing patients into two groups, fluent and nonfluent. These two classifications are defined as follows: fluent speech is effortlessly produced, well articulated with normal melody and rhythm, and consisting of long, grammatically correct phrases; nonfluent speech is uttered slowly and hesitantly with great effort and poor articulation, and with short, grammatically incorrect phrases (Goodglass and Kaplan, 1983). However, there may be dissociations between these features.

The most detailed classifications of aphasia are provided in aphasiology, but within the field there are several schools, all using different terminology. The clinical classification of aphasics is done on the basis of aphasia tests. In order to understand how the classification is performed one must study the tests in detail. From a clinical

point of view, the most important theories in the field are the Boston theory (c.f. Goodglass and Kaplan, 1983; Caplan, 1987) and Luria's aphasia theory (c.f. Luria, 1970, 1973, 1976). Both theories are more or less directly based on the classical connectionist models. The general principle of the connectionist models can be summarized by the following chart in which the major "centers" are 6 (auditory images of words), 7 (motor images of words) and "x" (intellectual processing). The lines between the centers are neural pathways that connect the centers.

Figure 2.1 Lichtheim's Classification of Aphasia Types
(c.f. Caplan, 1987: 145)



1 subcortical sensory aphasia
2 transcortical sensory aphasia
3 conduction aphasia
4 transcortical motor aphasia
5 subcortical motor aphasia
6 Wernicke's aphasia
7 Broca's aphasia

In clinical testing, the types of aphasia are distinguished in the following ways: ("-" indicates a lack of difficulties, "+" the presence of difficulties):

	production	repetition	comprehension
7	-	-	+
4	-	+	+
3	+	-	+
6	+	-	-
2	+	+	-

The above comparison is somewhat simplified. In order to distinguish between the cortical and subcortical aphasias, more attention has to be paid to the actual symptoms and symptom complexes, for it is the nature of the symptoms that is also important in the diagnosis of aphasia types.

In the Luria (1976) and Boston (Goodglass and Kaplan, 1983) classifications the number of categories is the same, but they are not completely overlapping. In the clinical practice, the two approaches differ in that Luria's classification focuses more on the assumed explanations for the classification than on the exact diagnostic criteria of the distinguished aphasia types. Table (2.1) compares some of the classifications that are referred to later. Information on the lesion localization is not provided but the interested reader is referred to H. Damasio (1981). The syndrome descriptions are

provided by A. Damasio (1981). All current lesion localization studies using the most recent brain imaging techniques seem to be based on the Boston classification.

Table 2.1 Comparison of Aphasiologic Clinical Classifications

localization		Darley et al. (1975)	Goodglass and Kaplan (1985)
anterior	nonfluent	dysarthria	
			Broca's aphasia
			transcortical motor aphasia
		apraxia of speech	
			conduction aphasia
posterior	fluent	aphasia	
			Wernicke's aphasia
			anomic aphasia
			transcortical sensory aphasia

It is difficult to compare dysarthria and speech apraxia with the aphasia categories. According to Love and Webb (1986), speech apraxia is an element of classic Broca's aphasia, but it can also appear in a pure form. Dysarthria and speech apraxia are not syndromes in the same sense as the types of aphasia. Dysarthria and speech apraxia are not "polytypic", but attempt to be explanatory (c.f. chapter 2.2). Broca's aphasics are nonfluent, whereas Wernicke's aphasics are fluent. Conduction aphasics are usually regarded as fluent. However, the problem is complicated by the fact that conduction aphasics are sometimes divided into two groups -- efferent and afferent (Kertesz and Phipps, 1977). The "efferent" conduction aphasics are considered to be nonfluent, and the "afferent" conduction aphasics, fluent. The aphasia syndromes proposed by Luria (e.g. 1970, 1973) partly focus on different features than the Boston classification.

In the past, researchers have ignored the sub-phonemic vs. phonemic nature of errors in the various classifications. According to Luria (e.g. 1973) and Hardcastle (1987), the reason that "articulatory errors" occur in fluent aphasia is due to the lack of normal feedback from articulators. Luria speaks in terms of segmental errors (in afferent motor aphasia), whereas Hardcastle discusses abnormal lingual contact patterns. There is also no general agreement about the sub-phonemic vs. phonemic nature of "articulatory errors" in nonfluent aphasia. According to Shinn and Blumstein (1983) and Love and Webb (1986), relevant generalizations about errors in speech apraxia can be made in terms of articulatory gestures or distinctive features. Thus, in this framework, "phoneme errors" in speech apraxia result from a lack of co-ordination

of the articulatory gestures. On the contrary, Darley et al. (1975) and Mlcoch and Square (1984) only speak in terms of phoneme errors. The relation between speech apraxia and conduction aphasia remains controversial. Conduction aphasia is traditionally described by postulating a disruption of the neural pathway connecting "auditory images of words" to the "motor images of words", a link that is of central importance in the repetition test. This theory provides no basis for differentiating between articulatory gestures and phonemes as units of errors in conduction aphasia. Other explanations for conduction aphasia have also been proposed, but they also fail to solve the present problem. In recent studies, phoneme substitutions have been considered to be clinically most salient in conduction aphasia (Shinn and Blumstein, 1983; Kohn, 1985).

The methodology used in the present study does not allow for an explicit comparison of segmental and gesture or feature errors. The analysis focuses only on segmental errors, and an attempt is made to distinguish between different types of errors. Furthermore, the relation between segmental errors and phonetic variation is studied. The results will also be discussed in relation to the diagnostic categories mentioned above, although the subjects were not prediagnosed.

3 Theoretical Background and Research Questions

3.1 Speech - Language Interface and Phoneme Substitutions

Jakobson, Fant and Halle (1951) view speech production and perception as having underlying invariant phonemes. The authors define phonemes using three characteristics: perceptual, articulatory, and acoustic features.

The past literature on speech perception has focused on the perceptual characteristics of the phoneme. Perceptual characteristics are important because children must be able to perceive speech (and the phonemes as one part of the language code) in order to learn to speak themselves (and thus to produce the phonemes). Furthermore, the theory of the self-organization of information states that certain kinds of adaptive systems give rise to geometrical maps in which natural basic percepts are organized according to their mutual similarities. This provides a basis for explaining linguistic concepts such as phonemes.

In the current literature on spoken word recognition, a distinction is made between the concepts "word recognition" and "lexical access". According to Tyler and Frauenfelder (1987),

> "the process of recognizing a spoken word begins when the sensory input - or, more precisely, a contact representation (a representation computed from the auditory input) - makes initial contact with the lexicon. In this initial contact phase, the listener takes the speech wave as input and generates the representation(s) which contact the internally stored form-based representations associated with each lexical entry". (p. 3)

The amount of speech required to compute the contact representation determines the moment when initial contact can occur. After initial contact and activation of a subset of the lexicon, accumulating sensory input continues to map onto this subset until the intended lexical entry is eventually selected. "Word recognition" refers to the end-point of the selection phase when the listener has determined which lexical entry was actually heard. The goal of lexical processing is to make available the stored knowledge associated with a word so that this can be used to develop a meaningful interpretation of an utterance. The term "lexical access" refers to the point at which the various properties (e.g. phonological, syntactic, and semantic) of stored lexical representations become available. "Phonology" has two components: the memorized phonological form which is one part of the lexical representation, and the contact representation which is computed from the acoustic input.

The wide range of different orientations towards lexical access is exemplified by the contrast between the cohort (Marslen-Wilson, 1987) and search models (Bradley and Forster, 1987). In the cohort model, all stored information is activated simultaneously upon initial contact (i.e. lexical access precedes word recognition, according to Tyler and Frauenfelder, 1987). In the search model stored syntactic and semantic information do not become available until a word is recognized (i.e. according to Tyler and Frauenfelder, 1987, word recognition and lexical access are indistinguishable). Most theories agree that some form-based information must be available in the initial contact phase of lexical processing. There is disagreement on the existence and nature of the contact representation (e.g. whether it is structured in terms of phonetic features, phonemes or syllables) and the point at which lexical knowledge becomes available. There also is no general agreement over the nature of the lexical knowledge.

Phoneticians and audiologists agree that some top-down processing is necessary for normal speech perception in the presence of noise. Experiments have been conducted in which subjects are presented with lists of words and non-words in optimal listening conditions. The type and amount of noise imposed on the speech signal has been varied (Hirsh, Reynolds and Joseph, 1954; Giolas and Epstein, 1963). In good listening conditions, people can hear what is said (i.e. non-words are heard correctly), but top-down processing seems to play an important role in speech perception in the presence of noise (i.e. non-words are heard as words).

There is considerable overlap between the theories of speech perception, speech motor control, and linguistic structure. The theory of self-organization may explain how memory for linguistic structures arises. It is not known how the phylogenetic process is related to speech perception in adults who have already learned the language (and the phonological forms). Some researchers think that it is impossible to account for speech perception abilities without reference to speech production, i.e., the motor systems play a role in speech perception (Liberman and Mattingly, 1985; Lieberman and Blumstein, 1988: 147). The relative importance of speech perception, speech production, and the memory representation of language are interpreted in different ways. In what follows the terms (speech) production and perception refer to both the phonetic and the linguistic aspects of the processes.

In order to learn about the functions of the motor system, it is first necessary to identify the informational units of co-ordination (Kelso, Tuller, and Harris, 1983: 138). The basic units of the speech-language interface may be phonetic features or articulatory gestures (of the lips, tongue, velum or larynx – those that can move relatively independently of one another), or segments (roughly of phoneme size), or

syllables, or even larger units, such as words or lexical entries. Also, in studies on speech perception, evidence has been found for units of several sizes.

MacNeilage (1970) has reviewed the literature on speech production. At least two different views of phonemic invariance have been advanced. According to the first view, the source of invariance is found in the "motor commands" that underlie speech. According to the second view, invariance lies in the specification of the vocal tract configuration required for a phoneme, or, in other words, an idealized "target" position which is defined in a space coordinate system.

In general, the authors of phoneme-based models consider the lack of correspondence between the phoneme and its peripheral correlates to be the result of three factors: (a) the mechanical constraints inherent in the peripheral vocal structures, (b) limitations in the response capabilities of the neuromuscular system, and (c) overlapping in time of the effects of successive phoneme commands (MacNeilage, 1970: 183).

According to MacNeilage (1970), a proponent of the target theory, the basic problem in speech production is not the one considered central to most theorists, namely, focussing on why articulators do not always reach the same position for a given phoneme. Rather, the central question should be, how do articulators always reach the same position as they do? MacNeilage proposes that the essence of the speech production process is not an inefficient response to invariant central signals, but an elegantly controlled variability of response to the demand for a relatively constant end.

According to the two-stage view of speech production, there is a pre-motor stage of segment selection and sequencing that is thought to occur after lexical selection and before the final stage of direct motor control. Logically, it is somewhat surprising that we would need a selection and sequencing phase. The segments and their order have to be memorized, i.e., specified in the lexicon. However, the most compelling evidence in favor of the pre-motor stage of the segmental processing is the presence of speech errors in which two segments, sometimes separated by several words, are permuted in an otherwise correct sequence (MacKay, 1970). This suggests that some mechanism must be responsible for sequencing segments. The independence of this stage from the motor control stage is indicated by the fact that the segments are correctly produced in their new context, even though the new context typically demands different articulatory movements from those demanded by the correct context. Thus, the movements for production of segments are assumed to be planned after the order of segments has been assigned.

According to Shattuck-Hufnagel and Klatt (1979), most phoneme errors (of slips of the tongue) at the pre-motor stage of speech production occur as the result of a mis-selection between two similar planning segments competing for a single location in an utterance. Thus, there is no tendency for linguistically unmarked consonants to replace marked consonants. In this model, serial ordering of segments is accomplished by a scan-copy mechanism that scans representations of words selected for an utterance, and copies these representations onto a matrix of canonical syllable or morpheme structures arising from suprasegmental properties of the utterance. Elements that change places are linguistically motivated: features, phonemes, morphemes, or words. The specification of articulatory targets takes place at a later, unspecified stage.

3.2 Phonological Deficits in Aphasia

Linguistic units such as phonemes or distinctive features are usually considered to be abstract entities. In some production models only allophones are described in articulatory terms. This solution has been criticized, for example, by Liberman, Ingeman, Lisker, Delattre and Cooper (1959). It is somewhat difficult to determine exactly what the term "abstract" means in relation to aphasia. One concrete interpretation of "abstract" is to consider phonemes to be modality-independent (i.e. the deficits should come to surface in both speech perception and production, as well as in reading and writing).

Linguistic units are usually considered to be modality-independent, or "central". In an earlier tradition (for example, Baudouin de Courtenay, 1917) modalities were considered to be separate. Instead of modality-independent phonemes, there were the concepts "articuleme" and "phoneme": "articulemes" were articulatory segments and "phonemes" were auditory segments. Evidence from aphasia may support this early concept. Traditionally, at least, production and perception difficulties were considered to be typical of different types of aphasia. However, the linguistic and psychological analysis of aphasia may not be sufficiently sophisticated to distinguish between linguistic, and perceptual and motor difficulties (c.f. Allport, MacKay, Prinz and Scheerer, eds., 1987). Thus, it is not clear that the concept of (central) phonological aphasia has empirical reality. In a "central" phonological disorder, the phonemic errors should be present in both production and perception (and there should be reason to assume that they are not due to a combination of two independent deficits).

There are relatively few perception studies on neurolinguistics. The main question discussed seems to be whether or not the comprehension problem of Wernicke's aphasics can be accounted for by an auditory discrimination problem (e.g. Saffran, Marin and Yeni-Komshian, 1976; Blumstein, Baker, and Goodglass, 1977; Jauhiainen and Nuutila, 1977; Miceli, Gainotti, Caltagirone and Masullo, 1980). The answer seems to be negative, i.e., some higher level of perception or comprehension processes must be assumed.

In contrast to speech perception, speech production abilities have been studied more intensively. There has been a long standing disagreement over the nature of the phonological disorder in aphasia: some results show a difference between phonetic and phonological factors, whereas others do not (Lecours and Nespoulous, 1988). As a starting point for discussion, the criteria proposed by Lecours and Lhermitte (<1969> 1973) will be presented. They specify how it should be possible to distinguish between phonetic and phonological disorders in speech production.

> 1. Phonological transformations appear in the context of a rapid abundant speech flow; phonetic transformations in the context of slow laborious speech flow.
>
> 2. In connection with a phonological disorder the productions of the patients can be segmented in phonemes that belong to the inventory of the locutor's tongue; patients with phonetic disintegrations often produce neo-phonemes, this is phonemic units that do not belong to the phonemic stock of the locutor's linguistic community.
>
> 3. The direction of phonemic substitutions is probably indifferent in connection with phonetic disintegration whereas in patients with phonological disintegration marked phonemes are substituted by unmarked ones.
>
> 4. The structure of transformations is relatively variable in phonological disintegration of speech, stable in phonetic disintegration of speech: in response to multiple presentations of a same stimulus, the patient with phonological disintegration will produce transformations of different morphology; whatever the delay and linguistic activity between presentations, the patient with phonetic disintegration of speech will tend to produce the same transformation over and over.
>
> 5. The syntagmatic relations between the phonemic units of a sequence are usually simplified by transformations type of phonetic disintegration whereas difficult erroneous clusters are often realized in transformations of the type of phonological disintegration.
>
> 6. Paretic and/or dystonic factors are often obvious in the clinical picture of phonetic disintegration, never so in pure cases of phonological disintegration.
>
> 7. Other extralinguistic criteria can also be important points of differential diagnosis, for instance: associated neurological signs (e.g. buccofacial apraxia and right hemiparesis with phonetic disintegration); longitudinal evolution; methods and results of reeducation. (p. 104)

The basis for the phonetic vs. phonological distinction is that there are patients who seem to produce well-articulated speech, and others who seem to struggle in articulation. It is supposed that both the phonetic and the phonological component can be

disordered in a transparent way. At the phonological level, the deficit results in a mis-selection of phonemes from the phoneme inventory. Articulation is supposed to remain intact in this case. If speech is poorly articulated, it is because of an articulatory trouble at a lower level of speech production. In this case, no relevant generalization can be made using linguistic concepts (i.e. markedness). It is assumed that at the phonological level the unit is the phoneme, whereas at the phonetic level it is smaller than the phoneme.

It is not clear which phonetic characteristics lie behind the impression of rapid, abundant speech flow and slow, laborious speech flow. For example, the "neophonemes" obviously are distortions that the listener "hears" as "neophonemes". Articulatory simplification may produce phonological complications. For example, if the patients speak very slowly and the transitions between sounds are lengthened, one may hear the transitions as additional segments. A complex sequence of sounds may also arise as a result of lack of co-ordination of several simultaneous articulatory movements. For example, in the cluster /nl/ the velar port should be closed, and at the same time the sides of the tongue should be drawn towards the middle to allow lateral air flow. However, if the speaker first closes the velar port and then draws the sides of the tongue towards the middle, a short closure arises that may be heard as a separate segment. As a result, the cluster is complicated and sounds like /ndl/.

No instrumental analysis has been performed to test whether or not the slips of the tongue that sound like pure phoneme substitutions are actually articulated the same way as correct sounds. The aphasic errors have received more attention, and evidence has been presented to establish that there are two types of errors: typically, fluent aphasics' errors are pure phoneme substitutions, and nonfluent aphasics' errors are articulatory distortions. The majority of this evidence has been obtained from studies of the voice onset time in word-initial stops (Freeman, Sands, and Harris, 1978; Itoh, Sasanuma, Tatsumi, and Kobayashi, 1979; Blumstein, Cooper, Goodglass, Statlender, and Gottlieb, 1980; Itoh, Sasanuma, Tatsumi, Murakami, Fukusako, and Suzuki, 1982). However, the static aspects of speech production are relatively well preserved in all aphasic patients (Shinn and Blumstein, 1983), and the results obtained with voice onset time did not predict the pattern of other temporal features, for example, the duration of vowels preceding word-final stop consonants (Tuller, 1984).

In addition to committing phonemic errors, all aphasics show some deviation in the timing of articulatory movements (Blumstein et al., 1980). It is difficult to distinguish between articulatory simplifications and the phonological changes in which unmarked phonemes have been substituted for marked phonemes. There have been

many studies on the markedness effect but the results are controversial. Blumstein (1973) found no difference between different patient groups, but in all segmental errors the unmarked sounds replaced the marked sounds. However, according to Nespoulous, Joanette, Ska, Caplan, and Lecours (1987), conduction aphasics did not show preferential error patterns in phonemic substitutions. Conduction aphasics made more serial ordering errors than Broca's aphasics did. Broca's aphasics tended to substitute unmarked phonemes for marked phonemes. Valdois, Joanette, Nespoulous and Poncet (1988) have differentiated between two types of conduction aphasia. In one group, intrusion phonemes shared more features with the surrounding phonemes than with target phonemes, and substitution errors often induced the simultaneous modification of both place and manner of articulation. In the second group, there was a high similarity between phonemes involved in the substitution processes, and these substitutions appeared to occur in the absence of a detectable "contextual effect".

A rather clear connection has been made between different aphasia syndromes and the classification of speech disorders into phonetic and phonological disintegration. Phonetic disintegration is associated with anterior (nonfluent, motor) aphasia, and phonological disintegration with posterior (fluent, sensory) aphasia. In linguistically oriented studies, apraxia of speech is often equated with phonetic disintegration. However, it is often claimed that errors are more variable in apraxia of speech than in dysarthria. Speech apraxia is not a generally accepted syndrome. An in-depth discussion of speech apraxia is found in chapter (2).

In many studies of aphasic speech, little attention is paid to the way in which data were collected. The most common ways of eliciting data are repetition or reading tests, but spontaneous speech and naming have also been used. Reading and writing will not be discussed in the present study, but various production and perception tests will be compared. The patient's phoneme substitutions in repetition tests may be a result of the patient's misperception of the original target. Furthermore, the data are often collected in clinical surroundings where there is background noise. The data are tape-recorded and transcribed. There is an abundant literature on the unreliability of transcriptions. All observed "errors" need not reflect the patient's speech production problem, for some mistakes may be due to the listener's "misperception" of deviant speech. The results by Miller and Nicely (according to Clark and Clark, 1977: 191-193) showed that the normal listener's mis-identification of normal speech sounds in the presence of different levels of noise, formed a regular pattern -- more closely related sounds were most easily confused.

Aphasiological data are often elicited in repetition. There are two speaker-hearer cycles in the repetition test that may cause errors:

(1) the examiner hesitates or slips when producing the target (which may lead to misperceptions)

(2) the patient misperceives the target, either due to (1) or due to the patient's own speech perception problem (e.g. hearing loss)

(3) the patient reproduces the misperceived target ideally ("phoneme" substitutions)

(4) the patient reproduces the target with great hesitation or distortion (in the most extreme cases it is difficult for the listener to distinguish a distortion from a false target)

(5) the examiner misperceives the patient's response because of external interference (e.g. the presence of background noise)

In naming and picture description tests, the role of speech perception is less obvious. However, even in these tests one should take into consideration the ways in which normal listeners interpret distorted speech (Buckingham and Yule, 1987). It may turn out that the above-mentioned factors account for only a few errors, and thus do not change the overall picture, but it is also possible that some groups of errors can be explained by the above factors.

In order to get more reliable information about the nature of the errors that look like sound substitutions, the following hypotheses will be considered:

(1) The Articulatory Hypothesis:
Increased Variation Results in an Increase in Errors

A sound substitution may be a result from increased variation in the aphasic patient's speech production. For example, the patient may not be able to control the duration of the sounds, and consequently the long and short sounds of Finnish are not kept separate in actual production. Furthermore, it is possible that for some phonetic segments (and different types of distortion), the resulting sound is more likely to be heard as a pure substitution by the hearer. In order to properly test this hypothesis, more information is needed about the nature of the acoustic consequences of the aphasic disturbances and their perceptual effects on the normal listener.

(2) Perceptual Factors

One possible source of "phoneme substitutions", especially in the repetition test, is the patient's false perception of the target. It is therefore important to take the patient's results in the repetition test and compare them to his/her performance results in the perception tests. The other perception-related question was already mentioned in (1), namely, how a normal hearer perceives abnormal speech. Factors such as background noise and its negative affect on perception must be taken into consideration. When analyzing the patient's performance in the perception tests, both the bottom-up and top-down processes of speech perception must be considered as possible sources of errors.

(3) Literal Paraphasias

In neurolinguistics phoneme substitutions are called literal paraphasias. Literal paraphasias refer particularly to those substitutions that cannot be accounted for by articulatory or perceptual factors. More qualitative information about the literal paraphasias is needed, as there may be several types of them. Kohn (1985) has noted that articulatory factors may be involved with the segmental errors. Thus, one should look closely at the way in which phoneme substitutions are articulated: are the substitutions really "pure" from a phonetic point of view? The phonological forms (and the phonemes they consist of) must be stored in the lexicon. A great deal of attention has been paid to the paradigmatic comparison of the erroneous segment and the target phoneme. In addition to paradigmatic factors, syntagmatic factors such as the effect of surrounding sounds and other sounds of the word form should be taken into consideration.

(4) Contaminations

Contaminations are slips of the tongue or aphasic errors where the speaker simultaneously recalls two words, and the produced word is an amalgam of these two words. In an extreme case we can think of a contamination where only one "phoneme" resembles one of the words and all the others belong to the other, thus leading to a "literal paraphasia". If this is the case, the patients should have many clear lexical contaminations and only some "literal paraphasias". In practice, the problem with testing such a hypothesis is that it is difficult to determine the origin of the amalgam.

It is not known whether lexical contaminations are related to neologisms. Neologisms are relatively common in aphasic speech, especially in fluent (Wernicke's) aphasia (Kohn, 1985). Neologisms may be compared with glossolalia and assumed to be due to the functioning of a "random string generator" (Buckingham, 1987). However, it should also be kept in mind that fluent aphasics often have comprehension problems that may, at least in principle, be related to their jargon.

In past research, attempts have been made to find systematic differences in the phonological errors. Many studies have focused on the types of literal paraphasias. Alajouanine, Ombredane, and Durand (1939) did not differentiate between articulatory and (segmental) phonological deficits, but contrasted the articulatory deficit with a deficit of lexical representations. Joanette, Keller, and Lecours (1980) proposed that the initial strength and permanence of the target's internal representation are important for the proper functioning of the phonological production mechanism. Thus, according to these researchers, the target itself may be impaired, its initial representation may not be strong enough to permit correct outputting and comparison, or even if it is initially adequate, it may decay over time.

Results from the Burns and Canter (1977) study indicate that paraphasic speech is characterized by "complex confusions" that often occur word-finally. They contend that the predominance of word-final errors may be due to word-finding difficulties. They point out that it is often the first sound of a word that initiates or predominates in the word search, but there are instances when phonemes in other word positions may also be used. If a real word exists that is related to the target through meaning and sound, it will tend to dominate in the response and may be fused with, or substituted for, the target. In Wernicke's aphasia, the intrusion of semantically related words is more profound than in conduction aphasia where phonological factors dominate. Also results from Blumstein's research (1973: 56) show that for Broca's aphasics the errors in word-initial consonants predominate, whereas for Wernicke's aphasics word-final errors predominate. Valdois, Joanette, and Nespoulous (1988) found systematic differences in the intrinsic organization of sequences of phonemic approximations. A more careful analysis of contextual factors (word position etc.) seems promising for the description of patterns of phonological errors. These types of contextual errors are less problematic from a perceptual point of view than are literal paraphasias: contextual errors do not coincide with any known pattern of perceptual confusion.

3.3 Objectives of the Present Study

In linguistically oriented studies, it is often assumed that a phonological (or phonemic) deficit would be modality-independent, i.e. it should be manifested in both perception and production. This assumption is most often tacit rather than being a conscious and reasoned opinion. For example, Jakobson (1941-42) did not discuss the phonological errors in relation to speech production and perception. The phonological deficit is contrasted to an auditory deficit and a problem of speech motor control that should be restricted to one modality. In the following pages, this hypothesis will be tested, and the nature of the deficits (i.e. phonological, auditory, motor) will be discussed.

The present study compares the production and perception deficits in various tests. The production tests were diadochokinesis, repetition of CV-syllables, words, and non-words, naming, and picture description. The perception tests were auditory syllable discrimination and word-picture matching. The tests are described in detail in chapter (4).

The tests in the present study are basically similar to the tests used in the aphasiological test batteries. It was assumed that the traditional tests would reveal the possible modality-specific and test-specific deficits, as the strongest evidence for the existence of modality-specific language disturbances comes from the aphasiological research tradition. In some instances, existing clinical tests were used. The main problem in using such tests is that the linguistic features (e.g. word frequency, word length and phonetic composition, derivational complexity) are not varied systematically. Thus, several factors can account for the observed differences in the patients' test performance. On the other hand, the exclusion of some variables may result in a very easy or in a very difficult test, and subsequently in so-called floor or ceiling effects. The clinical tests were considered adequate for the present purpose – that is, for the study of the modality-specificity and the error types in various production and perception tests.

Only those tests that focus on the production and perception abilities in a direct way were included in the present study. In other words, tests that were more obviously "off-line" were not considered for the study. For example, lexical decision tests were excluded because a good performance in these tests was based not only on linguistic variables but on other cognitive variables as well. An attempt was made to minimize the role of such cognitive variables.

In addition to the study of the modality-specificity and test-specificity of the errors, the phonological errors in speech production will be analyzed in greater detail.

An attempt will be made to distinguish between different types of phonemic errors. The interpretation of the observed error types is based on the assumption that different error types are a result of different underlying error mechanisms. This assumption may, of course, be a simplification. At least in principle, several underlying mechanisms or an interaction of several underlying mechanisms could produce similar error types, or one underlying deficit could create several types of errors.

In recording and transcribing data, errors can result from the transcriber's own misperception of abnormal speech. Two additional experiments were performed to detect sound substitution errors produced by the transcriber. Sub-samples of the data were subjected to a listening experiment and an acoustic analysis. These experiments will also help clarify the factors underlying the common clinical classification of aphasic speech into fluent vs. nonfluent. The sources of phonetic variation, and the relation of this variation to the phonological errors, will also be discussed.

As mentioned earlier, the primary objective of the present study was to look for different patterns of phonological disturbances. For this reason, a group of patients that was not pre-selected was preferred over a comparison of traditional aphasia syndromes. In this study, most patients were tested more than one year after the onset of aphasia. Diagnostically, most of the present subjects would not be classified under traditional aphasia syndromes, but would instead be called residual aphasics. Very few aphasic patients exhibit the traditional aphasia syndromes in a pure form, and the exact criteria for a "pure type of aphasia" depend on the aphasia theory. The nature of the deficits in residual aphasia have received less attention than the deficits in the traditional aphasia syndromes. In fact it has sometimes been claimed that residual aphasics have no observable differences. This claim will be tested in the present study, which uses a sophisticated linguistic error analysis.

Since the number of patients in the present study was restricted to fifteen, it was possible to base the study on case analyses. Case descriptions are most suitable for revealing the dissociations between symptoms. At the end of the study, groupings of the deficits will be proposed, and the results will be discussed in relation to the clinical classifications.

3.4 Some Basic Terms and Concepts

Since different error types will be frequently referred to in the following chapters, a classification of terms is in order. The most common term is "phonological". In this study, it is used in a very broad sense as a cover term for all errors that are related to the phonological form of the words, its production and perception. For example, the following items are referred to as phonological errors: distortions, phoneme substitutions, errors related to the syllable structure, neologisms, and misperceptions due to difficulties in auditory discrimination. There are three major groups of phonological errors: (1) phonetic errors, (2) phonemic or segmental errors, and (3) lexical phonological errors. One of the main objectives of this study is to provide a classification of phonological errors and additional information about the nature of the error types. Thus, the following definitions should be considered preliminary.

Phonetic errors are poorly articulated, often with abnormal voice quality, and these errors cannot be described with reference to the phonemes. The term phonological form refers to the representation of the word form in the memory, and it is thus a part of the lexical representation. Errors related to the phonological form are called lexical (phonological) errors. It is assumed that the phonological form consists of several tiers, one of them being the segmental tier. Thus, some lexical phonological errors can be phonemic, but some of them may need to be described in terms of other units than the phoneme. Errors that are to be described with reference to the phonemes are called phonemic or segmental errors.

There are several types of phonemic errors: substitution, anticipation, perseveration, and metathesis errors. Substitution errors are paradigmatic phoneme substitutions which are not motivated by other sounds of the word form, substitution errors may or may not be articulatory simplifications. Anticipation and perseveration errors refer to assimilatory phoneme substitutions, the assimilation being either contact assimilation or, as is most often the case, remote assimilation. In metathesis errors, two segments interchange. This study is primarily concerned with single words, and consequently metathesis errors occur within a word. In past studies, metathesis errors may also have been a result of the exchange of sounds of different words, but these errors are not found in the present data. When classifying errors, it became clear that the metathesis errors can be of different types, depending on whether or not they obey the phonotactic constraints of Finnish. Also errors like *kamppi* instead of *pankki* 'bank' were considered simple metathesis errors, the nasal consonant's place of articulation being determined "automatically" by the place of articulation of the following stop

consonant, and the duration of the consonant being determined in another tier of the phonological form than the segmental tier. The nature and theoretical implications of the error types will be discussed in the following chapters.

4 Research Material

4.1 Tests Used in Eliciting the Data

Data were elicited from several speech production and perception tests. This allowed for a comparison of the nature of phonological difficulties in the two modalities. Speech perception tests, articulation tests, confrontation naming and picture description tests were adopted from the literature. The repetition test was more comprehensive, as it consisted of both words and non-words, and several variables (such as word length and phonetic composition) were systematically varied. In the following pages I shall briefly describe these tests. The complete test battery is found in appendix (1). Appendix (2) presents background information about Finnish phonology for those readers who are unfamiliar with Finnish.

(i) The Syllable Discrimination Test

The syllable discrimination test used by Miceli, Gainotti, Caltagirone and Payer-Rigo (1978) served as a model for the present test. The test corpus included 26 pairs of syllables that were read to the subjects by the author. The subject was advised to say "yes" if two syllables were similar, and "no" if they were different. The test was administered in such a way that prevented the subject from lipreading (for example, the examiner avoided sitting face-to-face with the subject, and/or the examiner held the test sheet so that lipreading was impossible). Fourteen syllable pairs were similar, and twelve were different. Of the fourteen different syllable pairs, four differed with respect to the vowel, and eight differed with respect to the consonant. Four consonant pairs differed by only one distinctive feature, and four differed by more than one distinctive feature (e.g. manner or place of articulation).

(ii) The Auditive Word - Picture Matching Test

The auditive word-picture matching test was adopted from the unstandardized Finnish version of Tsvetkova, Akhutina and Pylajeva's (1981) aphasia test (Hänninen, Valtonen, Varpamäki, Koivuselkä-Sallinen, and Uhlbäck, 1987). A page with ten pictures was presented to the subject. There were six different picture sheets, three with objects (nouns) and three with actions (verbs). On one sheet (both for nouns and

verbs) words were unrelated, on another they were phonologically related (i.e. minimal pairs) and on still another sheet the words were semantically related. Words were presented one, two and three items at a time. The test was administered in such a way that did not allow lipreading (the examiner did not sit face-to-face with the subject, and she looked down at the testing material while the subject was advised to look directly at the pictures).

(iii) The Articulation Tests

Diadochokinesis was tested. The subjects were asked to say (1) papapa, (2) tututu, and (3) takeli takeli takeli (Salonen, 1984). The subjects were also asked to repeat ten CV-syllables. A speech pathologist then evaluated the speaker's voice quality. She listened to the subject's picture description (test vi) and analyzed seven features of voice quality, rating them on a six point scale.

(iv) The Repetition of Real Words and Non-Words

The repetition test consisted of 313 items, 255 of which were real words and 48 non-words (consisting of two or more syllables). Of the real words, 185 were nouns, 25 adjectives, 33 verbs and twelve adverbs. The majority of the test words were bisyllabic. There were also sixteen monosyllabic words, ten trisyllabic words, and thirty-three "long" words (consisting of at least four syllables), some being compounds and others derivations. In addition, ten international words were eliminated from the analysis.

The phonetic composition of the bisyllabic words was systematically alternated. There was a sub-sample of words (mostly bisyllabic nouns) in which the first syllable vowel was alternated -- the eight vowel phonemes of Finnish occurred in this position, and there were at least six items with a short vowel and six items with a long vowel. Also, the consonants between the first and the second syllable vowels were alternated in a systematic way, with at least five items containing /k/, /kk/, /t/, /tt/, /p/, /pp/, /s/, /ss/, /n/, and /nn/. Words with consonant clusters word-medially were also included in the test. There were twenty nasal + obstruent clusters, ten containing a short obstruent (either /p/, /t/, /k/ or /s/), and ten containing a geminate obstruent. In these clusters, the nasal consonant was always homorganic with the obstruent (a phonotactic restriction in Finnish). There were also thirty clusters in which the first element was a liquid (/l/, /r/) and the second element was an

obstruent. Of these clusters, there were thirteen single obstruents and seventeen geminate obstruents. Word frequency was not varied systematically because the Frequency Dictionary of Finnish is based on a small corpus and contains only 12663 words.

(v) The Confrontation Naming Test

The unstandardized Finnish version of the Boston Naming Test (Kaplan, Goodglass and Weintraub, 1983; the Finnish version by Laine, 1985) was administered. This test consisted of sixty pictures, beginning with common objects having short names, and ending with more difficult items.

(vi) The Picture Description Test

In an attempt to evaluate verbal skills in descriptive speech, the subjects were asked to describe two sets of pictures, one adopted from Paradis (1987) that consisted of six drawings, and the other, a park scene taken from Hänninen et al. (1987).

The tests were presented to the subjects in a fixed order, beginning with automatisms and the picture description test, and continuing with the articulation, repetition and naming tests. All speech production tests (i.e. iii, iv, v, vi) were tape-recorded with a Tandberg II (two track) tape recorder and a Sennheiser MD408 microphone on Scotch 208 (7") reel-to-reel tapes (speed 19). The author recorded the patients' responses from the speech perception tests on an answer sheet.

The items presented auditorially to the subjects were produced by the examiner. The reason for not presenting the words in a more standard way was largely practical -- it provided a more natural and relaxed testing situation, using only one tape recorder. The tests analyzed in the present study were only a subset of the tests administered. For example, reading tests and tests that were only indirectly related to normal production and perception situations were omitted from the study (e.g. lexical decision tests).

For aphasic subjects, the testing session lasted approximately one hour. For the controls, and for some of the mildest patients, all tests were administered during one session which lasted approximately two hours. The maximum time spent with one subject (the sum of all the sessions) was approximately six hours. It was impossible to administer all the tests to the most severe patients.

4.2 Subjects

Fifteen aphasic patients were tested. There were no particular selection criteria for the patients, as patients were accepted on a first come, first served basis. However, a few patients with very mild (mostly anomic) deficits were excluded from the sample for it was desirable to have a certain number of patients with more pronounced articulatory or phonological deficits. Also, those patients with very severe forms of aphasia were excluded due to their inability to perform the tests.

The site of the testing was a quiet room in clinical surrounding. One patient was tested at the Department of Phonetics, at the University of Helsinki.

Five age-matched controls were tested with the same tests. As to education and sex, an attempt was made to achieve the same kind of a distribution for the controls, as the patients exhibited. The controls were tested at home except for Subject 20 who was invited to the Department of General Linguistics, at the University of Helsinki.

Table (4.1) presents the subjects' background information. All the subjects were right-handed native speakers of Finnish. Neurological information about the aphasic subjects is found in table (4.2). The variables were selected on the basis of Brookshire (1983). There was no audiological background information available but the subjects were asked about their hearing. If they had experienced some hearing problems, this is indicated in table (4.2). The aphasic patients were not pre-diagnosed with a standard aphasia test, but instead, the author used the Aphasia Severity Rating Scale provided by Goodglass and Kaplan (1983) to determine the severity of the patients' aphasias. The results of the severity rating are provided in table (4.2).

Table 4.1 Background Information about the Subjects

Subject	Sex	Age	Occupation	Dialectal Background	Knowledge of Foreign Languages (learned through formal instruction, if not otherwise indicated)
1	male	68	bricklayer	Northern Savo dialect	none
2	male	62	farmer	Kymenlaakso dialect	some Swedish (bilingual area)
3	female	35	housewife	Northern Häme dialect	some Swedish
4	male	65	building inspector	Southern Häme dialect	unknown
5	female	68	farmer	childhood: Karelia dialect, adult life: Southern Satakunta dialect	none
6	male	67	master mechanic	childhood: Savo dialect adult life: Southern Pohjanmaa dialect	none
7	female	49	saleswoman	Northern Häme dialect	none
8	male	49	restaurant manager	childhood: Karelia and Southern Pohjanmaa dialects, adulthood: Southern Häme dialect	Swedish, German, English
9	male	50	warehouse manager	Southern Savo dialect	some Swedish
10	male	54	store owner & manager	Northern Häme dialect	none
11	male	41	business representative	childhood: Northern Pohjanmaa dialect adulthood: Helsinki area	German, Italian
12	male	79	retired (metal worker)	childhood: Southern Pohjanmaa dialect, adulthood: Helsinki area	Swedish (bilingual area), English, French
13	female	42	assistant nurse	Southern Häme dialect	none
14	male	55	bus driver	childhood: Karelia and Southern Central Finland dialects, adulthood: Helsinki area	none
15	male	58	head curator	Helsinki area dialect	German, English, Swedish
16	male	61	telegraphist	childhood: Southern Pohjanmaa dialect, then Upper and Southern Varsinais-Suomi, then Helsinki area	English, German, Swedish
17	female	52	store owner & manager	Southern Varsinais-Suomi	none
18	male	52	store owner & manager	Southern Varsinais-Suomi	none
19	male	59	forester	childhood: Western Satakunta dialect, adulthood: Helsinki area	Swedish, English, some German
20	male	54	office worker	Childhood: Southern Pohjanmaa dialect, adulthood: Helsinki area	Swedish, Spanish, some German

Table 4.2 Neurological Information about the Aphasic Subjects

Subject	time post-onset	etiology	lesion localization	hemiparesis	further symptoms	severity of aphasia*
1	12 years	two infarcts (embolus)	brain scan: bilateral lesion in the area of central sulcus	severe in the right hand, milder in the lower extremity	hearing impairment?	5
2	2 years	infarct	CT: lesion in the area of left frontal lobe, capsula interna and basal ganglia	right-sided hemiparesis that is severe in the upper extremity and milder in the lower extremity	hearing impairment?	4
3	10 months (12 years)	two ICHs (hydro-cephalus)	CT: lesion in the area of left parietal lobe	72: mild right-sided hemiparesis (more severe in the upper extremity), 86: more severe right-sided hemiparesis, 87: paraplegia	none	5
4	4 years	two ICHs, multiple TIAs, mild atrophy	CT: 1. in the area of left temporal lobe, 2. posterior areas of the left temporal lobe	mild right-sided hemiparesis after the second ICH, recovered quickly	general slowness	2
5	2 years	infarct (trombosis)	no information available	mild right-sided hemiparesis post-onset, recovered quickly	none	3
6	3 years	2 infarcts, epileptic seizures	EEG: activation has slowed down in the left hemisphere, delta activity particularly in the temporal area, relatively stable asymmetry (hyperventilation)	right-sided hemiparesis	none	3
7	2 years	infarct	CT: posterior areas of the left frontal lobe	right-sided hemiparesis	depression	4
8	3 years	2 infarcts	CT: left temporal lobe; an old right-sided infarct was disclosed as well	mild right-sided hemiparesis	none	3
9	1 year	ICH (aneurysm)	CT: lesion in the area of left temporal lobe	right-sided hemiparesis which recovered quickly after the operation	hemianopia	3
10	2 years	2 infarcts	CT: lesion in the area of left temporal lobe, an old left-sided CVA was disclosed	right-sided hemiparesis post-onset, recovered quickly	none	4
11	1,5 months	infarct	CT: left temporopariental area, basal ganglia	severe right-sided hemiparesis	none	1
12	8 months	infarct	CT: posterior regions of the left pariental lobe, nucleus caudatus, brain stem (around the IV ventricle)	none	inadequacy?	5
13	2,5 months	ICH (trauma)	CT: left temporal lobe	right-sided hemiparesis, recovered quickly after the operation	none	4
14	1 year	2 infarcts, epilepsia	EEG: relatively constant delta theta activity in the left temporal and temporoparietal areas, 84: brain stem infarct	five years ago mild left-sided hemiparesis; traumatic tetraparesis; in -85 right-sided hemiparesis	none	3
15	4 years	infarct	CT: left temporoparietal areas	right-sided hemiparesis	depression?	4

* The severity of aphasia is rated according to the Aphasia Severity Rating Scale (Goodglass and Kaplan, 1983) where "0" indicates the lack of usable speech or auditory comprehension, and "5" indicates minimal discemible speech handicaps (for full definitions, c.f. p. 42); ICH = intracerebral hemorrhage, TIA = transient ischaemic attact, CT = computerized tomography

The categories used by Goodglass and Kaplan (1983) are the following:

0. No usable speech or auditory comprehension.

1. All communication is through fragmentary expression; great need for inference, questioning, and guessing by the listener. The range of information that can be exchanged is limited, and the listener carries the burden of communication.

2. Conversation about familiar subjects is possible with help from the listener. There are frequent failures to convey the idea, but patient shares the burden of communication with the examiner.

3. The patient can discuss almost all everyday problems with little or no assistance. Reduction of speech and/or comprehension, however, makes conversation about certain material difficult or impossible.

4. Some obvious loss of fluency in speech or facility of comprehension, without significant limitation on ideas expressed or form of expression.

5. Minimal discernible speech handicaps; patient may have subjective difficulties that are not apparent to the listener.

Due to human factors, it was sometimes necessary to leave certain tests out, or to only partially administer them. Table (4.3) presents a summary of the tests that could not be performed by some patients. There were four subjects who could not complete all the tests. Usually only one test or some items of one test were omitted. Subject 4 was very slow, and after testing him for six hours (several one hour sessions during two weeks), the testing had to be discontinued. The data were not eliminated from the analysis, because there were enough data to show some peculiar dissociations and error types.

Table 4.3 Tests and Items not Administered

Syllable discrimination test:

The test was not administered to Subjects 4, 10, and 11. Four items from the beginning were administered to Subject 10, but he subsequently refused to continue with the test.

Word-picture matching test:

Items 24-50 and 57-60 were not administered to Subject 4.

Repetition test:

Some long words were omitted when testing Subject 4. Non-words 21-48 were not administered to Subject 5.

Naming test:

Items 31-60 were eliminated in the testing of Subject 4.

Picture description:

Only one picture -- the park scene -- was presented to Subject 4.

5 Speech Perception and Production Abilities

5.1 Speech Perception

According to Blumstein, Baker and Goodglass (1977), the deficit in phonemic hearing cannot account for the comprehension deficit in Wernicke's aphasia. However, Miceli, Gainotti, Caltagirone and Masullo (1980) found a significant but partial correlation between disorders of phonological analysis (measured by a syllable discrimination test) and disorders of auditory comprehension. They also found a significant but incomplete correlation between phonemic output and phonemic analysis.

In the present study, the perception tests aim at a more detailed analysis of auditory discrimination and comprehension. The two speech perception tests that were administered to the subjects were a syllable discrimination test and a word-picture matching test (c.f. chapter 4). Two measures of auditory discrimination are obtained from these tests: syllable discrimination, and the discrimination of minimal pairs (words that differ by one phoneme). In order to be able to match phonologically related words with the pictures, it is not enough to discriminate between the words, but the subject ought to comprehend the item as well (in order to be able to select the right picture). In the comprehension test, the phonologically related items are contrasted to unrelated items and semantically related items. The results obtained from the tests will be described in more detail in the following pages.

5.1.1 Syllable Discrimination

The syllable discrimination test could not be administered to Subjects 4, 10 and 11. Table (5.1.1) presents the results. The absolute number of errors is reported for each of the subjects. In general, all subjects performed well on the test, the majority of the subjects committing 0-2 errors. Only three subjects (Subjects 1, 7, and 19) made more mistakes, and one of the three was a control subject (Subject 19). Table (5.1.1) reveals that vowels did not present a problem for the subjects.

Subjects 1 and 19 made errors with syllable pairs differentiated by a consonant (either by one feature or by several features of the consonant). It was predicted that subjects with auditory discrimination problems would make more errors with pairs that were closely related (differed only by one feature). However, this was not always the case. The features were not varied systematically so that no generalizations could be made concerning the degrees of difficulty.

Table 5.1.1 Results from the Syllable Discrimination Test

Numbers indicate the total number of errors in the different conditions of the test.

Variables:
total = the total number of errors (the total number of items in the test was 26)
simil = the number of errors in similar syllable pairs (14 items)
cons-1 = the number of errors in consonant pairs differentiated by one feature (4 items)
cons-s = the number of errors in consonant pairs differentiated by several features (4 items)
vowel = the number of errors in vowel pairs (4 items)

subject	total	simil	cons-1	cons-s	vowel
1	5	1	3	1	0
2	1	1	0	0	0
3	2	2	0	0	0
5	1	0	1	0	0
6	2	1	0	1	0
7	8	4	2	2	0
8	0	0	0	0	0
9	0	0	0	0	0
12	1	1	0	0	0
13	2	2	0	0	0
14	2	0	0	2	0
15	1	0	1	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	3	0	1	2	0
20	1	1	0	0	0

The subjects sometimes claimed that similar syllables were different. This was not due to a response bias but rather to the somewhat different phonetic quality of the syllables produced by the examiner. In general, the subjects made one or two such errors, but Subject 7 made several "random" errors. She often repeated the syllable pair correctly, and yet the similarity judgement was incorrect. These errors occurred randomly among all the test items, and there was no response bias. It was obvious that her problem was something other than auditory discrimination.

One control subject had difficulties in the syllable discrimination test. The reason for this is not known. One possible explanation is that hearing impairments may be relatively common in the middle-age or elderly population. For the present subjects, there was no audiological background information available. Subjects 1 and 2 reported that they experienced some hearing loss. For Subject 2, this hearing problem did not affect the performance in the present syllable discrimination test.

5.1.2 Word-Picture Matching

Several factors were varied in the word-picture matching test: (1) the words (and the pictures) were nouns (objects) and verbs (actions), (2) the words were either unrelated, phonologically related, or semantically related, and (3) the items were presented either one, two, or three at a time.

Tsvetkova, Akhutina and Pylajeva (1981: 19) state that the selection of the test material allows for focusing on both (1) the deficits of acoustic analysis and the memory for audio-motor traces and (2) difficulties with semantic differentiation between words. According to Tsvetkova et al. (1981), these are the factors that can underlie a difficulty in understanding words. Luria makes a distinction between acoustico-gnostic and acoustico-mnestic aphasia. The former is due to disturbances in the differentiation of groups of simultaneously presented acoustic stimuli and also of consecutive series of sounds of different pitch or rhythmic acoustic structures, the latter is due to "alienation of word meaning". In this connection Luria (1973: 124, 310) refers to Lissauer who distinguished two types of visual agnosia, apperceptive mental blindness and associative mental blindness. Tsvetkova et al. (1981) assume that phonologically related items are particularly difficult for patients with sensory aphasia, whereas semantically related items are difficult for both sensory and motor aphasics. The number of items presented at a time is assumed to have an influence on all the subjects' performance and it does not differentiate between aphasia types. Patients with sensory aphasia are supposed to have the severest difficulties in the test, but also patients with motor aphasia fail (especially when three items are presented at a time). According to the data (Tsvetkova et al., 1981: 37) verbs are somewhat more difficult than nouns, but this finding is not explained in detail.

The proportion of correct answers was calculated. When items were presented one at a time, the value was either 1 or 0. When three items were presented simultaneously, the value was either 1, 0.66, 0.33, or 0. When no answer was obtained or when there was something unclear in how the answer was marked on the answer sheet (as occurred a few times), the information was omitted (missing information). A few pictures turned out to be somewhat misleading, and for this reason it was necessary to accept two answers as correct. The verb *kiilata* is ambiguous. In the test, the verb is supposed to refer to a picture with two cars, one of them passing the other so close that the driver is forced to get out of the way. However, the picture for the verb *hakata* 'chop' is a possible associate for the verb *kiilata* in the sense 'key, wedge'. There was also another ambiguous verb. The verb *lakata* was used in the

sense 'polish one's nails'. However, some of the male subjects were obviously looking for a picture for 'varnish a wooden object', another sense of the same verb. Consequently, these subjects chose a wrong picture. Subject 4 was only administered one half of the test.

The performance of the subjects varied between no errors (three subjects: two controls and one patient) and about 75 % accuracy. Thus, none of the subjects had a severe comprehension problem at the single word level.

There were differences between the three conditions (unrelated, phonologically and semantically related items). This was true for both nouns and verbs. The subjects performed best in the condition where the items were unrelated. The phonological and semantic conditions were equally difficult. Semantically related nouns were easier than phonologically related nouns, whereas semantically related verbs were more difficult than the phonologically related verbs.

When the individual subjects were considered, especially patients 1 and 9 attracted attention in showing a double dissociation between phonological and semantic factors. The proportion of correct answers for nouns in the three conditions of the test was the following:

subject	unrelated	semantic	phonological
1	0.90	0.90	0.65
9	0.90	0.62	0.92

The results obtained for verbs showed the same tendency:

subject	unrelated	semantic	phonological
1	1.00	1.00	0.88
9	1.00	0.62	0.87

Subject 9 performed relatively well with phonologically related nouns, but he had some difficulties with phonologically related verbs. Subject 1 performed surprisingly well with the phonologically related verbs.

When the phonological and semantic conditions were compared, Subjects 1, 5, 6, 10, 11, and 12 found the phonologically related items more difficult than other items, and Subject 9 (but also Subjects 7 and 15) found the semantically related items the most difficult. Subject 1 also had difficulties in syllable discrimination. This comparison was based on the overall results and on the results for nouns. For the verbs, the results may look different. In the following pages, the difference between nouns and verbs will be discussed in detail.

Possibly Intervening Factors

The purpose of the present discussion is not to provide a general evaluation of the test, but to focus on phonological information. The data were subjected to an analysis of variance for the proportions of correct answers. The results of the statistical analysis are reported in appendix (3). Statistically significant main effects were observed for subject, relation (i.e. unrelated items vs. phonologically vs. semantically related items), and part of speech (i.e. nouns and verbs). Also, an effect for the number of simultaneously presented items was observed, although it was weaker. The more items presented simultaneously, the more difficult was the task. There were so many variables and so little data that it was impossible to check for all the interactions. Of those that could be analyzed, the interactions between subject and relation, and between subject and part of speech, were highly significant. There was also a weaker interaction between relation and part of speech, and between the number of simultaneously presented items, relation, and part of speech.

Appendix (4) presents the proportions of correct answers for the different conditions of the word-picture matching test. In the following pages, I shall discuss the data in more detail, with special reference to the factors that may "confuse" the interesting dissociation between the phonologically and semantically related items.

(1) Part of Speech and Depiction

There was a significant difference between the subjects' performance in verbs and nouns. As the tables in appendix (4) indicate, the difference was clearest for semantically related items. Verbs were more difficult than nouns. When the subjects were analyzed individually, two subjects (Subjects 5 and 13) performed far worse with verbs than with nouns.

Unrelated nouns were easy and did not differentiate between subjects. Only Subjects 4 and 14 had frequent errors with unrelated verbs, and the errors that were made occurred in those conditions of the test where more than one item was presented simultaneously. Most subjects also found the semantically related nouns easy. There were, nevertheless, subjects who made errors in these items (Subjects 9, 15). Subjects 3, 9, 11, and 13 made many errors in semantically related verbs. For nouns, the phonologically related items were the most difficult, and Subjects 1, 10 and 11 committed many such errors. Subjects 1 and 5 had difficulties with phonologically related verbs.

One possible difference between verbs and nouns is the difficulty in depicting actions. Thus, it may be more difficult to select the correct picture for verbs. We can hypothesize that some pictures spontaneously evoke the name the examiner is going to say, but there are times when the subject is not expecting to hear the word given by the examiner. In the latter case, the subject does not associate the pictures with the given name spontaneously. Possibly, he or she searches through the pictures, attempting to find one that fits the heard word. Thus, for pictures that do not evoke the right name, the failure in picture-matching performance may be due to a selection deficit. Furthermore, the subject may easily forget a word, if several words have to be kept in mind while searching. This is most likely to happen when several items are given simultaneously.

The differences in depiction were checked by performing an additional experiment. Two sets of pictures (one consisting of nouns and one of verbs) were randomized. Ten normal, highly educated, young adults were first asked to name the nouns, and then the verbs. The entropy of the answers was calculated for each picture (for statistical details, c.f. 6.4). The entropy varied between 0 and 1, 0 occurring when all subjects gave the same name, and 1 when all subjects gave a different name. Entropy is not an optimal measure for the depiction problem, because it does not take into consideration the cases where all the subjects agree but provide a different name than was assumed. However, this was rare. For nouns there were six items which were named "wrong" by more than half the subjects (four of them phonologically related and two semantically related; for two of the phonologically related items the entropy was high, for two items the entropy was small). For verbs, there were four items where most subjects provided a different name than was assumed (three of the items were phonologically related and one was semantically related; the entropy was high for all these items). Table (5.1.2) presents the statistical results. The difference between nouns and verbs can be accounted for by the depiction effect: the entropy for verbs was clearly higher than for nouns. The easiest items to name were unrelated. Phonologically related verbs elicited several different names, as did semantically related verbs and phonologically related nouns. These conditions were also difficult in the word-picture matching test.

The depiction effect does not predict the subjects' performances in the test. In aphasia there was a double dissociation between the phonological and semantic conditions. On the average, the aphasic patients performed relatively equally in the two conditions. However, there were clear differences in the depiction: semantically related items were easier than phonologically related items. Thus, there is some other,

obviously deficit-related factor that renders the semantically related items difficult for many aphasics.

Table 5.1.2 Naming of the Pictures of the Word-Picture Matching Test

Ten young adults were asked to name the items of the word-picture matching test. Relative entropy was used as a measure of variation for the naming responses. Relative entropy was 0 when all subjects gave the same name, and 1 when all subjects provided a different name.

		nouns	verbs	combined
phonologically	mean	0.43	0.64	0.53
related	std	0.45	0.35	0.41
unrelated	mean	0.26	0.22	0.24
	std	0.28	0.35	0.31
semantically	mean	0.19	0.49	0.34
related	std	0.34	0.37	0.37
total	mean	0.29	0.45	
	std	0.37	0.39	

(2) Number of Simultaneously Presented Items

The most interesting result in word-picture matching was the double dissociation between phonological and semantic conditions. The condition where only one item was presented differentiated neither between the subjects nor between the different conditions. Thus, no double dissociation can be observed when the number of simultaneously presented items is not varied.

Tsvetkova et al. (1981) assumed that the phonological versus semantic difficulties were additive, i.e. there were no qualitative differences between the conditions of the test where several items were presented simultaneously and the conditions where one item was presented. All aphasics had equal difficulty with several, simultaneously presented items. In the original set of tests of this dissertation (all of which are not discussed here), the performance of the subjects was compared in a larger set of different tests where the number of simultaneously presented items was varied (e.g. repetition of words, syllable matching). It was assumed that patients having a memory problem would perform poorly in all the tests, and that the quality of performance decreased proportionally to the increased number of simultaneously presented items. It was found that especially Subject 15, and to a lesser extent also Subjects 11, 12, and 13, had difficulties with the longer series of items. However, meaningless and meaningful items did not provide comparable results: the effect of the number of

simultaneously presented items was always more pronounced with meaningful items (Kukkonen, unpublished data).

In the word-picture matching test, the number of items had the greatest effect for the semantically related items. When the patients were studied individually, Subject 15 found longer series of items to be especially difficult. He did not perform equally poorly in all the conditions of the test, but he scored all correct for both unrelated nouns and verbs, and he had most difficulties with semantically related items. The number of items presented may partly account for the difficulty many subjects experienced with semantically related items.

(3) Frequency

Word frequency is one remaining variable that may influence a subject's performance. In the word-picture matching test, the frequency of the items was not varied systematically. Tsvetkova et al. (1981) note, however, that unrelated items were more frequent than other items. The frequency of the items was determined post hoc, and this analysis was based on the Frequency Dictionary of Finnish. The frequency of an item was calculated as the sum of absolute frequencies of the word type in the four types of data reported in the dictionary. The results are presented in table (5.1.3).

Table 5.1.3 Frequencies of the Items of the Word-Picture Matching Test

The frequency of the items was determined post hoc on the basis of the Frequency Dictionary of Finnish. The frequency of an item was the sum of absolute frequencies of the word type in the four types of data reported in the dictionary.

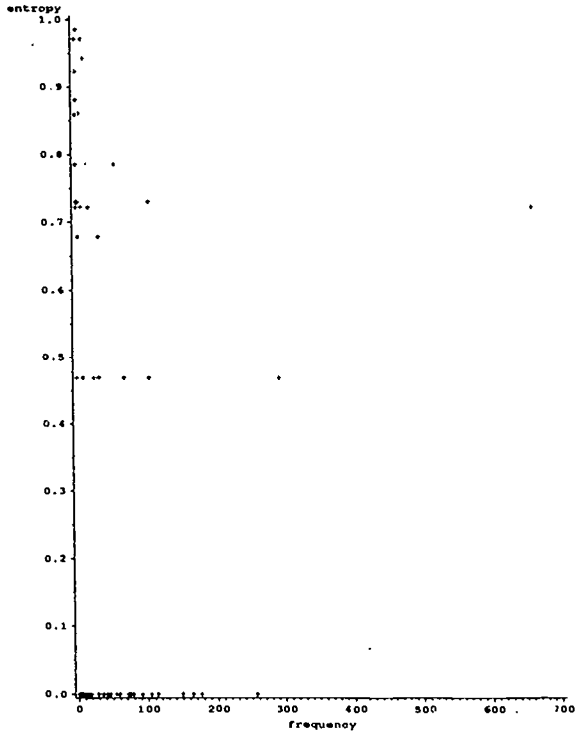
		nouns	verbs	combined
phonologically related	mean	7.60	10.10	9.35
	std	6.26	22.20	15.97
unrelated	mean	198.00	72.60	135.30
	std	179.28	38.90	141.71
semantically related	mean	9.90	18.90	14.40
	std	8.54	22.69	17.32
total	mean	71.83	34.20	
	std	135.07	39.44	

The Finnish version was similar to the original Russian test in that the unrelated items were the most frequent. On the average, nouns were more frequent than verbs. There was considerable variation between the items (the standard deviations were high). Figure (5.1.1) clearly shows that frequency alone can hardly account for the

double dissociation between phonological and semantic conditions of the test because no regular relationship can be seen between the variables.

Figure 5.1.1 Scattergram of Entropy and Frequency

Ten young adults named the items of the word-picture test. Variation for the naming responses was described by calculating the relative entropy of the answers. The figure presents the comparison of the relative entropy with the frequency of the items.



Phonologically Related Items

The results obtained in the phonological condition will be analyzed in more detail in the following pages. The other conditions did not allow for such a qualitative analysis because of the homogeneity of the picture sheets. The phonological condition consisted of several sets of minimal pairs. The errors could occur either within the pairs, or across the pairs. In connection with the word-picture matching test, "phonological errors" refer to mischoosing between items of a minimal pair. Table (5.1.4) presents the number and type of errors in the phonological condition.

Table 5.1.4 Errors in the Phonological Condition of the Word-Picture Matching Test

Variables: "total" = total number of errors, "phon" = number of phonological errors (e.g. the subject heard the word *kaula* and pointed to *naula*, i.e. a word that differed by only one phoneme), "others" = number of other types of errors.

Under "remarks" I have given some characteristics of the "other errors": "pict" = misinterpretation of the picture, "del" = deletion of an item, "persev" = perseveration (an item of the series is substituted by an item in the previous series), "unsyst" = unsystematic, random errors (e.g. the subject may have forgotten the item but subsequently guesses and randomly points to pictures). Sometimes the "phonological structure" of the item interfered with the structure of the following item, e.g. the presented series was *kortti kaula* and the subject pointed to *kortti korkki*. The number of such errors is given in parentheses. Such errors were not frequent.

subject	total	phon	others	remarks
1	9	9	0	
2	2	2	0	
3	1	0	1	unclear picture
4	3	0	3	del + persev
5	9	1	8	unsystem
6	10	3	7	persev (series)
7	1	0	1	unsyst (1)
8	0	0	0	
9	3	3	0	
10	13	3	10	del, unsyst (1)
11	10	3	7	del, (2)
12	4	1	3	pict?, persev?
13	3	0	3	unsyst, (2)
14	3	1	2	del, (1)??
15	4	1	3	del, persev, (1)
16	0	0	0	
17	1	1	0	
18	1	1	0	
19	2	2	0	
20	0	0	0	

Subjects 1, 5, 6, 10, and 11 made a high number of errors in this condition of the test. However, omissions and perseveration errors outnumbered the phonological errors. For example, Subject 6 made frequent perseveration errors in the longer series. The proportion of phonological errors was high for Subjects 1, 2, 9, 17, 18, 19. The control subjects only made phonological errors. The total number of phonological errors was relatively small for all subjects, with the exception of Subject 1. Table (5.1.5) shows the distribution of phonological errors in the phonological condition of the word-picture matching test. Only those subjects making phonological errors are included in the comparison.

Table 5.1.5 Distribution of Phonological Errors

The numbers indicate the number of errors made in each condition of the test.

subject	verb number of items 1	2	3	noun number of items 1	2	3
1	0	1	2	0	3	3
2	0	1	0	0	0	1
5	0	0	1	0	0	0
6	1	0	0	1	0	1
9	0	0	1	0	1	1
10	0	0	1	0	0	2
11	0	0	0	0	2	1
12	0	0	0	0	0	1
14	0	1	0	0	0	0
15	0	0	0	0	0	1
17	0	0	0	0	0	1
18	0	0	0	0	0	1
19	0	0	0	0	1	1

Subject 14 made one error that was difficult to interpret. The mistake could be considered a typical phonological error, or an error of sequence interference. The subjects had most phonological errors in series of two and three items. The errors committed by Subject 1 are listed below. All his errors were phonological.

words given	items pointed to
heltta neula	teltta keula
kaula kortti	kaula korkki
teltta kortti kaula	teltta korppi kaula
neula taltta korppi	neula taltta korkki
naula keula heltta	naula keula teltta
pakkaa viilaa	lakkaa viilaa
pakkaa harjaa viilaa	lakkaa harjaa kiilaa

Such examples of phonological confusions are the best evidence for phonological difficulties. However, phonological difficulties may possibly combine with other difficulties so that the subject produces another kind of error. For example, the patient may have a tendency to perseverate in longer series, combined with auditory discrimination problems. In longer series of phonologically related items, both difficulties interact, and the patient perseverates more than in series of semantically related items.

Errors were more common in the series of phonologically related nouns than in the series of phonologically related verbs. The pairs for nouns (*naula, neula, kaula, keula*, and *korppi, kortti, korkki*, and *teltta, taltta, heltta*) were obviously better in eliciting phonological confusions than the pairs of verbs (*pakkaa, hakkaa, lakkaa*, and *viilaa, kiilaa,*

keilaa, laulaa, and *halaa, haraa, harjaa*). Vowel contrasts were more common in the pairs of nouns, and more contrasts occurred word-medially. The verbs operated more on word-initial consonants, and the items were often distinguished by several contrasts. For example, there was no minimal pair for the verb *laulaa*. In future experiments, the phonological features should be varied systematically in order to study the nature of phonological confusions in closer detail.

5.1.3 A Summary of the Speech Perception Tests

An analysis was made of the several variables in the speech perception tests. The most interesting results are presented in figure (5.1.2). A diagram was drawn of the performance scores (for an example, c.f. chapter 5.2.4). Subjects with low performances were distinguished on the basis of visual inspection of the diagram.

Figure 5.1.2 A Comparison of the Variables in Speech Perception Tests

Variables:
sem = particular difficulties in the semantic condition of the word-picture matching test
predom phon = subjects whose errors were predominantly in the phonological condition of the word-picture matching test
phon common = the subjects with the greatest number of errors in the phonological condition of the word-picture matching test
phon phon = subjects who confused the minimal pairs in the phonological condition of the word-picture matching test
number = subjects who especially had difficulties with a series of three items
syll discr = subjects who failed the syllable discrimination test

The numbers indicate the subjects who had difficulties according to the analyzed variable.

1. sem					7	9					15			
2. predom phon	1		5	6			10	11	12					
3. phon common	1		5	6			10	11						
4. phon phon	1	2				9						17	18	19
5. number				6			10	11		13	15			
6. syll discr	1				7									19

The result supports the double dissociation between phonological and semantic factors: the subject's success or failure in the test depended on different variables. The control subjects made few errors, all being confusions of phonologically related words. The phonological condition of the test was sensitive in catching the sound discrimination problems that resulted in comprehension problems. The condition with nouns (objects) was better than the one with verbs (actions). For verbs, there were more intervening factors, such as low depiction. The frequency differences in the phonological and

semantic conditions of the test did not appear to account for the results, but in future studies they should be controlled.

There was one subject (Subject 1) who failed in both the phonological condition of the word-picture matching test and in the syllable discrimination test. This showed that both tests were sensitive to the discrimination problem. It also confirmed the results according to which severe comprehension problems are not usually due to a speech perception problem. In certain critical instances (i.e. minimal pairs) speech perception problems do interfere with comprehension. Thus, the result by Blumstein, Baker and Goodglass (1977) was confirmed. The severe comprehension problems experienced by the aphasic patients seem to be due to other kinds of problems.

Several measures of speech perception were used, each giving slightly different results. The reasons for these differences remained unclear. Thus, either the phonological errors in the phonological condition, or the total amount of errors in the phonological condition could be counted. The former variable caught the problem experienced by Subject 1. Subject 10 (who refused to do the syllable discrimination test) made many errors in the phonological condition of the word-picture matching test, but these mistakes were not "phonological errors". The control Subject 19 made several errors in the syllable discrimination test, but he did not have difficulties in the word-picture matching test (although he had more phonological errors than the other controls). It is possible that the two variables partly refer to different kinds of speech perception problems.

It is difficult to determine whether or not the double dissociation observed in the word-picture matching test should be interpreted as a dissociation between bottom-up processing and top-down processing in speech perception, i.e. a dissociation between speech recognition and lexical access, or as a dissociation between phonological and semantic aspects of lexical access. The former hypothesis seems preferable because the phonological deficit observed is modality-specific (c.f. 5.4.1). Thus, the phonological deficit could reflect speech perception aspects (bottom-up processing) or even hearing loss, whereas the semantic deficit could reflect lexical, top-down processing. There may be other symptoms (neologisms etc.) that refer to different aspects of lexical retrieval and/or access. It is impossible to make very specific claims about the role of the lexicon on the basis of the present data – rather, the present results form a basis for more detailed investigations.

5.2 Articulation

According to the medical diagnosis, all the subjects (except the five controls) had aphasia. There was no mention of dysarthria. However, dysarthric problems are often very mild in comparison with other problems, and in aphasic patients mild dysarthria is often ignored. Furthermore, there is no generally accepted theory about the speech-language interface that could serve as a basis for clinical classification. For this reason it is difficult to test accurately the speech motor functions and related linguistic functions in a clinical context.

Accurate speech production requires great precision of articulatory movements. Darley, Aronson and Brown (1975: 69) distinguish six salient features of articulatory movements: (1) strength, (2) speed, (3) range, (4) accuracy, (5) steadiness, and (6) tone. According to them, "it is generally agreed on that the different factors associated with the non-linguistic stages of speech production can best be assessed with non-linguistic material which reveals the underlying troubles in speech production that come into surface in a more complicated form in conversational speech." However, when using non-linguistic tests, it is difficult to know to what extent the results can be applied to normal conversational situations. For example, some studies support the conclusion that oral and verbal apraxia are independent of one another (e.g. Kertesz and Hooper, 1982). This makes sense if different areas of the cortex control for the different movements or if the organization of movements in memory is different. At lower levels of motor control it may be more difficult to distinguish between speech and other oral movements.

In the present study, all the tests that were assigned to the subjects required the combinatory functioning of the phonatory, respiratory, resonatory, and articulatory systems. This functioning was thus evaluated in complex speech situations. A speech pathologist rated the voice quality of the subjects. Diadochokinesis (the adequacy of alternate and sequential motions) was tested. In the alternate motion test the subjects were asked to produce (1) *papapa*, and (2) *tututu*, i.e. a series of alternating a closure with an open vowel articulation. In the sequential motion test the subjects were asked to produce (3) *takeli takeli takeli*, i.e. a more complex series of articulatory movements. The answers were tape-recorded and transcribed. The Intelligent Speech Analyser (ISA), a computerized equipment designed by the Finnish engineer R. Toivonen, was used to produce oscillograms of the subjects' answers.

Alajouanine, Ombredane and Durand (1939) distinguish three types of the phonetic disintegration syndrome: paralytic, dystonic and apractic. The paralytic disorder is

characterized by de-differentiation of the articulation. In the dystonic disorder the articulatory movements are too extensive and strong. The apractic disorder is an ideo-motor disturbance in which, for example, sounds may change places. For example, Love and Webb (1986) also discuss three different types of motor speech production problems, dyskinetic and spastic dysarthria and apraxia of speech.

5.2.1 Voice Quality

According to Love and Webb (1986), patients with dysarthria usually have an abnormal voice quality. Patients of the present study may have had a complex syndrome with both aphasia and dysarthria. For this reason a speech pathologist listened to the tape recordings (picture description) and evaluated the voice quality of the speakers. She was not provided with information about the speakers -- which were aphasics, and which were controls. Attention was paid to seven features: breathy, rough, creaky, aphonic, strained, back, and nasal voice. They were rated on a six point scale (0 - 5) where "0" marked the lack of the property in question, and "5" marked its greatest prominency. Also an average score was calculated. Table (5.2.1) presents the results.

In addition to the features indicated in table (5.2.1), Subject 3 had respiration problems which were obviously related to her pareses and to her being strapped into a wheel chair. Her voice was asthenic. According to the speech pathologist's intuitive judgement, Subjects 5 and 14. had abnormal voice qualities. Subject 5 had spastic dysphonia. The average score did not differentiate between normal and abnormal voice qualities. According to the average scores, the voice problem was noteworthy for the following subjects (the severest is mentioned first): 5 > 19 > 15 > 14 / 8. For research purposes it would be helpful if the scale could reliably differentiate between the normal, and at least the most prominently abnormal, voices.

Table 5.2.1 Voice Quality

The seven features of voice quality (breathy, rough, creaky, aphonic, strained, back, and nasal voice) were rated on a six point scale (0 - 5) where "0" marked the lack of the property, and "5" marked its greatest prominency. Also an average score (score) was calculated.

subject	breathy	rough	creaky	aphonic	strained	back	nasal	score
1	2	2	0	0	1	1	0	0.86
2	0	0	0	0	0	0	1	0.14
3	1	0	2	0	0	0	1	0.57
4	1	2	2	0	0	0	0	0.43
5	3	4	3	3	3	0	0	2.29
6	1	2	1	0	0	0	0	0.57
7	1	1	2	0	2	0	0	0.86
8	2	3	2	0	0	0	0	1.00
9	1	1	1	0	0	1	0	0.57
10	2	1	0	0	0	0	0	0.43
11	1	1	3	0	0	0	0	0.71
12	3	1	0	0	0	0	0	0.57
13	0	0	0	0	0	0	2	0.29
14	2	3	0	0	2	0	0	1.00
15	1	2	3	0	1	1	0	1.14
16	1	0	1	0	0	1	0	0.43
17	0	1	2	0	1	0	0	0.57
18	2	2	1	0	0	0	0	0.71
19	3	4	3	0	0	2	0	1.71
20	0	2	1	0	1	1	0	0.71

5.2.2 Alternate Motions

In the test of alternate motions the subjects were asked to say (1) *papapa*, and (2) *tututu* after a model pronounced by the examiner. According to Darley, Aronson and Brown (1975: 93), this test addresses the speed and regularity of reciprocal muscular movements. When analyzing the subject's test performance, attention should be paid to slow or fast rate, dysrhythmia or arrhythmia, and restriction in amplitude of motion. In this study, the way of administering the tests differed somewhat from the way they usually are described in the literature (Darley, Aronson and Brown, 1975; Baken, 1987). In fact, there are some differences between the ways of administration in the literature as well. At least the most serious disturbances can be detected even if the tests are administered in slightly different ways.

In order to determine the nature of the normal variation, the control data were analyzed first. The following features were observed: (1) the last syllable in the series was often the longest (final lengthening), (2) there was slight weakening towards the end of the series, (3) the average duration of one syllable depended on the total number of syllables in the series (the more syllables there were, the shorter the

syllables were), (4) the most common number of syllables in the series was six, and the average duration of a syllable varied between 182 - 197 ms. The oscillograms in figure (5.2.1) show the nature of these findings in controls; attention must be paid to the lengthening (Subjects 17 and 18) and weakening (Subject 19) of the last syllable(s). In comparison with the normal findings, there were some deviations in the data for Subjects 5, 6, 11, 12, and 14. The oscillograms in figure (5.2.2) show the nature of the difficulties.

Several types of difficulties were observed. There was relatively strong weakening in the last items of the series for Subjects 5 and 14. Control Subject 19 also weakened the last syllable, but there was a quantitative difference between normal and abnormal weakening. Subject 6 had a number of pauses in the repetition of the series. Subject 11 (and possibly 5 as well) tended to impose a rhythm on the series, i.e. the items were not produced at equal intervals. On the average, these items were somewhat longer than in the control data for Subjects 3, 5, 6, 8, 14, and possibly 9. Lengthening was most prominent for Subject 6.

Figure 5.2.1

Alternate Motions (comparison data)

The following control subjects' responses show mild lenghtening and weakening of the final syllables. The oscillograms are made with ISA.

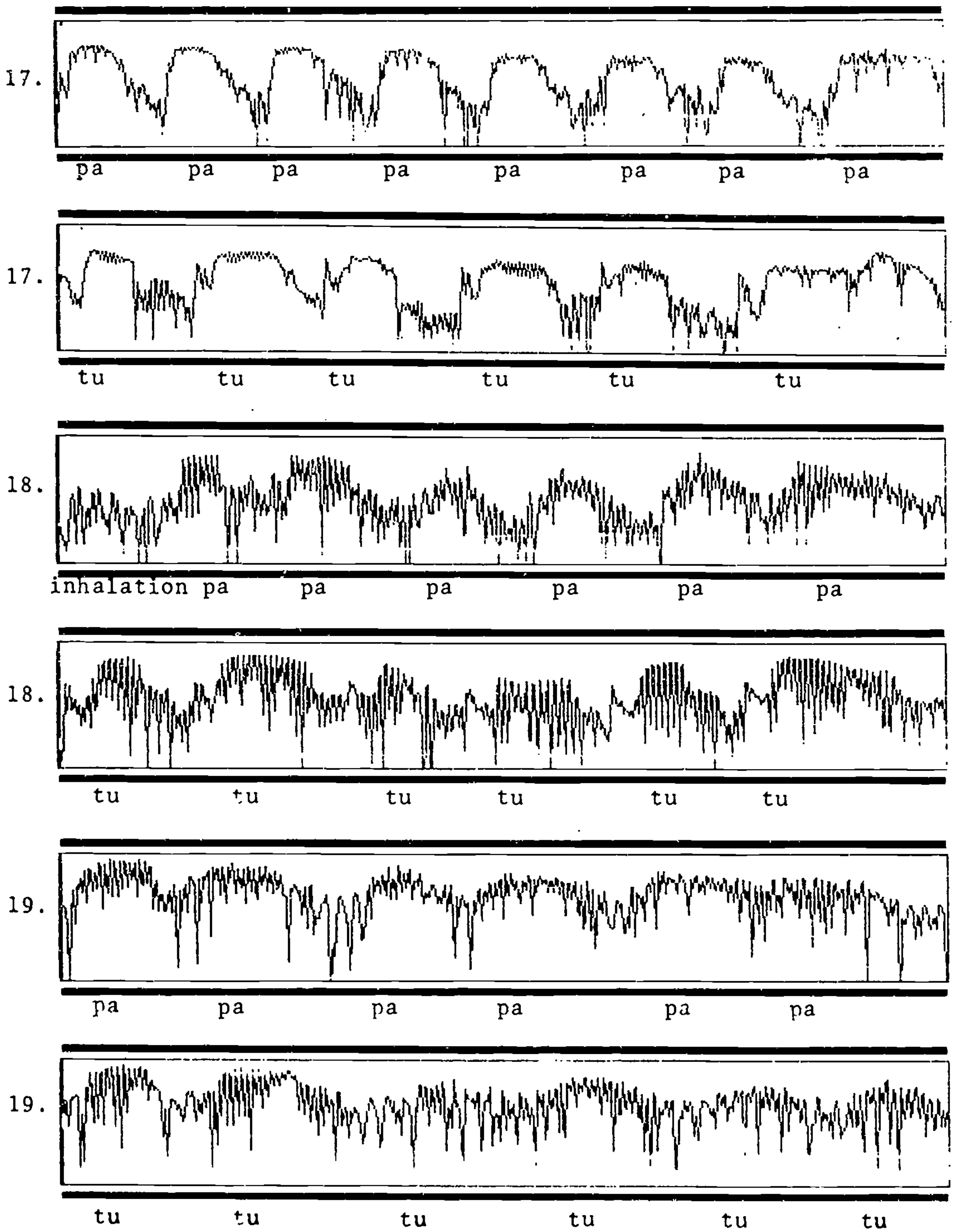


Figure 5.2.2

Alternate Motions (aphasic speakers)

For Subjects 5 and 14, there was a weakening of the last items in the series. Subject 6 paused many times in the production of the series. Subject 11 (and possibly 5 as well) tended to impose a rhythm on the series, i.e. the items were not produced at equal intervals. Oscillograms were made with ISA.

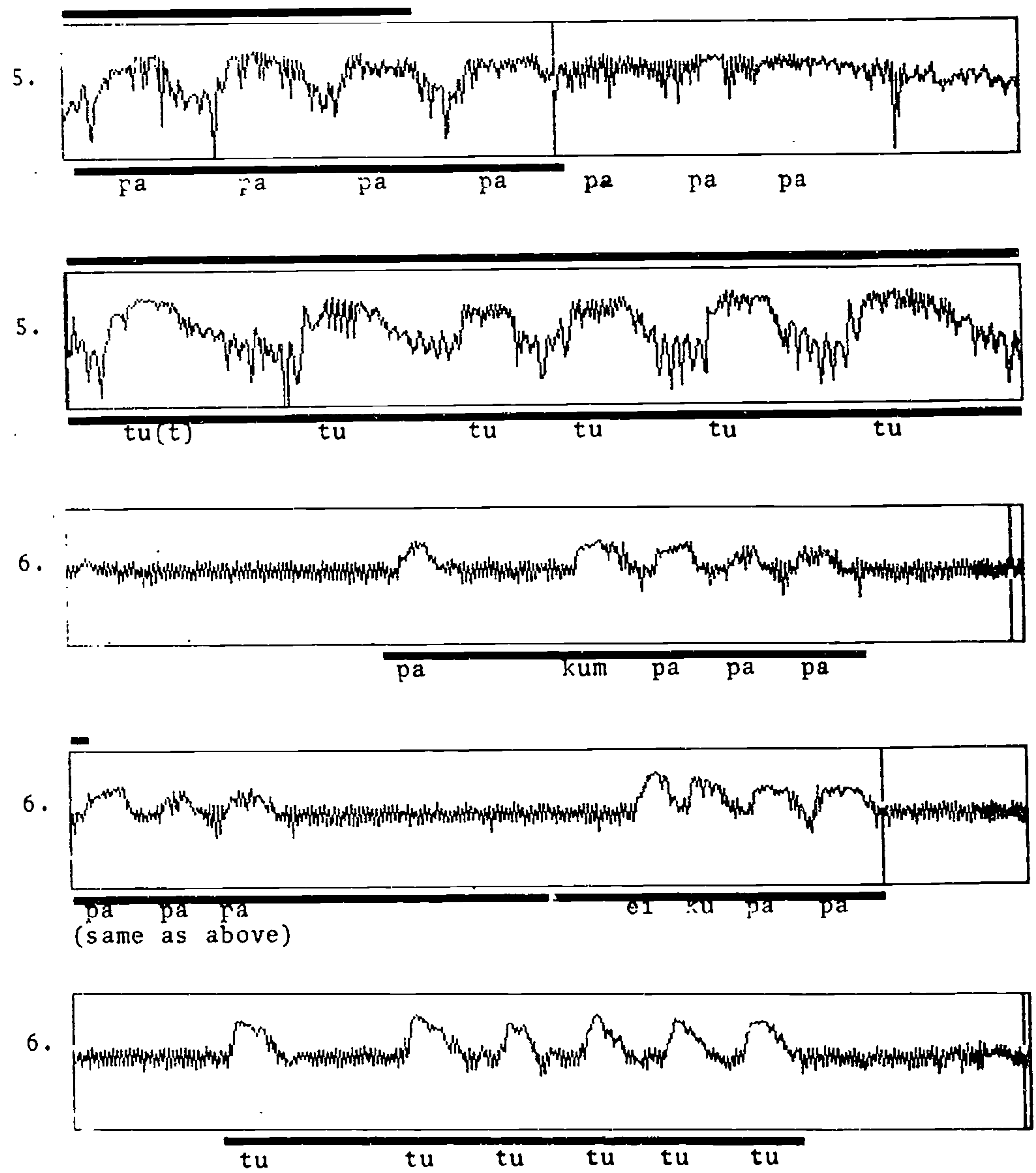
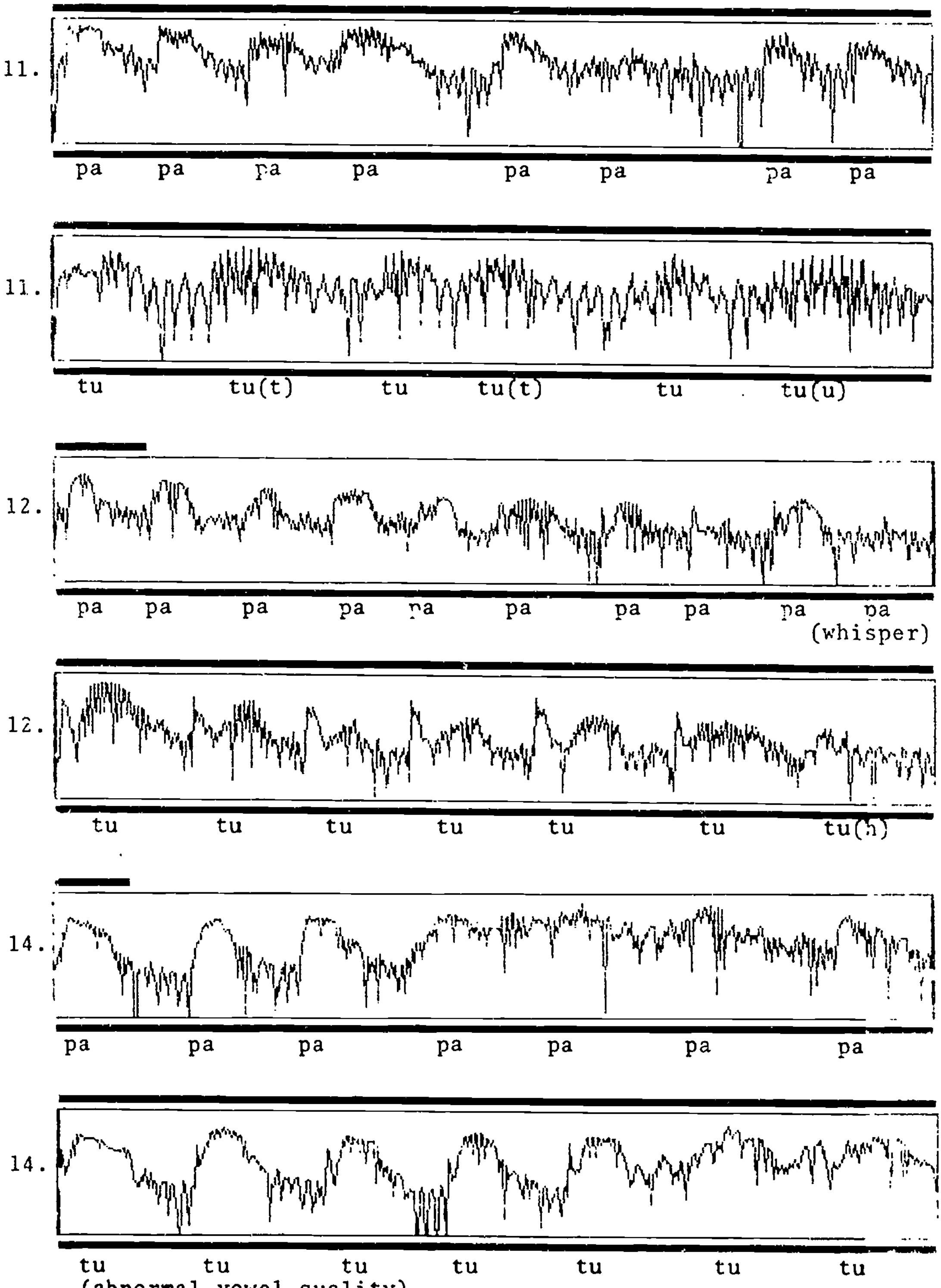


Figure 5.2.2 contd.



5.2.3 Sequential Motions

According to Darley, Aronson and Brown (1975: 94), the most useful tool for predicting motor programming difficulties associated with speech apraxia is a test that focuses on the ability to move quickly from one articulatory position to another. Darley et al. differentiate between dysarthria and speech apraxia on the basis of different error types.

Apractic patients had a tendency to break down in their transition between the sounds, often blocking, transposing, or omitting sounds. Dysarthric patients had little difficulty making smooth transitions from one sound to the next, but their total production was characteristic of their particular type of dysarthria.

In the present study, when the examiner gave the subjects a model containing three items, then in turn, the control subjects usually produced a three item answer. The duration (Tdur) of the series usually varied from 1400 to 1700 ms, but it was sometimes longer (especially when more items were produced). Subjects 2, 4, 5, 6, 8, 9, 10, 11, and 14 differed from the controls. Table (5.2.2) presents the transcriptions of these subjects' answers.

Table 5.2.2 Errors in the Sequential Motion Test

The transcriptions of those subjects' productions that differed from the control data are provided. The numbers refer to the subjects, the dots indicate breaks in the series, and the hyphens refer to syllable segregation.

2: takeli takeli takeli ... takeli
4: taken ... taken ta taki ... kili ta takeli ... takeli takeli takeli takeli
5: pakeli ... a(h) ... i ... a ... pakeli pakeli
6: sa ... eikun takeli kateli takeli voih
8: kateli katei mhm takeli takeli takeli
9: kakeli takeli takeli
10: tah ... takeli takeli takeli
11: kateli kateli kateli
14: a-te-li ta-te-ti-ti ta-te-ti ei o hyvä ... ja-te-li ta-te-ti-li

Subjects 2 and 10 made errors that were not necessarily pathological, but instead could be interpreted as hesitations. Subject 4 produced a long series of approximations before producing the correct targets. According to the test of alternate motions, Subjects 5, 6, 11, and 14 showed signs of "dysarthria", and will be discussed later.

In addition to the dysarthric errors, a common error type was metathesis. Subjects 6, 8, and 11 made metathesis errors. In all instances, the stops /k/ and /t/ were interchanged. It may be the case that /k/ is a sound that is easily anticipated. In an electropalatographic study of articulation in speech apraxia, Hardcastle (1987) showed

that his subject had common inappropriate /k/ articulations, either as substitutes for other sounds, or as extra articulations occurring simultaneously with other sounds (especially with stops). However, there may be other explanations for the present errors. For example, consonants may have a preferred order, such as a sonority order (the more sonorous the consonant, the later it occurs in a word), or the preferred order may be related to the consonant's place of articulation. The current error simplifies the structure of the word so that consonants with common places of articulation occur closer to one another: a dental-velar-dental string becomes a velar-dental-dental string. In principle, the fact that series are "repeated" after the examiner (i.e., the speech perception factors) also should be taken into consideration.

Subject 9 made an anticipation error in the first item of the series. Shattuck-Hufnagel (1987: 20) proposed that metathesis errors were, in fact, a combination of anticipation and substitution: often a segment that occurred later in the word was substituted for the first consonant of the word (anticipation), and the first segment was kept in mind and produced later in the word in place of the anticipated consonant. Shattuck-Hufnagel considered this to be an argument in support of the separate representation of segments and the slots of the segments (for example, in the syllable tier).

According to Darley et al. (1975), patients with dysarthria should fail in the alternate motion tests. The same patients should perform well in the sequential motion tests, or their difficulties should be of the same type as in the alternate motion tests. In the present study there were five subjects (5, 6, 11, 12, 14) who had some difficulties with alternate motions. Of these subjects, the only patient to perform well in the sequential motion tests was Subject 12. In fact, his behavior in the alternate motion test (whispering the last syllable) is not necessarily a sign of dysarthria. Thus, in the present data no clear-cut difference was found between "dysarthria" and "apraxia of speech". Theoretically, this result could give rise to different speculations, but as far as the present patients are concerned, the most likely solution is the complex nature of their syndromes with some dysarthric, apractic and aphasic signs.

Love and Webb (1986) considered voice quality to be a feature that distinguished dysarthria from apraxia of speech. In the present study there were two patients (5 and 14) who had voice disorders. Subject 5 had spastic dysphonia, and Subject 14 had a rough, strained, and breathy voice. Both had dysarthria according to Darley's et al. classification. According to the criteria of Darley et al., Subject 6 clearly fell into the dysarthric group. However, Subject 6's voice quality was difficult to judge because of background noise in the recording.

On the basis of the descriptions by Alajouanine et al., patients with paralytic disorders have some de-differentiation in their articulation. Thus, the contrasts between, for example, an open vowel articulation and a closed consonant articulation should become less differentiated. This kind of a behavior surfaces in the alternate motion test as a weakening of final syllables. Subjects 5 and 14 showed such final syllable weakening. In the sequential motion test, these subjects made assimilation errors. When Subject 5 produced the sequence *pakeli a(h)-i aa pakeli pakeli*, the hesitation *a(h)-i* looked like an attempt to say *pakeli* on the oscillogram. The overall durational pattern was similar to the other items, and the vowels of the first and third syllables were "correct". Subject 14 generally assimilated all the consonants to /t/. All the sounds were lengthened. Subject 9 also made an assimilation error which was somewhat difficult to hear, and could give rise to different interpretations in a listening experiment. The assimilatory segmental errors in the sequential motion test were somewhat different from the articulatory de-differentiation in alternate motions. The phenomenon observed in alternate motions can be described as gesture reduction (Valdois, Joanette, Nespoulous and Poncet, 1988). These symptoms will be discussed in chapter 5.4.2.

In a dystonic disorder, articulatory movements are too extensive and strong. The phonological errors should show strengthening, for example stops could be substituted for fricatives. Sounds should also be longer than normal. In the present study, the series in the sequential motion test consisted of maximally differing sounds: there were many vowels and stops. However, the consonant /l/ of *takeli* could be substituted by a stop, probably /t/, in a dystonic disorder. Subject 14 may have shown some of this tendency, for he said *a-te-li ta-te-ti-ti ta-te-ti ... ja-te-li ta-te-ti-ti*. The items were articulated syllable-by-syllable, as well as possibly being lengthened. Lengthening was strongest for Subject 6, whose items also contained the highest number of pauses.

Articulation deficits seem to be qualitatively different. On the basis of the present data it is difficult to say which behaviors were dissociated.

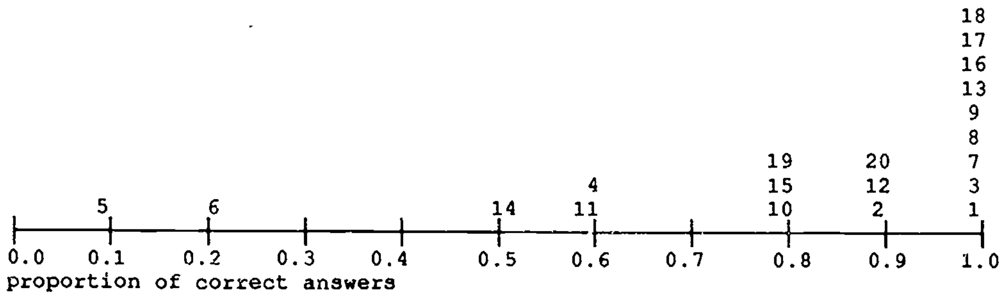
5.2.4 Repetition of CV-Syllables

Another measure of articulatory "fluency" is the repetition of syllables. Subjects who are unable to repeat syllables (i.e. articulate them properly) are sometimes considered to have motor control problems.

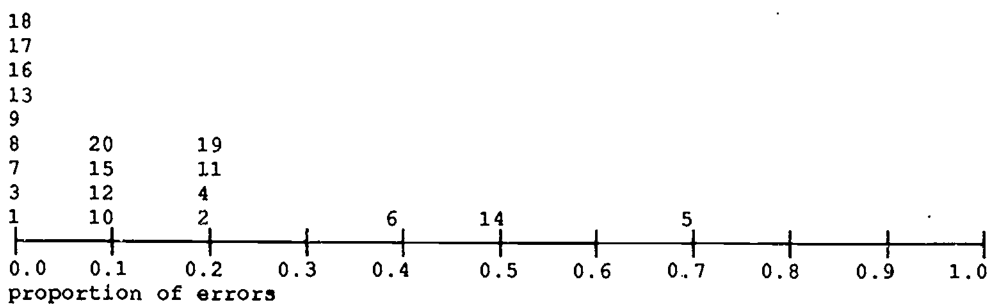
The following scales present the number of errors occurring in CV-syllable repetitions. The errors were of two types, either no answer was given, or a phonological error was made. The results are presented in figure (5.2.3). Scale (a) presents the total amount of errors, and scale (b) presents the number of phonological errors.

Figure 5.2.3 Repetition of CV-Syllables

a. Prop··tion of correct answers
(the numbers refer to subjects)



b. Proportion of phonological errors
(the numbers refer to subjects)



Subjects 5, 6, 14, 4, and 11 frequently made errors in the test. Phonological errors were typical for patients 5, 6, and 14. Subject 5 made many errors where the vowel of the CV-syllable was considerably lengthened, which often changed the syllable into a word (e.g. *pä* > *pää* 'head', *su* > *suu* 'mouth')

5.2.5 Results from the Articulation Tests

Results from the articulation tests are presented in figure (5.2.4). The most interesting variables differentiating between subjects are listed, as well as the subjects who had particular difficulties with these tests. The selection of the subjects (variables 4 and 5) was done on the basis of a visual inspection of a diagram which compared the subjects' performance (an example of such a diagram for variables "repetition errors" and "phonological errors", as well as the selection criteria for subjects who differed from the others, is found in figure 5.2.3).

Figure 5.2.4 Results from the Articulation Tests

The results from the tests differentiating between subjects are included in the comparison. Numbers refer to subjects who had more difficulties than other subjects according to the variable in question. Variable 4 (repetition errors) is determined on the basis of the proportion of correct answers in the syllable repetition test, and variable 5 (phonological errors) is determined on the basis of the proportion of phonological errors in the syllable repetition test.

1. voice quality:		5	?					14
2. alternate motions:		5	6			11	12	14
3. sequential motions:	4	5	6	8	9	11		14
4. repetition errors:	4	5	6			11		14
5. phonological errors:		5	6					14

Three patients (5, 6, 14) had extensive articulatory difficulties (dysarthria) that accompanied their aphasia, and these problems appeared to set this group apart from the others. These patients had abnormal voice qualities, difficulties in the alternate motion test, and they also made numerous phonological errors in the repetition test. Subjects 11 and 12 also had some articulatory difficulties. The sequential motion test proved difficult for all those subjects who failed the alternate motion test. However, Subject 12 showed evidence of a possible double dissociation between alternate and sequential motions. Results from the sequential motion test and from the syllable repetition test (according to the variable "total amount of errors") were similar: the same subjects had difficulties in both tests. These variables revealed more abnormalities than did the alternate motion test, evaluation of voice quality and the syllable repetition test (variable "phonological errors").

5.3 Repetition, Naming and Picture Description

The speech samples that were obtained from the repetition, naming and picture description tests were transcribed. The present analysis is somewhat "superficial" as it is based solely on the transcriptions made by the author. However, the aim of the analysis is to provide a general overview of the problem. Sub-samples of the data will be analyzed in more phonetic detail (c.f. chapter 6). The present study focuses on the segmental errors that were committed. In order to be able to compare the tests, a coding system was designed on the basis of the literature and the present data.

5.3.1 Coding of the Data

Different error types are usually associated with different types of aphasia. For example, according to Kohn (1985), three stages of naming can be distinguished on the basis of error types. Neologistic responses are characteristic of the "highest" stage of naming, patients who suffer from a deficit of the pre-articulatory coding make literal paraphasias, and patients with motor speech production difficulties make distortions. The coding categories used in the present study are very traditional: phonological (literal) paraphasias, semantic paraphasias, verbal paraphasias and neologisms. This data is reported in the tables entitled "error types". The definitions of the categories are presented in table (5.3.1). Of these error types, phonological paraphasias and neologisms together will be referred to as phonological errors.

Table 5.3.1 Error Types Used in the Error Classification

Phonological paraphasia: Those forms containing single sound substitutions or forms in which there is a more complex cluster of several sound substitutions. The result is a non-word, or a word that is inappropriate for the context. In the repetition and naming tests the targets are known to the author, and it is easy to identify the phonemic substitution(s) (for example, *sänty 'sänky'*, *kameri 'kameli'*, *katitsa 'katiska'*, *kaksu 'kaktus'*, *huuli hamp lamppu 'huuliharppu'*). Even in picture description, the target words are usually easy to guess.

Semantic paraphasia: Words that are semantically related to the target, i.e. they belong to the same semantic field, are close associates, semantic opposites, etc. (for example, *piisami* 'muskrat' instead of *majava* 'beaver'; *tuoli* 'chair' instead of *pöytä* 'table'; *siili* 'hedgehog' instead of *etana* 'snail').

Verbal paraphasia: Words that are not similar in sound or meaning to the target, i.e. not a phonemic or a semantic paraphasia (for example, *riikinkukko* 'peacock' for *pyramidi* 'pyramid'; *lammas* 'sheep' for *naamari* 'mask'). These errors were rare in the data, and this category does not appear in the tables. Special mention is made of this type of errors in chapter 5.4.2.

Neologism: Non-words that are impossible to interpret, i.e. forms that do not resemble a word in the language, and that cannot be interpreted as a word containing several phonemic paraphasias (for example, *perkyrikoona* instead of *pingviini* 'penguin'; *masyrsmy* instead of *majava* 'beaver'; *balkki* instead of *pingviini* 'penguin')[1] .

Perseveration: Used only in the naming test, this category refers to the process of being fixated on the name of a previous item, and a continued reference to subsequent items by the same name.

In their analysis of sequences of phonemic approximations, Joanette, Keller and Lecours (1980) found that patients with conduction aphasia were more successful in correcting their own errors than patients with other types of aphasia. The phonemic approximations were analyzed with a computer program that determined the phonemic substitutions according to a feature system.

For the purposes of the present study, only the total number of two attempt and three or more attempt sequences were calculated. Furthermore, the number of successful corrections were recorded (i.e. the last item of the sequence was the correct target). The study focused on phonological sequences only. Thus, semantic sequences of the type *tuo virtahepo eiku sarvikuono tämä o* 'well hippopotamus no rhinoceros is this' were ignored. False starts in the beginning of a sequence were not calculated as attempts when they contained a vowel or a CV-syllable. Longer "syllables", however, were calculated. CV-syllables that occurred between longer trials were also calculated. Phonological sequences that were attempts at a semantic paraphasia were treated as if the semantic paraphasia were the correct target. For example, *pen se tota peli* 'game'

[1] In the error data there are items that are not easy to classify. For example, a patient with severe articulatory problems and semantic difficulties may give a naming response that looks like a neologism, even if it may, in fact, be a distorted circumlocution or a contamination error. The distinction between literal paraphasias and distortion errors can also be problematic. Many patients make both types of errors, and the listener may easily become accustomed to a subject's particular "style". However, interpretative difficulties are not very common, and they do not change the overall results.

instead of *maila* 'racket' was considered a successful correction.[2] This data and the error types are reported in the tables entitled "error types".

In the speech apraxia literature it is claimed that the longer the word, the more prone the speech apractic patient is to make phonological errors. The phonetic composition of the item has an effect, too – the more complex it is, the more common the errors (consonant clusters have proved to be particularly troublesome). In order to test these results, the proportion of phonological errors was compared for targets of varying length in the repetition and naming tests. This data is reported in tables entitled "comparison of short and long targets".

Phonological paraphasias are most often classified as substitution, deletion, addition or metathesis errors (e.g. Niemi, Koivuselkä-Sallinen, and Hänninen, 1985). According to Blumstein (1973), these categories do not differentiate between types of aphasia. However, it has been suggested that a more detailed error analysis may reveal differences between types of aphasia (Caplan, 1987).

One of the most extensively studied aspects of phonemic paraphasias is the markedness effect. According to Blumstein (1973) and MacNeilage (1983), errors are simplifications (unmarked sounds tend to be substituted for marked sounds, regardless of the criteria for markedness). However, according to Shattuck-Hufnagel and Klatt (1979), sound substitutions that occur in slips of the tongue are not simplifications. Similar results have been obtained for some types of aphasia. Thus, there is controversy about the nature of phoneme substitutions in aphasics (Lecours and Nespoulous, 1988). In order to find out whether or not there are differences between aphasia types, and whether or not all sound substitutions are simplifications, the analysis of aphasic speech errors must be made with phonetic precision. The speech

[2] For subjects with both semantic and phonological problems, the categorization of sequences was sometimes problematic. An attempt was made to count the phonological approximations and ignore the semantic errors. The combination of the two error types was characteristic for subjects 9 and 11. Subjects 15 and 19 also made some of this sort of errors.

During the testing sessions (especially with patients who had severe naming difficulties), there were instances in which the examiner needed to say something, for example, to ask if the picture was clear enough, or to encourage the subject to take his/her time and think about the name. Only answers provided before the examiner's "interruptions" were analyzed. However, examiner's short comments such as *joo* 'yea' were not considered interruptions.

The effect of different types of cues was not studied in detail, and the types of cues given depended on the examiner's intuition. Preferred cues were those that appeared to be most helpful to the patient - some patients benefited from phonological cues, whereas some patients found semantic cues more helpful.

The number of phonological errors depended on whether attention was paid to the first attempt, or to the last attempt (that was often correct). When the proportions of different error types were analyzed, the last attempt in a series of approximations was always analyzed. In contrast, when the phonological error types were analyzed in closer detail, incorrect answers before the patient's own corrections were also included in the analysis. The inclusion of all phonological errors (regardless of the patient's ability to correct the errors) provided a more solid data base for the linguistic analysis of error types.

production errors should be distinguished from the listener's misinterpretations which may be common when deviant speech is analyzed.

There is ample evidence that word-initial errors are very common in speech apraxia. According to Burns and Canter (1977), patients with posterior lesions made most of their errors word-finally. Thus, the location of the error in the word may differentiate between types of aphasia.

Keeping in mind all the aforementioned issues, an error classification system was developed. It was tested with the error data obtained in the repetition, naming and picture description tests. If some interesting features of the errors caught the attention of the author, these features were added to the classification system. Thus, the system is a compromise between the features reported in the literature and the features found in the present data. The results of the error classification are reported in the tables entitled "phonological characteristics of the errors". These tables give the following information:

1. total number of phonological errors

2. Errors were classified under four categories: real words (in the repetition test only), neologisms, literal paraphasias (defined as phonological paraphasias with only ONE sound substitution) and complex phonological paraphasias (with two or more literal paraphasias). If no errors of the given type were found in the test, the category was then deleted from the table (for simplicity of presentation).

3. number of syllable deletions

4. number of anticipations (e.g. *rorsu 'norsu'*), metathesis errors (e.g. *kamppi 'pankki'*, *kesikelä 'kesäkeli'*) and phoneme perseverations (e.g. *titta 'tippa'*)

5. number of errors with consonants and vowels

6. The word-initial errors of the repetition test were classified in three categories: x>p, x>t, and x>k. In the naming test such a classification was not useful (a remarkable number of errors were left unclassified). Thus, a more useful classification was used: the errors were classified under deletions and substitutions of the word-initial sound (usually consonant), deletions of the word-final sound, and word-final additions of sounds.

7. The errors were classified under three categories -- word-initial, word-medial, and word-final errors.

5.3.2 The Repetition of Real Words and Non-Words

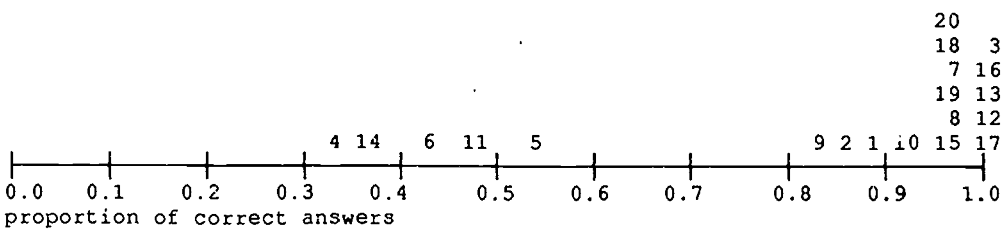
A description of the repetition test is found in chapter 4 (iv). Syllable repetitions were discussed in connection with the articulation tests (c.f. chapter 5.2).

Figure (5.3.1) presents the proportion of correct answers in the repetition test (correct answers/items presented): (a) the repetition of real words and (b) the repetition of non-words. Subjects 4, 5, 6, 11, and 14 had the worst performances on the repetition test. Here, the most typical errors were phonological errors. Sometimes the subjects did not give an answer, in which case they often asked the examiner to repeat the item.

Figure (5.3.2) presents the proportion of phonological errors in the repetition test (errors/items presented): (a) for real words and (b) for non-words. The result shows that the phonological factors accurately predict the overall performance of the subjects. Some minor factors (e.g. the effect of speech perception) may also be involved. These effects should be studied with more sensitive experimentation.

Figure 5.3.1 Proportion of Errors in the Repetition Test

a. Proportion of correct answers in the repetition of real words
(the numbers refer to subjects)



b. Proportion of correct answers in the repetition of non-words
(the numbers refer to subjects)

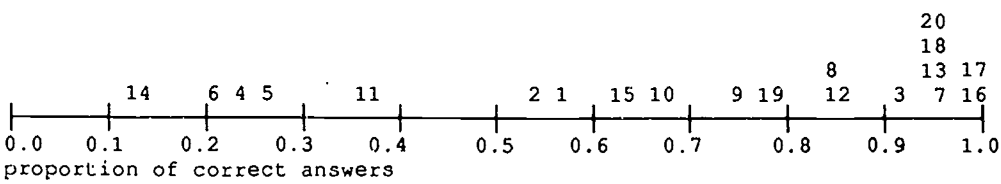


Figure 5.3.2 Number of Phonological Errors in the Repetition Test

a. Proportion of phonological errors in the repetition of real words
(the numbers refer to subjects)

```
    8
20 10
18  1
17 15
16 12
13 19
 3  7 2   9            5  11      4   6  14
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
0.0      0.1       0.2       0.3       0.4       0.5       0.6       0.7       0.8       0.9       1.0
proportion of errors
```

b. Proportion of phonological errors in the repetition of non-words
(the numbers refer to subjects)

```
  7 12
 18 20
 17 13     15            11                        14
 16  3   8 10 19 1   9      2   4         5         6
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
0.0      0.1       0.2       0.3       0.4       0.5       0.6       0.7       0.8       0.9       1.0
proportion of errors
```

According to both analyses, non-words were more difficult than real words. The subjects' performances (the proportion of correct answers) varied between 0.35 and 0.99 for words, and between 0.15 and 0.98 for non-words. Valdois, Joanette, Nespoulous and Poncet (1988) did not report such differences between words and non-words. They maintained that the length of the items between words and non-words had not been controlled in earlier experiments. However, the controls of the present study made some errors when repeating non-words but they made very few errors when repeating long words. Item length alone does not account for the observed differences. This means that repetition must be facilitated by either the meaningness of the item, or a subject's familiarity with the item (i.e. the existence of the item in a subject's lexicon). It is difficult to determine whether or not the effect should be attributed to the production or perception aspects of the repetition test. The extent of top-down processing in speech perception is often characterized by the degree to which non-words are repeated as real words. Repetition of non-words as real words was a common error type for Subjects 6, 11, and 14. These subjects did not have difficulties in the syllable discrimination test, but they had some speech

perception or comprehension difficulties judging from their performances in the word-picture matching test. They also had some difficulties in the articulation tests (c.f. chapter 5.2.2).

McCarthy and Warrington (1984) have distinguished between a lexical strategy and a phonological strategy in speech production. According to this two-route hypothesis, words and non-words could be processed by different strategies. Another interpretation of a double dissociation between word and non-word repetition states that the difference gives us some qualitative information about the nature of the repetition process (which is somewhat different for words and non-words). This problem will be discussed in detail in chapter 5.4.1.

In the repetition test, there were no semantic paraphasias, verbal paraphasias or neologisms. All errors were phonological paraphasias. For this reason, table (5.3.2) only deals with information about the subjects' attempts at self-correction.

Table 5.3.2 Error Types in Repetition

Variables:
total = number of errors of sound structure (successfully corrected items were not counted as errors)
2 = number of sequences of phonemic approximations with two items
≥3 = number of sequences of phonemic approximations with three or more items.

The numbers in brackets indicate the number of sequences that end with a correct answer, i.e. that self-correction is successful.

subject	total	2		≥3	
1	11	5	(4)	1	(0)
2	21	3	(1)	0	(0)
3	0	1	(1)	0	(0)
4	117	20	(3)	29	(0)
5	85	9	(4)	12	(4)
6	134	12	(4)	4	(3)
7	3	2	(2)	0	(0)
8	12	7	(6)	2	(0)
9	32	1	(0)	3	(0)
10	11	9	(7)	1	(0)
11	96	15	(0)	16	(2)
12	5	5	(5)	0	(0)
13	1	0	(0)	0	(0)
14	149	10	(1)	7	(2)
15	6	4	(3)	2	(0)
16	1	2	(2)	0	(0)
17	1	0	(0)	0	(0)
18	1	0	(0)	0	(0)
19	2	0	(0)	0	(0)
20	0	0	(0)	0	(0)

The controls made few errors in the repetition test. These subjects seemed to be unaware of their errors, otherwise they would have tried to correct the errors. One could, thus, conclude that the errors were misperceptions. The two errors of Subject 16 were "jokes" which he corrected with an apology (he was asked to take the test

seriously). The greatest number of corrections were made by Subjects 1, 7, 8, 10, 12, and 15 who made only few phonological errors. Those subjects who made frequent phonological errors (Subjects 4, 5, and 11) also corrected their errors, whereas Subjects 6 and 14 made no attempt to correct their errors. A lack of self-correction may indicate that either the subject is not aware of the error, or that he or she finds the situation hopeless: the speech output problem is so pervasive that it is futile to try and correct the errors. The nature of the subjects' response depended on the length of the item. For some patients, like Subjects 8 and 10, longer words were tongue-twisters, and these patients often produced a series of approximations in long words.

In the word repetition test, it is a common observation that the longer the items and the more complex their phonetic composition, the more frequent phonological errors occur. These factors were varied also in the present repetition test. The words were divided into three groups: bisyllabic words without a consonant cluster between the first and second syllables (103 words), bisyllabic words with a consonant cluster between the first and second syllables (51 words), and words longer than three syllables (31 words). The long words were further divided into two groups -- derivations and compounds. The items in each group are listed in appendix (5). Table (5.3.3) provides information about the subjects' performance in these word groups.

Table 5.3.3 A Comparison of Short and Long Targets in Repetition

The number of errors for different types of targets are compared: "simple" words are bisyllabic words without consonant clusters, words entitled "cons-clusters" are bisyllabic words with a consonant cluster between the vowels of the first and second syllables, and "long" words consist of four or more syllables. These are further divided into derivations and compounds. The items of each word group are listed in appendix (5).

The abbreviations in the tables are:
pho = number of phonological errors
non = number of non-answers (indicated only if non-answers were provided)
pro1 = proportion of phonological errors
pro2 = proportion of incorrect responses (phonological errors and non-answers combined).

table 5.3.3 continued on the following page

a. simple words, words with consonant clusters, and long words

subj	long				simple				cons-clusters			
	pho	non	pro1	pro2	pho	non	pro1	pro2	pho	non	pro1	pro2
1	5		0.16		6	(1)	0.07	(0.08)	1	(4)	0.02	(0.10)
2	7		0.23		8	(1)	0.10	(0.11)	8	(1)	0.16	(0.18)
3	1		0.03		2		0.02		0			
4	19	(2)	0.83	(0.91)	43	(2)	0.51	(0.54)	27	(3)	0.53	(0.59)
5	19	(2)	0.61	(0.68)	27	(6)	0.32	(0.39)	16	(2)	0.31	(0.35)
6	22		0.71		46		0.55		34		0.67	
7	0				0				0	(1)	0	(0.02)
8	8		0.26		1		0.01		1		0.02	
9	10		0.32		9	(1)	0.11	(0.12)	4		0.08	
10	8		0.26		4		0.05		2	(1)	0.04	(0.06)
11	21	(5)	0.68	(0.84)	31	(3)	0.37	(0.40)	21	(2)	0.41	(0.45)
12	1		0.03		2		0.02		1		0.02	
13	1		0.03		1		0.01		0			
14	26		0.84		47		0.56		36		0.70	
15	2	(1)	0.06	(0.10)	2	(2)	0.02	(0.05)	1		0.02	
16	0				1		0.01		0			
17	0				1		0.01		0			
18	0				1		0.01		1	(1)	0.02	(0.04)
19	2		0.06		6		0.07		3		0.06	
20	0				0	(1)	0	(0.01)	2		0.04	

b. derivations and compounds

subj	derivations				compounds			
	pho	non	pro1	pro2	pho	non	pro1	pro2
1	3		0.20		2		0.12	
2	4		0.27		3		0.19	
3	1		0.06		0			
4	7	(2)	0.70	(0.90)	12		0.92	
5	8	(1)	0.53	(0.60)	11	(1)	0.64	(0.75)
6	10		0.67		12		0.75	
7	0				0			
8	6		0.40		2		0.12	
9	6		0.40		4		0.25	
10	4		0.27		4		0.25	
11	11	(2)	0.73	(0.87)	10	(3)	0.62	(0.81)
12	0				1		0.06	
13	0				1		0.06	
14	14		0.93		12		0.75	
15	2		0.13		0	(1)	0	(0.06)
16	0				0			
17	0				0			
18	0				0			
19	1		0.06		1		0.06	
20	0				0			

Most of the aphasic subjects found "simple" bisyllabic words to be the easiest. Bisyllabic words with consonant clusters were somewhat more difficult. Two subjects (Subjects 6 and 14, and possibly a third -- Subject 2), showed a clear difference in performance with "simple" and "complex" bisyllabic words. This difference could be attributed to the increase in difficulty due to consonant clusters. "Long" words (as compared to "simple" bisyllabic words) caused difficulties for Subjects 2, 4, 5, 6, 8, 9,

10, 11, and 14. The aphasic patients all had more difficulty with the long words than with the bisyllabic words containing consonant clusters. For those subjects with few phonological errors (Subjects 1, 3, 7, 12, and 13), the effect of length was negligible.

As far as long words are concerned, one could predict that compounds would be less difficult than derivations. It is relatively natural to reproduce compounds as two words, but it is more difficult to divide derivations into shorter parts. Subjects 8, 9, and 14 (as well as to Subject 11 to a lesser extent) had most difficulties with derivations, whereas Subjects 4, 5, and 6 clearly had more difficulties with compounds than with derivations. It is possible that Subjects 8, 9, and 14 had an articulatory disorder which allowed them to take advantage of the linguistic structure of the word. In contrast, Subjects 4, 5, and 6 had a more complex aphasia, with also other than phonological problems. More detailed studies of the morphological structure and its reflection in aphasic speech are needed in order to properly interpret the above finding.

Table (5.3.4) presents the subjects' errors, classified according to the phonological features presented in chapter 5.3.1. For the purposes of this study, only the words of the acoustic analysis (c.f. appendix 5) were studied. The words of the acoustic analysis were relatively homogeneous as to phonetic composition. Thus, in this sample there were neither long words nor words containing consonant clusters. On the one hand, this simplifies the comparison; on the other hand, it may also bias the results because some patients make errors only in long words. Furthermore, the error types may differ slightly, depending on whether the phonetic composition of the words is simple or complex.

Most subjects made more consonant errors than vowel errors, with three exceptions -- two controls (19, 20) and patient 4. The errors made by patient 4 differed from the other patients' errors in other respects as well: he had more complex errors than literal paraphasias, and word-final errors were the most common. This patient often substituted the last vowel of the word with an /i/, (this occurred in twelve examples in the acoustically analyzed data). An extra consonant was added word-finally in six responses, either a /t/ (the plural suffix) or a /n/ (the genitive, accusative, sg 1 person suffix). Other aphasics with phonological difficulties had a tendency to make errors either word-initially or word-medially. For those patients, either literal paraphasias predominated, or there was an equal mixture of literal paraphasias with complex errors in their responses. These results will be discussed in chapter 5.4.2.

Table 5.3.4 The Phonological Characteristics of the Repetition Errors

(the analysis is based on the acoustically analyzed data;
the definitions of the error types are provided in table 5.3.1)

Subject	Number of errors	word substitution	literal paraphasia	complex paraphasia	syllable deletion	anticip	metathesis	perseverat	cons	vowel	x > p	x > t	x > k	initial	middle	final
1	5	4	1	0	0	0	0	0	1	0	0	0	1	1	0	0
2	12	4	5	0	1	0	0	1	3	2	0	0	2	4	1	0
3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	54	6	21	27	4	0	2	11	5	49	0	0	1	2	22	47
5	39	3	28	11	0	4	0	0	36	15	0	4	3	24	19	3
6	59	8	19	16	0	5	2	0	32	7	1	0	4	53	14	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	1	0	0	2	0	0	2	0	0	0	0	2	0	0
9	11	3	6	1	1	0	0	1	5	4	0	1	1	5	3	0
10	9	5	1	?	0	1?	1?	0	3	1	0	0	0	2	2	1
11	37	4	24	12	0	4	5	1	40	1	0	3	19	32	15	3
12	3	0	1	2	0	0	0	1	3	2	1	0	0	2	2	1
13	1	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0
14	63	11	30	27	0	7	2	4	73	8	1	5	9	41	48	3
15	3	1	2	0	0	0	0	0	2	0	0	0	1	2	0	0
16	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0
18	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	7	4	2	1	0	0	0	0	0	2	0	0	0	0	0	3
20	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0

Additional remarks about the subjects' errors:

Subject 2: There were two distortion errors.
Subject 4: A consonant was added word-finally ten times, word-final vowel was substituted by /i/ 22 times (sometimes /i/ was produced unclearly and resembled the neutral vowel.
Subject 5: A word-initial consonant was deleted in nine items, word-final vowel was substituted by /i/ once.
Subject 6: A word-initial consonant was deleted or substituted in 39 items.
Subject 9: The items were produced with an intonation typical of word lists.
Subject 10: Some errors were difficult to classify.
Subject 14: A word-initial consonant was deleted in 6 items, a short word-medial consonant was produced as long in 16 items.
Subject 19: A word-final vowel was substituted by /i/ in two items.

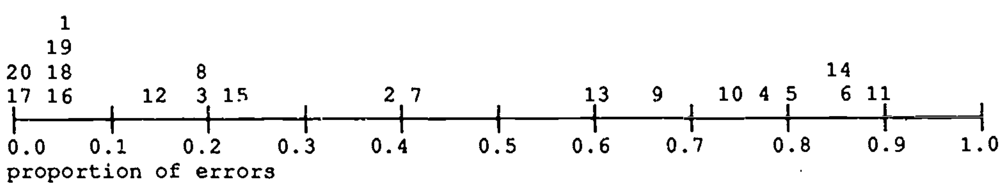
5.3.3 Confrontation Naming

The subjects were administered the Finnish version of the Boston Naming Test (Kaplan, Goodglass, and Weintraub, 1983; Laine, 1985). Subject 4 was given a modified version consisting of thirty words from the beginning of the test.

Most of the aphasic subjects made many errors in the naming test. At least 25 % of the items were left unnamed or were named incorrectly by Subjects (2), 4, 5, 6, (7), 9, 10, 11, 13, 14, and 15. Of these subjects, 2 and 7 committed the fewest errors. The reasons for the errors in the naming test can be attributed to the following factors: poor knowledge of the test items (e.g. sarcophagus), visual difficulties in recognizing the pictures, or the inability to recall the name of an item (i.e. either its meaning or its phonological form). Thus, the linguistic difficulties may have resulted in circumlocutions, semantic paraphasias, or phonological errors. Perseveration errors also appear to be linguistic in nature. In contrast, the omission of an answer may result from both linguistic and other difficulties (e.g. visual difficulties). This study focused on the (segmental) phonological errors that were most typical for Subjects 4, 5, 6, 14 (and to a lesser extent for Subjects 8, 9, and 11). Neologisms were calculated as phonological errors, whereas verbal paraphasias were not. Figure (5.3.3) presents a comparison of (a) the subjects who had difficulties in general with naming items (errors/items presented), and (b) the subjects who made phonological errors when naming items (phonological errors/items presented).

Figure 5.3.3 Naming Errors

a. Proportion of errors in the naming test
(the numbers refer to subjects)



b. Proportion of phonological errors in the naming test
(the numbers refer to subjects)

```
15
10
 1
20  3
18  2
17  7    13
16 19    12     8 9 11   6          5           4          14
|----+----------+----------+----------+----------+----------+----------+----------+----------+----------|
0.0  0.1        0.2        0.3        0.4        0.5        0.6        0.7        0.8        0.9        1.0
proportion of errors
```

The controls made no phonological errors in the naming test. Three of the aphasic subjects who performed poorly in the naming test (especially Subject 10, but also Subjects 9 and 11) made few phonological errors. Thus, poor performance on the naming test can be a result of different underlying deficits, and phonological errors appear to be independent from the other error types. This observation cannot necessarily be generalized for all types of phonological errors. One might assume that, for example, neologisms are more closely related to semantic difficulties than some other types of phonological errors, e.g. distortions.

The subjects' errors were categorized as follows: (1) phonological errors were segmental phonological errors spontaneously produced by the patient before the examiner gave a cue, and not corrected by the patient (neologisms were excluded from this category), (2) neologisms, (3) semantic errors, (4) perseveration of a previous name, and (5) non-answer. The number of answers obtained after a semantic cue was also calculated (a semantic cue was given when the patient had remained silent for a long time). The answers occurring after a phonological cue have not been analyzed systematically. However, for Subjects 9, 11, and 12, phonological cues elicited many phonological errors and series of approximations. In the present analysis, the category "semantic errors" was broad, including semantic paraphasias, circumlocutions (of one word), as well as possible visual confusions.

The degree to which subjects tried to correct errors was analyzed to determine the extent to which the subjects were able to correct their own errors. In table (5.3.5), the number of two-item sequences is listed under the variable "2". Sequences containing three or more items are listed under the variable "≥3". The figures in parentheses indicate the number of successful self-corrections.

Table 5.3.5 The Error Types in Naming

abbreviations:
phon = segmental phonological errors spontaneously produced by the patient before the examiner gave a cue, and not corrected by the patient; neologisms were excluded from this category
neol = neologisms
sem = semantic errors
pers = perseveration of a previous name
non = non-answer
cue = the number of answers obtained after a semantic cue (that was given when the patient had remained silent for a long time). The number is also included in non-answers.
2 = the number of two-item sequences (successful self-corrections in parentheses)
≥3 = number of the sequences containing three or more items (self-corrections)

Thirty items (out of sixty) were presented to Subject 4.

subject	2	≥3	phon	neol	sem	pers	non	cue
1	0 (0)	0 (0)	0	0	7	0	0	(0)
2	2 (1)	2 (1)	1	1	21	0	6	(0)
3	2 (2)	0 (0)	0	0	7	0	1	(0)
4	6 (3)	12 (0)	18	0	5	0	3	(2)
5	8 (4)	6 (1)	21	1	24	0	8	(3)
6	4 (1)	6 (1)	19	2	13	0	19	(1)
7	1 (1)	0 (0)	1	0	12	0	10	(1)
8	4 (2)	10 (7)	7	0	3	0	0	(0)
9	2 (1)	16 (6)	20	0	14	0	19	(0)
10	0 (0)	0 (0)	0	1	7	2	36	(4)
11	5 (2)	10 (0)	9	4	5	15	16	(1)
12	8 (8)	11 (9)	0	0	7	1	1	(0)
13	2 (1)	4 (1)	2	2	16	1	12	(6)
14	2 (1)	1 (0)	43	2	11	0	1	(1)
15	2 (2)	0 (0)	0	0	11	0	3	(1)
16	0 (0)	0 (0)	0	0	2	0	0	(0)
17	0 (0)	0 (0)	0	0	2	0	1	(0)
18	0 (0)	0 (0)	0	0	4	0	0	(0)
19	2 (2)	0 (0)	0	0	2	0	0	(0)
20	0 (0)	0 (0)	0	0	2	0	0	(0)

In addition to the above-mentioned categories, Subject 13 made a number of verbal paraphasias (c.f. 5.4.2). As in the repetition test, the subjects who produced the most phonological errors did not produce the highest number of series of approximations. Thus, their articulatory problem may have been so pervasive that they soon abandoned any attempt to correct phonological errors (especially Subject 14), and, in general, the few attempts to correct the errors were not very successful. The above generalization did not hold true for Subject 8, for 65 % of his sequences of approximations were successful. Also Subject 4 was very persistent in his attempts at self-correction, even if his trials were not successful. On the contrary, the subjects with fewer phonological errors (especially Subjects 3, 7, 12, 15, and 19, but also Subject 8) seemed prone to self-correction, and they were more successful in these corrections.

Subjects 11 and 13 had the most acute aphasia, and these subjects had the greatest number of neologistic responses. Perseveration was typical of Subject 11 who was tested only seven weeks post-onset. Subjects 2 and 5, and to a lesser extent also Subjects 6, 7, 9, 13, 14, and 15, made a high number of semantic errors. Subjects 6, 7, 9, 10, 11, and 13 often failed to provide answers in the naming test. Subject 6 appeared to have a pervasive language disability because he had articulatory, phonological, and semantic errors in naming, and he also frequently failed to produce names for the stimuli. Subjects 5, 9, and 14 made both phonological and semantic errors, and they also had articulatory difficulties. Subject 7 resembled this latter group to some extent, although she successfully corrected her phonological errors, and she had no obvious phonetic distortions. Subject 10 often reported that he did not know the name of the stimulus, and therefore it was difficult to determine the linguistic nature of his difficulty which, as a rule, was determined on the basis of the error types. Subject 10 committed a few semantic errors, and after a cue given by the examiner he also produced a few phonological errors.

From these results we can conclude that most subjects appeared to have complex naming disorders. Articulatory difficulties can be distinguished from more complex syndromes on the basis of articulatory distortion. There are also subjects with predominantly semantic difficulties. Most subjects had some type of phonological problem, and the different types of phonological errors will be discussed later. The errors made by patients who were tested immediately after the onset of aphasia seemed to differ from the errors committed by other aphasic subjects.

Table (5.3.6) organizes the data concerning the effect of word length on naming. Appendix (5) provides a list of the bisyllabic, trisyllabic and compound words. There was a direct relation between word length and errors – the longer the word, the more errors occurred. The deterioration of phonology due to the increasing word length was clearest for Subjects 2, 4, 6, 8, 11, and 14. Subjects 9 and 13 had the severest difficulties with trisyllabic items. The possible effects of word frequency have not been analyzed.

Table 5.3.6 A Comparison of Short and Long Targets

Abbreviations:
sb = subject
tot = number of phonological errors
pro = proportion of phonological errors in relation to the total number of items
error = proportion of phonological errors in relation to phonologically correct targets
answer = proportion of correct targets in relation to targets of the type in question (bisyllabic etc.)

sb	overall		bisyllabic		trisyllabic		compound	
	tot	pro	error	answer	error	answer	error	answer
1.	0		0	(0.94)	0	(1.00)	0	(0.85)
2.	4	0.07	0	(0.89)	0.12	(0.67)	0.40	(0.38)
3.	2	0.03	0.06	(0.94)	0	(0.92)	0.12	(0.62)
4.	20	0.67	0.56	(0.75)	0.75	(0.50)	1.00	(0.57)
5.	31	0.52	0.58	(0.67)	0.33	(0.25)	1.00	(0.38)
6.	19	0.32	0.33	(0.50)	0.67	(0.25)	1.00	(0.31)
7.	1	0.02	0	(0.78)	0	(0.50)	0.12	(0.62)
8.	15	0.25	0	(0.94)	0.20	(0.83)	0.33	(0.92)
9.	21	0.35	0.09	(0.61)	0.67	(0.50)	0.50	(0.31)
10.	3	0.05	0	(0.28)	0	(0.25)	0	(0.23)
11.	16	0.27	0.29	(0.39)	1.00	(0.25)	1.00	(0.01)
12.	8	0.13	0.06	(0.94)	0	(0.83)	0.36	(0.85)
13.	6	0.10	0.08	(0.67)	0.20	(0.42)	0	(0.15)
14.	49	0.82	0.56	(0.89)	0.75	(0.67)	1.00	(0.85)
15.	0		0	(0.78)	0	(0.75)	0	(0.77)
16.	0		0	(1.00)	0	(0.92)	0	(0.92)
17.	0		0	(0.94)	0	(1.00)	0	(1.00)
18.	0		0	(1.00)	0	(0.92)	0	(0.92)
19.	0		0	(1.00)	0	(1.00)	0	(0.92)
20.	0		0	(0.94)	0	(1.00)	0	(1.00)

Table (5.3.7) presents the phonological characteristics of the naming errors. The differences in the number of errors in the tables (5.3.5) and (5.3.7) reflect the coding criteria used (c.f. chapter 5.3.1, footnote 2).

The differences between the repetition and naming tables are the following: the repetition of an item as another word is substituted by the category "neologism" which was more informative in the case of naming. Only one subject (Subject 13) had a few verbal paraphasias, all the other "words" were semantically related to the target. The categories x>p, x>t, x>k word-initially did not prove useful in the case of naming (few answers were coded there), and so these categories were substituted by the following classifications: the omission of a word-initial sound, the omission of a word-final sound, the substitution of a word-initial sound, and the omission of a word-final sound.

Table 5.3.7 The Phonological Characteristics of the Naming Errors

(The error types were defined in table 5.3.1)

subject	Number of errors	neologism	literal paraphasia	complex paraphasia	syllable deletion	anticipat	metathesis	perseverat	cons	vowel	initial deletion	initial substitution	final deletion	final addition	word-initial	word-medial	word-final
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	1	3	0	0	0	0	2	2	1	0	0	0	0	0	3	0
3	2	0	2	0	0	0	0	2	1	1	0	0	0	0	0	1	1
4	20	0	1	18	3	0	0	1	8	6	0	0	+	6	1	0	20
5	31	1	17	15	1	0	17	3	25	5	7	5	0	0	16	19	3
6	19	2	10	9	1	4	0	0	15	2	4	7	0	0	10	7	2
7	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0
8	15	0	7	6	0	3	3	17	12	1	0	0	0	0	1	10	1
9	21	0	7	3	1	1	1	0	8	2	0	0	0	1	1	3	7
10	3	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1
11	16	4	2	7	0	0	3	0	7	0	0	1	0	1	3	6	2
12	8	0	8	5	0	0	0	0	5	4	0	2	0	0	4	7	2
13	6	2	2	4	0	0	0	0	0	2	0	0	0	1	0	0	3
14	49	2	12	37	0	14	1	5	30	0	4	10	0	0	16	13	4
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Additional remarks about the subjects' errors:

Subject 1: Some distortion, four semantic paraphasias, circumlocutions.
Subject 2: One series of approximations.
Subject 3: One simplification of a consonant cluster (mp > mm).
Subject 4: Perseveration of items.
Subject 5: The word-final syllables of one item were deleted.
Subject 6: A consonant was added word-initially in one item.
Subject 9: 21 sequences of approximations, 13 were successful self-corrections.
Subject 10: One sequence of approximations.
Subject 11: Some sequences of approximations, perseveration of words was common.
Subject 12: Numerous successful sequences of approximations.
Subject 13: Some semantic sequences of approximations.
Subject 14: The consonant /p/ is often substituted for other consonants, especially if /p/ follows later in the word.

Subjects 4, 11, 13, and 14 made more complex errors than literal paraphasias. Of these, Subjects 11 and 13 had many neologisms, whereas the complex errors of Subjects 4 and 14 were "accumulations" of literal paraphasias (thus, the target can be recognized). Subjects 5, 6, and 8 made an equal number of both complex errors and literal paraphasias, whereas all other subjects committed predominantly literal paraphasias. Anticipation was typical of Subject 14, but also of Subjects 6 and 8. For all subjects, errors in consonants outnumbered errors in vowels, although two subjects (Subjects 4 and 12) also had a high proportion of vowel errors. Subjects 4 and 9 had a tendency to make errors word-finally, whereas Subjects 6 and 14 had the most severe difficulties with the word-initial position. Subjects 8, 11, and 12 produced many errors word-medially.

5.3.4 Picture Description

A series of six pictures from Paradis (1987) was used to elicit descriptive speech. The park scene from Hänninen et al. (1987) was presented to Subject 4. Descriptive speech can be considered more comparable to spontaneous speech than the repetition and naming of isolated words. As opposed to spontaneous speech, in picture description there may be somewhat more hesitation due to, for example, the visual processing of pictures. In picture description the main "content" was provided by the stimulus pictures. Even if the present analysis will focus on phonological errors in descriptive speech, the relation of phonological errors to the defining characteristics of grammatical fluency will also be discussed.

Grammatical fluency

Spontaneous speech or picture descriptions are useful for classifying speech output as either fluent or nonfluent. "Fluent" speech is effortlessly produced and well articulated with normal melody and rhythm. Here, phrases are relatively long and grammatically correct or paragrammatic. "Nonfluent" speech is uttered slowly and hesitantly with great effort and poor articulation. In nonfluent speech, phrases are relatively short and agrammatic. Of the features mentioned, the present analysis will focus primarily on phrase length and grammatical correctness. The articulatory characteristics have been discussed in connection with the articulation tests (c.f. chapter 5.2), and will be studied further in chapter 6.

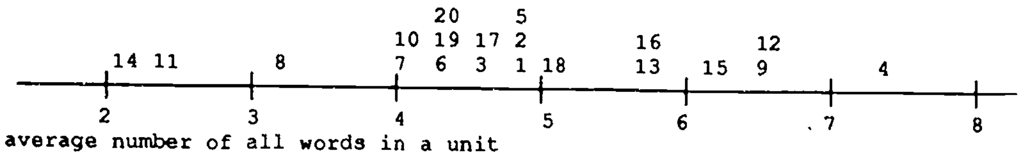
Finnish is more inflective than English. Thus, in Finnish, within phrases or utterances there are fewer function words and more inflections (suffixes). For this reason, the criteria for determining grammatical fluency may differ for the two languages. When analyzing Finnish data, one should first determine the variables that would be most sensitive to differences in fluency.

In the present analysis, the speech sample was divided into grammatical units (simple sentences). The main criterion for a unit was adopted from Hakulinen, Karlsson and Vilkuna (1980): there was one finite verb in a unit. Elliptic structures without a verb were also coded as units. Thus, both main clauses and subordinate clauses were units. The number of subordinate clauses is provided in table 5.3.8. "Units", "words" and "content words" were counted. There are several ways in which one can count the words, and two variables were included in the present analysis: all items – including fillers, false starts and repetitions but excluding inarticulate sounds like *mm* – were included in the variable "all words", whereas in the count of "words", fillers, false starts and repetitions were excluded. Nouns, verbs, adjectives and adverbs that brought "new information" were counted as "content words". When a content word was repeated (e.g. a phonological error or a semantic paraphasia was corrected by the patient), the word was counted as only one occurrence. Figure (5.3.4) summarizes the results (c.f. also table 5.3.8).

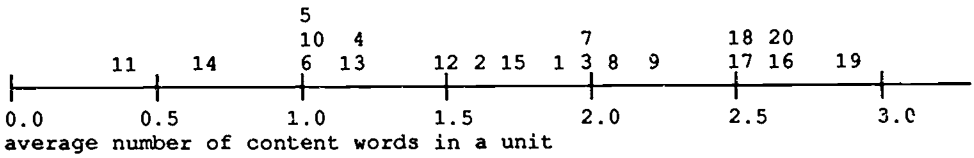
Figure 5.3.4 Features of Grammatical Fluency

There are several ways that one can quantify features of descriptive speech. The following variables will be presented:
unit: simple sentence with one finite verb
all words: fillers, false starts, and repetitions were counted as words
content words: nouns, verbs, adjectives, and adverbs that bring "new information"
words: fillers, false starts and repetitions were excluded from the word count

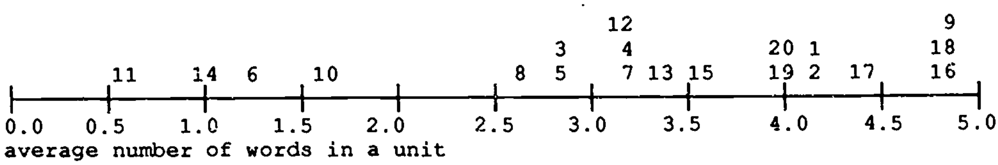
1. The mean of "all words" in a unit (variable "all words per unit")
(the numbers refer to subjects)



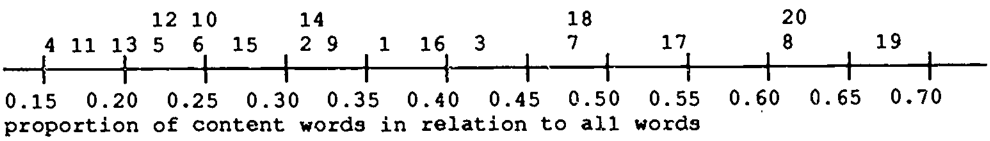
2. The mean of "content words" in a unit (variable "content words per unit")
(the numbers refer to subjects)



3. The mean for "words" in a unit (variable "words per unit")
(the numbers refer to subjects)



4. The proportion of "content words" in relation to "all words"
(variable "content words per all words")
(the numbers refer to subjects)



Results varied, depending on the way in which the data were quantified. Variable 1, "all words per unit", seemed to provide the means of differentiation between patients. The controls and a number of patients were located in the middle, whereas the scores for obviously "nonfluent" patients (8, 11, 14) and "fluent" patients (4, 9, 12, 15) differed from the average (normal) scores. According to variable 1, nonfluent subjects produced units containing less than four items, whereas fluent subjects produced units with more than six items.

The variable "words per unit" (in which fillers, false starts and repetitions were not counted) produced different results. Subjects 11 and 14 remained nonfluent, but Subjects 6 and 10 did not differ from them. In contrast, Subject 8 was more fluent according to the variable "words per unit" than according to the variable "all words per unit". The controls were the most fluent (and Subjects 1, 2 and 9 did not differ from them). Thus, the variable "words per unit" did not differentiate between "fluent" aphasics and control subjects.

The role of "empty elements" was further studied by counting the number of content words in the speech samples. In this case, not only fillers, false starts and repetitions, but also function words such as the copula, were eliminated from the

corpora. There was a negative correlation between the proportion of content words in descriptive speech (the number of content words divided by the number of units) and word-finding difficulties in naming -- the less difficulty in naming, the greater the proportion of content words. This finding is presented in figure (5.3.5). For example, Subject 10 named very few items, and his descriptive speech was scanty. Subject 9 was the only subject not to show such a correlation: he had more difficulties in the naming test than in descriptive speech. As compared to the proportion of content words, a similar result was obtained by counting the number of "empty units" (i.e., units with fillers only, or a stereotypic phrase) and dividing it by the total number of units. Content density can be characterized by dividing the number of content words by "all words" (c.f. figure 5.3.6). Such a variable does not differentiate between patients and controls, but it does catch variations in the comparison data.

When the variables "all words", "words", and "content words" were plotted in relation to each other, there was a correlation between "words" and "content words", but "all words" was more independent of the other variables (c.f. figure 5.3.6). The speech of Subjects 12, 13, 6, and 4 had numerous "empty elements", such as false starts, corrections, and fillers. These "empty elements" were not analyzed in detail. However, the number of "empty elements" in the aphasic subjects' speech may contribute to a listener's overall judgement of fluency: speech without "empty elements" is considered nonfluent, whereas speech containing numerous "empty elements" is considered fluent.

Figure 5.3.5 Scattergram of Content Words and Naming Errors

The average number of content words in a unit (picture description test) is plotted against the number of naming errors (confrontation naming test). The numbers refer to subjects.

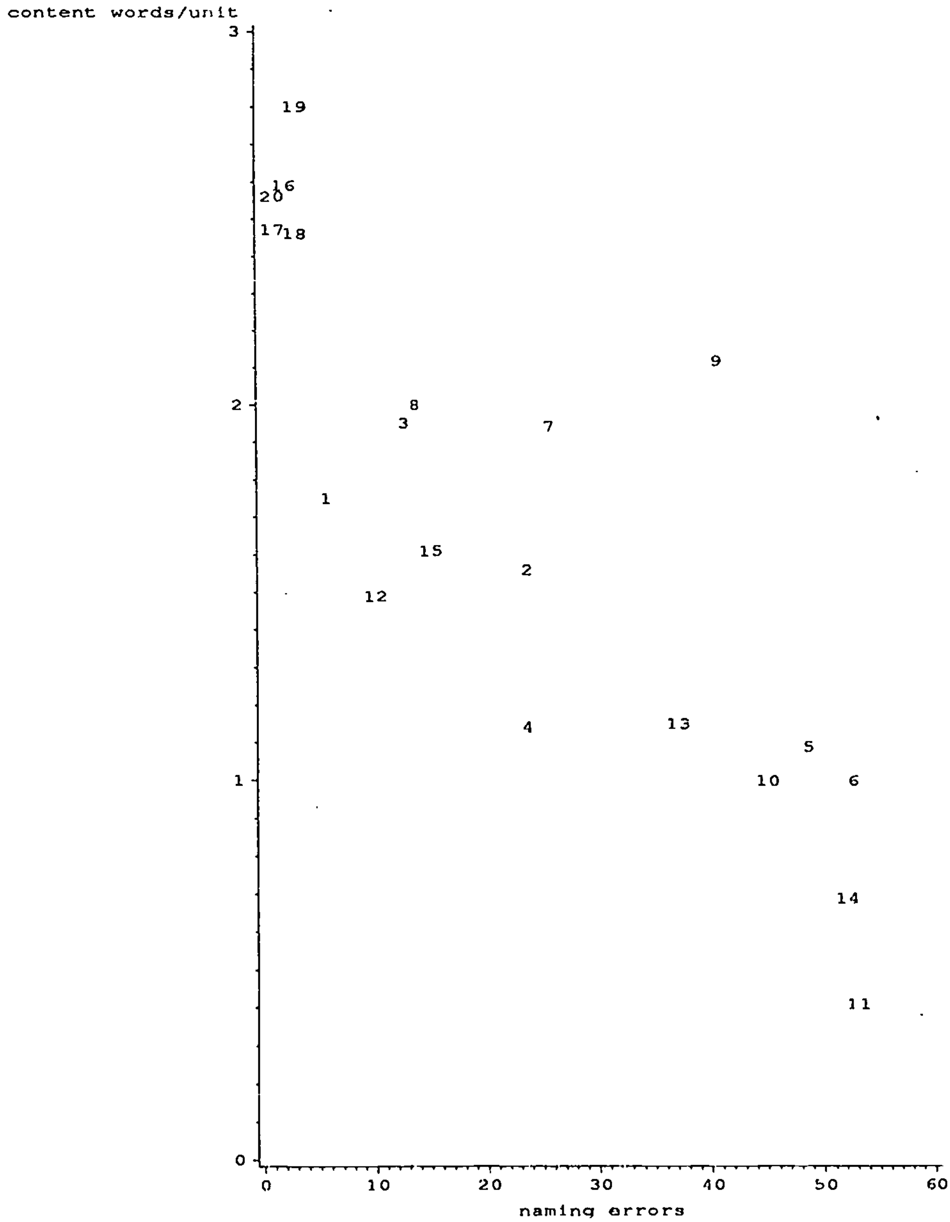


Figure 5.3.6 A Comparison of the Variables "All Words", "Words", and "Content Words" of the Picture Description Test

All words: fillers, false starts, and repetitions were counted as words
Words: fillers, false starts, and repetitions were excluded from the word count
Content words: nouns, verbs, adjectives and adverbs that bring "new information"
The numbers refer to subjects.

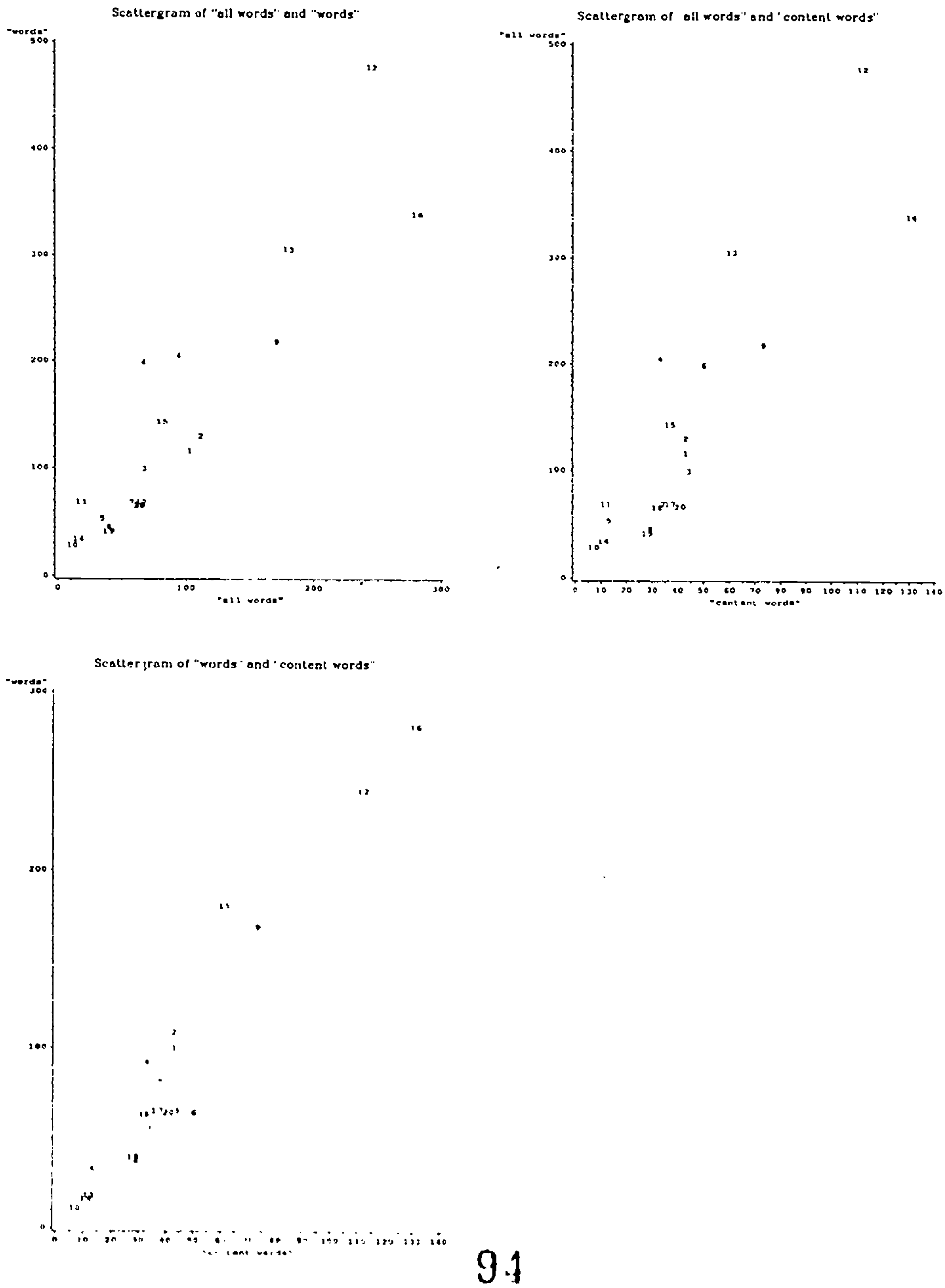


Table (5.3.8) provides additional information about the "grammatical" aspect of descriptive speech. The variables used in this study were based on Paradis (1987). The present analysis provides only an overall characterization of the grammatical structure. The variables are as follows: the mean length of unit, the mean length of the five longest units, the number of paragrammatisms (i.e., any deviant use of grammatical morphemes, except omission), the number of missing obligatory grammatical morphemes, the number of word-order errors, the number of subordinate clauses, the number of stereotypic phrases, the number of "all words" (i.e. all items including fillers, etc.), the number of content words, the number of units, and the number of (segmental) phonological errors.

Table 5.3.8 Characteristics of Descriptive Speech

Abbreviations:
L1 = mean length of unit
L2 = mean length of the five longest units
para = number of paragrammatisms
agr = number of missing obligatory grammatical morphemes
ord = number of word-order errors
sub = number of subordinate clauses
str = number of stereotypic phrases
wo = number of all words
co = number of content words
un = number of units
err = number of (segmental) phonological errors

subj	L1	L2	para	agr	ord	sub	str	wo	co	un	err
1	4.8	7.2	0	0	0	4	1	116	42	24	5
2	4.6	7.4	3	0	0	1	0	130	42	28	1
3	4.5	8.0	5	3	0	1	0	99	43	22	3
4	7.3	12.6	0	0	0	1	1	205	32	28	10
5	4.8	6.0	0	2	1	1	0	53	12	11	6
6	4.1	7.2	0	0	0	0	1	199	49	49	16
7	4.0	5.8	0	0	0	2	1	68	33	17	5
8	3.2	4.4	1	3	0	0	0	45	28	14	14
9	6.4	12.0	8	0	0	9	0	218	72	34	11
10	4.0	5.0	0	0	0	0	1	28	7	7	1
11	2.3	4.0	2	1	0	0	8	68	12	29	6
12	6.4	14.4	13	0	0	13	4	477	112	75	21
13	5.8	10.0	0	1	0	1	7	305	61	53	11
14	2.1	3.2	0	0	0	1	4	34	11	16	12
15	6.2	10.2	1	0	0	2	0	143	37	23	5
16	5.8	14.0	0	0	0	8	3	339	131	58	5
17	4.5	7.6	0	0	0	0	0	68	37	15	0
18	5.0	6.8	0	0	0	2	0	65	32	13	0
19	4.1	5.4	0	0	0	1	0	41	28	10	1
20	4.1	7.0	0	0	0	1	0	66	41	16	0

The mean length of the five longest units provided interesting results. This measure was similar to the variable "all words per unit". According to these variables, the speech of Subjects 14, 11 and 8 could be characterized by short units. The variables of unit length differed from the variable "content words per all words", a characteristic

of content density. Thus, it may be possible to differentiate between two aspects of speech production – syntactic abilities and lexical retrieval.

Subjects 4, 11 and 14 used fewer verbs than the other subjects. The grammatical correctness of speech was characterized by the number of paragrammatisms and by the number of missing obligatory grammatical morphemes. Subjects 12, 9, 2 and 11 were somewhat paragrammatic, whereas Subjects 8, 5, and possibly 11 and 13, were judged to be agrammatic. Subject 3 both omitted grammatical morphemes and made paragrammatic errors. This analysis confirmed the results obtained with the variable "all words per unit": Subjects 9 and 12 were typically fluent aphasics (they also had the greatest number of subordinate clauses), whereas Subject 8 was nonfluent.

In the analysis of grammatical fluency, there were several variables that revealed differences between the aphasic subjects. However, it was difficult to determine which features were the most central when defining "grammatical fluency". The classification of a patient (e.g. Subject 6) as fluent or nonfluent depended on the variables used. Variables "all words per unit", "mean length of the five longest units", and "content words per all words" were of particular interest, because they focused on independent aspects of grammatical fluency. There were also differences between the control subjects (for example, Subject 16 was more fluent than Subject 20). For the aphasic speakers, the differences in grammatical fluency should be studied in greater detail, with special reference to the variation in control data.

Error Types in the Picture Descriptions

In determining lexical error types, the same categories were used as in the repetition and naming tests. Table (5.3.9) lists the number of neologisms, phonemic paraphasias resulting in words and non-words, semantic paraphasias, and verbal paraphasias. The number of series of two attempts, and of three or more attempts are also indicated, as well as the number of successful self-corrections.

Two subjects -- 4 and 12 -- produced a high number of sequences of approximations. Subject 4, unlike Subject 12, did not succeed in attempts at self-correction. Also Subjects 3, 6, and 13 produced some sequences. Thus, corrections may partially account for the relatively low number of content words in the speech of Subjects 4, 6, 12, and 13. For Subject 9, semantic and phonological factors amalgamated in sequences of approximations. Subjects 12 and 13 differed from the others in that they made many semantic and verbal paraphasias.

The phonological errors were further classified into neologisms, and phonological paraphasias resulting in words and non-words. Neologisms were produced by Subjects 6, 11 and 13. Phonological paraphasias resulting in non-words occurred in the speech of Subjects 14 (who had the greatest number), 4, 8, 9, 6, 5, 1, 11, 12 and 10 (who had only one such error). Phonemic paraphasias that resulted in words were found in the speech of Subjects 4, 6, 12, 2, 13, 15 (from the most to the least). Semantic paraphasias were typical of Subjects (mentioned in ascending order) 13, 12, 9, 2, 3, 7. In addition, Subjects 15 and 16 each produced one semantic paraphasia.

Table 5.3.9 Error Types in the Picture Descriptions

Abbreviations:
2 = number of series of two attempts (the number of successful self-corrections is in parentheses)
≥3 = series of three or more attempts (the number of successful self-corrections is in parentheses)
neol = number of neologisms
non = number of phonemic paraphasias resulting in non-words
word = number of phonemic paraphasias resulting in words
sem = number of semantic paraphasias
verb = number of verbal paraphasias

subj	2	≥3	neol	non	word	sem	verb
1	2 (1)	0	0	3	0	0	0
2	0	0	0	0	1	2	0
3	1 (1)	2 (1)	0	0	0	2	0
4	1	8 (1)	0	9	4	0	0
5	0	1	0	4	0	0	1
6	0	3 (1)	3	6	2	0	0
7	0	0	0	0	0	2	1
8	1	0	0	8	0	0	0
9	1 (1)	1	0	7	0	3	0
10	0	0	0	1	0	0	0
11	1	0	1	3	0	0	0
12	8 (7)	4 (3)	0	3	2	5	1
13	0	3 (2)	1	0	1	9	5
14	0	1	0	11	0	0	0
15	1 (1)	0	0	0	1	1	0
16	0	0	0	0	0	1	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0

In word-picture matching, a double dissociation was observed between phonologically and semantically related items. Semantic paraphasias did not occur in the repetition test, and a dissociation was found between patients who had difficulties surfacing in all tests (repetition, naming, and picture description), and patients who only had difficulties in the naming and picture description tests. Subjects 1, 4, 5, 6, 8, (11), 9, and 14 belonged to the former group, and Subjects 2, 3, 7, 9, 12, and 13 belonged to the latter group. The latter group would obviously be classified as

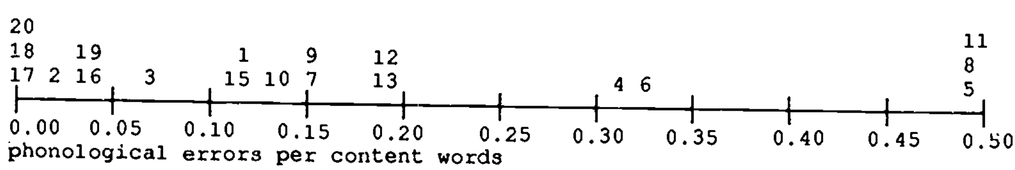
"aphasics" according to the criteria presented by Darley et al. (1975). These patients made semantic errors in both speech production and perception tests.

Phonological Errors in Picture Description

Information about subjects with phonological errors in descriptive speech is provided in figure (5.3.7). When studying the number of phonological errors in descriptive or spontaneous speech, it is necessary that the absolute number of errors be related to the total number of words produced. One way of doing this is to relate the number of errors to content words. It is not common for patients to make phonological errors in fillers or function words that are short and frequent. The proportion of phonological errors in relation to content words was high for Subjects 4, 5, 6, 8, 11 and 14. When the number of phonological errors was related to "all words", Subjects 14 and 8 had the greatest number of errors. The speech of Subjects 14 and 8 had few "empty elements" (i.e. fillers, false starts etc.).

Figure 5.3.7 Phonological Errors in Descriptive Speech

a. Proportion of phonological errors in relation to the number of content words(the numbers refer to subjects; Subject 14 had 1.10 phonological errors per content words, and did not fit into the figure)



b. Proportion of phonological errors in relation to "all words" (when "all words" were counted, fillers, false starts and repetitions were counted as words; in the figure, the numbers refer to subjects)

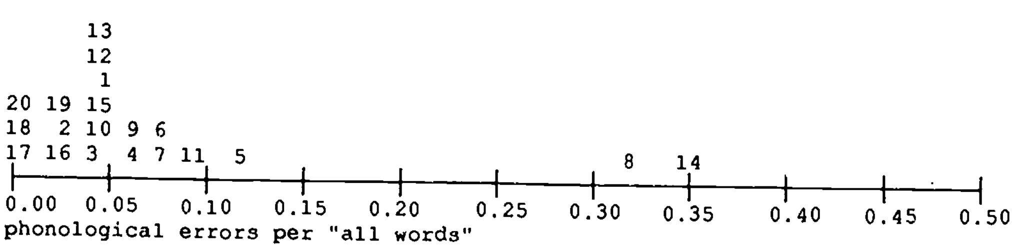


Table (5.3.10) presents the phonological classification of the errors found in the analyzed speech samples. The proportion of phonological errors (in relation to content words) was included in the table because the length of the speech samples varied.

Subjects 4, 5, 6, 8, 11, and 14 (and possibly 10) made many phonological errors. Subjects 5, 6, and 11 usually made their errors word-initially, whereas most of the errors in the speech of Subject 4 occurred word-finally. Consonant substitutions were the most frequent error type. Subject 14 was the only participant who often omitted consonants.

The picture description test differed from the repetition and naming tests in that the errors were more difficult to classify, and there were also errors where the target remained unclear. Unlike in the previous tests, a considerable number of errors was committed word-finally, these errors obviously being motivated by morphological factors. The following list contains examples of such errors: *ottava* (target was *'ottamaan'*, produced by Subject 1), *poikaita* (*'poikasia(an)'* Subject 5), *miene* (*'miehen'* Subject 8), *elääle* (*'selälleen'* Subject .10), *mennen* and *menne* (*'menee'* Subject 14). The sample of morphological errors was too small to allow for a detailed morphological analysis.

Table 5.3.10 The Phonological Characteristics of the Errors in Descriptive Speech

(The error types were defined in table 5.3.1)

Subject	Number of errors (total, total/cont)	neologism	literal paraphasia	complex paraphasia	syllable deletion	anticip	metathesis	persever	cons	vowel	initial deletion	initial substitution	final deletion	final addition	word-initial	word-medial	word-final
1	4 / 0.10	0	2	2	2	2	0	0	3	0	0	1	2	0	1	0	3
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1 / 0.02	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
4	8 / 0.25	0	1	7	5	0	0	0	1	0	0	0	0	0	0	0	7
5	3 / 0.25	0	3	0	0	0	0	1	2	1	1	2	0	0	3	0	0
6	15 / 0.31	2	5	5	?	3	0	1	15	0	1	5	0	0	8	1	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	6 / 0.21	0	6	0	0	0	0	1	5	2	0	0	?	0	0	6	0
9	4 / 0.06	0	4	0	0	0	0	0	4	0	1	1	0	0	2	2	0
10	1 / 0.14	0	0	1	0	0	0	0	1	?	1	0	0	0	1	?	0
11	5 / 0.42	0	3	2	1	1	0	0	3	?	1	1	0	0	4	0	1
12	1 / 0.01	0	0	1	1	0	0	0	0	0	0	0	?	0	0	0	1
13	4 / 0.07	0	1	?	0	0	0	0	1	0	0	0	0	1	0	1	1
14	7 / 0.64	0	3	4	0	0	0	1	7	1	2	0	0	0	3	3	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Additional remarks about the subjects' errors:

Subject 1: Some assimilation between words, morphological factors may interfere with these phonological errors.
Subject 2: One error was motivated by morphological factors.
Subject 3: Morphological factors may play a role in the errors.
Subject 4: Target often remained unclear, only one or two initial syllables were produced.
Subject 5: In addition to the phonological errors, there were two morphological errors.
Subject 6: Targets of three items remained unclear; there were two consonant additions word-initially.
Subject 7: There was progressive assimilation at junctures; sound durations were colloquial.
Subject 8: Ten items with sound deletions word-finally, not clearly different from colloquial speech.
Subject 9: There were some sequences of approximations; some morphological errors.
Subject 11: The target of one item remained unclear, two consonant additions word-initially, two consonants were substituted by /k/ word-initially, spontaneous speech was scanty.
Subject 12: One verbal paraphasia, some repetitions.
Subject 13: The targets of three items remained unclear, five verbal paraphasias.
Subject 14: Two morphological errors, two errors were difficult to classify.
Subject 15: Shortening and sound deletion word-medially, within normal limits (colloquial).

Grammatical Fluency and Phonological Errors

Those patients are usually considered nonfluent (according to the "grammatical" definition of fluency) who produce very short utterances. The patients who produced the fewest words in the picture description test often had articulatory difficulties and numerous phonological errors. Good examples of this type of patient were Subjects 14, 11, and 8. Those patients are nonfluent accoraing to both the articulatory (the amount and nature of articulatory and phonological errors) and grammatical (as defined by the variables "all words per unit") criteria. Subjects with "fluent" speech made only a few phonological errors. Subjects 9 and 12 were good examples of fluent patients with long units and few phonological errors, and they also tried to correct phonological errors. While Subjects 4 and 9 produced long utterances, they also made phonological errors, but these mistakes, unlike those of the other subjects with phonological difficulties, occurred word-finally (c.f. 5.4.2).

After evaluating the speech of all the patients, it was clear that reliable predictions about the characteristics of descriptive speech were impossible to make based on the average number of words in an utterance. Grammatical fluency was partly determined by the number of fillers and other "empty elements". There were patients who used few fillers and had few false starts or corrections but who nevertheless produced short "units" with a reasonable amount of phonological errors (e.g. Subject 8). On the other hand, patients like Subject 4 had frequent false starts and fillers but few content words with numerous phonological errors. Thus, we can conclude that there are several independent variables that contribute to the impression of fluency.

The "syntactic" and "lexical" measures (the mean length of the five longest units, the number of content words per all words) seemed to dissociate, but data from this study were not sufficient for the proper verification of these results. Results from the analysis of descriptive speech were more complex than the results obtained from the repetition and naming tests. That is because repetition and naming are linguistically less demanding than descriptive speech where morphological and syntactic factors are also involved, not to mention the cognitive demands of the description of a picture.

5.3.5 A Comparison of the Repetition, Naming and Picture Descriptions

Error Types in the Three Tests

The three tests elicited different error types. It was immediately apparent when constructing the tables, that the answers to the repetition test did not contain semantic paraphasias, verbal paraphasias or neologisms.

In the repetition test, some subjects made word substitutions that were phonologically motivated. Such errors were obviously caused by speech perception problems. However, there were subjects who had both neologisms and phonologically motivated word substitutions (Subjects 2, 6, 10, 14). Thus, those word substitutions need not be simply a problem of speech perception (i.e. an accidental misidentification of one phoneme) but lexical factors may also play a role.

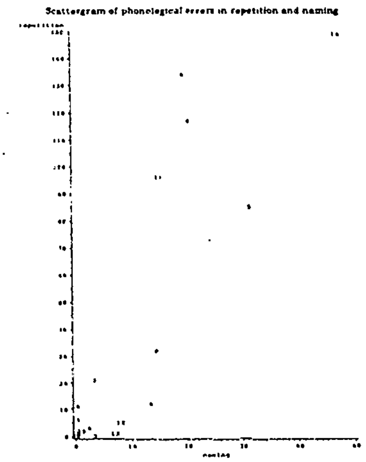
Neologisms, verbal and semantic paraphasias occurred only in the naming and picture description tests. Subject 13 made verbal paraphasias in both tests. Neologisms were characteristic of Subjects 6, 11, and 13 in both the picture description and naming tests, although other subjects also produced a few neologisms. The highest number of semantic paraphasias was made by Subjects 2 and 5 in the naming test, and by Subjects 12 and 13 in the picture description test.

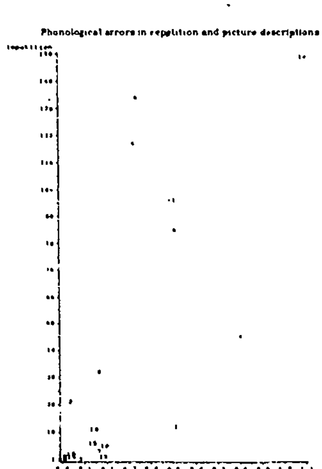
There are two basic orientations to the present data that can be used to explain the differences in the relative frequency of the error types in the naming and picture description tests (in addition to the variation due to the small samples): (1) The word-finding procedure is different in confrontation naming and picture description; in the latter, the presence of syntagmatic cues may influence lexical retrieval. (2) The word-finding procedure is basically the same, and the same patients have difficulties in both tests. The difference in performance scores could, for example, be explained by the fact that the descriptions of Subjects 2 and 5 were very short, whereas Subjects 12 and 13 produced long stories. In picture description, the absolute number of errors should be related to the total number of words (whichever is the best way to count them). It may also be more difficult to detect semantic paraphasias in picture description where the patient's exact intention (i.e. target word) is unknown to the examiner. In the naming test, the target words are known to the examiner (or, at least, it is assumed that the patient's targets are "correct"). Some subjects may use circumlocutions as a way of avoiding errors. These circumlocutions are more difficult to detect in picture descriptions than in a naming test. The comparison of naming

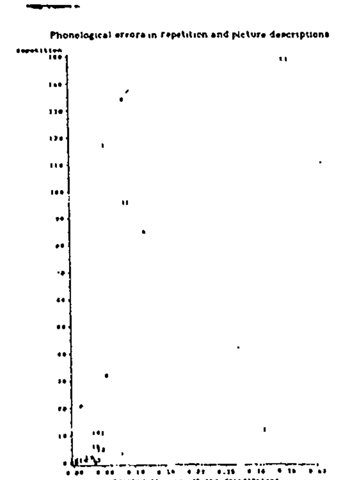
errors and the number of content words in picture description gave partial support to hypothesis two (c.f. figure 5.3.5 in chapter 5.3.4). The only exception to hypothesis two was Subject 9 who did not have word-finding difficulties in the picture description test, but who performed poorly in the naming test.

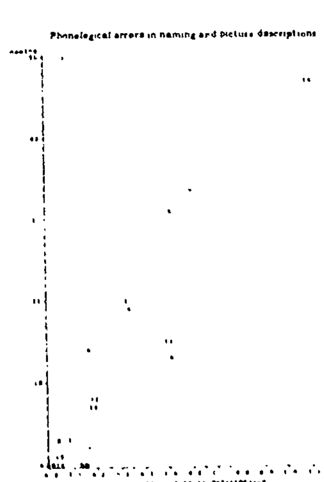
Figure 5.3.8
A Comparison of the Number of Phonological Errors in the Repetition, Naming, and Picture Description Tests

All words: fillers, false starts, etc., are included in the count.
Content words: nouns, verbs, etc., that bring "new information".
The numbers refer to subjects.









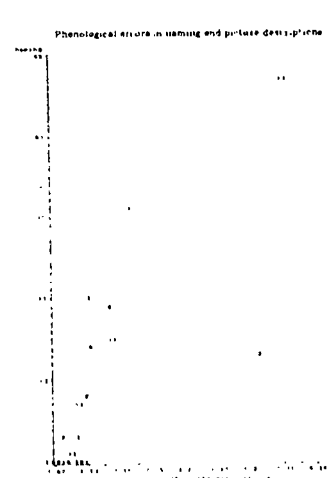


Figure (5.3.8) presents a comparison of the phonological errors in the tests. The proportion of (segmental) phonological errors seemed to be somewhat different in repetition as compared to the other two tests. As the scattergrams showed, repetition and naming tests provided similar results, whereas greater differences were observed when repetition and picture description were compared. However, the phonological errors may nevertheless result from the same underlying difficulties as Subjects 4, 5, 6, 11 and 14 made the greatest number of phonological errors in all the tests. Repetition may measure the amount of phonological difficulties in a relatively pure form. In the naming and picture description tests, there are other sources of errors as well. When other errors are common, there may not be opportunity for phonological errors to occur. The most obvious example of this is the amount of non-answers (i.e. the subject says he or she cannot say the word, does not remember the name, or did not hear the item) in the repetition and naming tests. This information is presented in table (5.3.11).

Table 5.3.11 Non-Answers in Repetition and Naming

subject	repetition	naming	subject	repetition	naming
1	5	0	11	10	16
2	2	6	12	0	1
3	0	1	13	0	12
4	7	3 /30	14	0	1
5	10	8	15	3	3
6	0	19	16	0	0
7	1	10	17	0	1
8	0	0	18	1	0
9	1	19	19	0	0
10	1	36	20	1	0

Subjects 4, 5, 6, 11, and 14 made frequent errors in the repetition test. Of these subjects, 6 and 11 often provided non-answers in the naming test, which may account for the smaller number of phonological errors in the naming test as compared with the repetition test. The number of non-answers in naming does not explain the differences between the test performances for Subjects 4 and 5. One additional intervening factor may be the amount of perseveration: there may be fewer phonological errors in perseverative answers than in the attempts to produce a correct answer.

The errors made in descriptive speech were more difficult to analyze because the speaker's intention was not known. There were also several uncontrolled variables (e.g. morphological and syntactic). Subject 8 committed very few errors in the repetition test, but had more errors in the naming test, and very frequent mistakes in descriptive speech. This difference in performance cannot necessarily be attributed to

the linguistic complexity of the test. The length of the utterance to be produced may also contribute to errors. In descriptive speech, the words are not produced one by one, but several words are covered by an "articulatory plan". Subject 5 differed from the other subjects in that she had greater difficulties with non-word repetition than with word repetition.

The comparison of error types provided most interesting results concerning patient classification, for there was a dissociation between phonological and semantic errors. Patients with nonfluent aphasia made articulatory / phonological errors, whereas patients with fluent aphasia made few (segmental) phonological errors, except verbal paraphasias and neologisms. Grammatically nonfluent patients usually had many (segmental) phonological errors. However, the qualitative error analysis provided some additional information about the phonological errors in nonfluent and fluent aphasia (c.f. 5.4.2).

Corrections

Three aspects of the corrections can be analyzed: the number of sequences, the length of sequences, and the amount of success in self-correction. The following tables summarize this information. The numbers in the tables refer to the subjects with the greatest number of sequences (table 5.3.12), subjects with sequences of two and three or more items (table 5.3.13), and subjects who succeed in correcting their own errors (table 5.3.14). The subjects' performance scores were plotted on a graph, and those subjects with the greatest number of errors were selected on the basis of a visual inspection of the graphs (for an example of a graph, c.f. chapter 5.2.4).

Table 5.3.12 Number of Sequences in the Tests

The numbers refer to subjects with many sequences, and those subjects with the most severe difficulties are mentioned first.

repetition	4	11	5	14	6		
naming	12	9	4	11	5	8	6
picture description	12	4	3	6	13		

Subject 12 produced very few sequences in the repetition test because he made few errors in the test, since he succeeded in correcting all errors. Subject 3 made mistakes only in the picture description test where she also corrected her own errors. Subject 11 had sequences in repetition and naming, but no sequences in the picture description test. This patient's descriptive speech also contained very few content

words. Subject 9 produced many sequences of approximations in the naming test, but in the repetition and picture description tests he did not produce sequences. For other aphasics, there was a correlation between the proportion of content words in descriptive speech and word-finding difficulties in the naming test. Subject 9, however, had more word-finding difficulties in the naming test than in descriptive speech. His word-finding difficulties obviously differ from those experienced by the other patients.

Table 5.3.13 Sequence Length in the Tests

The numbers refer to subjects with many sequences of the type in question.

	≥3 items	2 items
repetition	4 5 11	6 14
naming	4 6 8 9 11 12	5
picture descr	4 6 13	12

Sequence length did not allow for patient classification.

Table 5.3.14 Successful Self-Correction

The numbers refer to subjects who succeed in correcting their own errors. Subjects in parentheses are less successful than the other subjects.

	no success	success
repetition	4 (5 6) 11 14	
naming	4 5 6 (9) 11	8 12
picture descr	4 6	3 12 13

In general, the subjects who made few phonological errors succeeded in correcting their errors. Those subjects with the greatest number of errors (such as 6 and 14) seldom succeeded in correcting their errors. Those subjects who made mistakes in repetition were not able to correct these errors, and they were likewise unable to self-correct in other tests. The subjects who had sequences of approximations only in the naming and picture description tests were the most likely to correct their errors. Subject 9 differed from the other subjects in that he was able to correct his errors in the repetition and picture descriptions tests but not in the naming test.

The Effect of Word Length

Sub-samples of the repetition and naming data were subjected to a detailed analysis of the effects of increasing word length. The proportion of phonological errors was

calculated in comparable samples of short and long items. The comparison was based on the following groups of items:

short items:
simple bisyllabic words and bisyllabic words with consonant clusters from the repetition test, as well as bisyllabic words from the naming test

long items:
compounds from the repetition and naming tests

Table (5.3.15) presents the subjects who made frequent phonological errors in the tests. Table (5.3.16) lists the proportions of all errors made by the above subjects in short and long items of the repetition and naming tests.

Table 5.3.15 Subjects Having Difficulties with Short and Long Items

The numbers refer to subjects who made many errors. The subjects in parentheses made fewer errors than the other subjects.

	short items	compounds
repetition	4 (5) 6 (11) 14	4 5 6 11 14
naming	4 5 (6) (11) 14	4 5 6 11 14

Those subjects who experienced severe phonological difficulties made errors in all the compared conditions. However, for some of the subjects, the difficulties were more pronounced in longer items (compounds).

Table 5.3.16 The Proportion of Errors

The comparison is based on all repetition and naming errors made by Subjects 4, 5, 6, 11, and 14.

	short items	compounds
repetition	0.35 - 0.70	0.75 - 0.92
naming	0.62 - 0.92	1.0

The results show that naming was a more difficult task than repetition. The complexity of the naming test as compared to the repetition test was also indicated by neologisms, verbal and semantic paraphasias that occurred only in the naming and picture description tests. This evidence convincingly shows that the difference cannot be explained with reference to, for example, word frequency. Word length was an important factor contributing to the errors in both tests. However, in the repetition test, the errors of Subjects 1, 3, 7, 12, and 13 could not be correlated to word length, whereas in the naming test there were only two subjects -- 1 and 13 -- for whom

word length was not a factor. Thus, as the complexity of the test increased, the effect of word length also increased. The comparison was based on all types of errors. At first it might seem more reasonable to compare only the number of phonological errors in the two tests. This would, however, lead to false conclusions because some subjects named few compounds, and subsequently, the proportion of phonological errors in compounds was small (floor effect). The reason for the floor effect was unknown, but it could be related to phonological difficulties.

A Comparison of the Phonological Characteristics of the Errors in the Three Tests

In the following pages, a preliminary comparison of the phonological errors of the repetition, naming, and picture description tests will be presented. There are some important differences between these tests: the targets of naming and repetition tests were known to the examiner, whereas in the picture descriptions the speakers' intentions were not always known. Furthermore, the repetition data included only simple bisyllabic words (the acoustically analyzed data), whereas the items of the naming test were phonologically more heterogeneous.

It is important to note the differences between the tests when determining whether or not the linguistic complexity of the task (repetition vs. naming vs. picture description) contributed to the phonological errors. For simplicity, the repetition and naming tests will be discussed first. In an effort to prevent word length as a variable, only bisyllabic items were included in the comparison (the proportion of long items was higher in naming). Word frequency was not controlled. There are several ways in which the results of the comparison can be interpreted: (1) If there are more errors in repetition than in naming, then the perceptual or other factors specific to the repetition test may be playing a significant role. Another possibility is that there is a higher level deficit in the process of naming; the result is that the fewer the items named, the less chance for phonological errors. (2) On the contrary, if there are more errors in the naming test as opposed to the repetition test, spontaneous lexical retrieval of the word form may result in errors that do not occur in repetition (because the lexical item was selected or it received its activation when the item to be repeated was perceived. Table (5.3.17) is a comparison of the proportion of errors in the naming and repetition tests.

Table 5.3.17 The Proportion of Errors in Naming and Repetition

The proportion of phonological errors in the repetition of simple bisyllabic words is reported under "repetition", and the proportion of phonological errors in the naming of bisyllabic words is given under "naming".

sb	repetition	naming	more in
1	0.07	0	repetition
2	0.10	0	repetition
3	0.02	0.06	naming
4	0.51	0.56	naming
5	0.32	0.58	naming
6	0.55	0.33	(repetition)
7	0	0	
8	0.01	0	
9	0.11	0.09	
10	0.05	0	repetition
11	0.37	0.29	repetition
12	0.02	0.06	naming
13	0.01	0.08	naming
14	0.56	0.56	
15	0.02	0	repetition
16	0.01	0	repetition
17	0.01	0	repetition
18	0.01	0	repetition
19	0.07	0	repetition
20	0	0	

The subjects could be divided into groups based on the proportion of their phonological errors committed in the repetition and naming tests. Some subjects made more errors in the repetition test, whereas others made more errors in the naming test. However, double dissociation did not occur. The controls had more mistakes in the repetition test than in the naming test. These errors could be attributed to the controls' misperceptions, as is indicated by the following evidence. Firstly, control Subject 19 had difficulties in syllable discrimination, and he also made the greatest number of errors in the repetition test. Subject 1 also failed in the syllable discrimination test and he made more errors in the repetition test than in the naming test. However, Subject 15 also made his errors in the repetition test rather than in the naming test, but he did not show problems in the syllable discrimination test. Furthermore, the second factor that indicated that the controls' errors were due to misperceptions was that bisyllabic items were more difficult than longer items. This can be explained by the amount of redundancy. If a subject has slight speech perception problems, these difficulties can be overcome by top-down processing in the case of redundant, long items but this is not a solution for the bisyllabic items (c.f. Hirsh et al., 1954).

Of the patients with severe problems in alternate motions, Subject 14 had an equal amount of errors in the two tests. It was apparent that this subject had an articulatory problem. Subject 5 made more errors in naming and, thus, had special problems with naming. Subjects 6 and 11 had more errors in the repetition test. Subject 6 had a particularly high number of non-responses in the naming test. The proportion of phonological errors in relation to the answers given was 0.56. Thus, the proportion of phonological errors in the two tests was equal. Also Subject 11 had a high number of non-responses in naming. Subjects 8 and 10 demonstrated particular difficulties with long items in the repetition test. Subject 8 made more errors in naming than in repetition, especially with those words that were phonologically more complex. Subject 10 named very few items, and the few phonological errors that were produced occurred after a semantic cue. Subjects with semantic and verbal paraphasias and neologisms in naming and picture description were likely to make more phonological errors in the naming test than in the repetition test.

In general, the aphasic and the control subjects were different in that the former made more phonological errors in the naming test. To be more precise, the controls made no phonological errors in the naming test, but made some phonological mistakes in the repetition test. A detailed analysis of the errors may provide more information about the nature of the naming and repetition processes. Most interesting is the existence of qualitative differences between the errors in the two tests.

The proportion of literal paraphasias (one phoneme substitution in a word) as compared to complex errors (several substitutions in a word) was higher in the repetition test. Thus, the errors were simpler in repetition than in naming. This effect may have been due to the differences in the phonetic complexity of the analyzed words.

Subject 4 was the only subject to delete syllables, and these errors occurred word-finally. In fact, this subject usually produced only one or two initial syllables. Anticipation errors were characteristic of Subject 14. Subject 6 also made anticipation errors, but these errors more frequently occurred in the naming test than in the repetition test. In general, anticipation errors usually occurred in complex and long items. Metathesis errors were made by Subjects 8 and 11, the latter having the most frequent occurrence of this error type. Perseveration errors were typical of Subjects 4 and 14 in the repetition test, and for Subjects 2, 3, 5, and 14 in the naming test. Anticipation and metathesis errors will be discussed in greater detail in chapter 5.4.2.

In both tests, consonant errors were more frequent than vowel errors. In the repetition test, vowel errors frequently occurred in the speech of Subject 4, and to a

lesser extent in the speech of Subjects 5, 9, 12, 19, and 20. In the naming test, vowel errors were made by Subjects 12 and 13 (and to a lesser extent by Subject 4). Thus, the vowel errors more frequently occurred in the repetition test. There could be a link between vowel errors and speech perception. Vowel errors were not typical of subjects who displayed difficulties with alternate motions.

In the repetition test, the subjects made the most errors word-initially or word-medially. Subject 4 was the only exception, as his errors occurred most often in the word-final position. In repetition, Subjects 6 and 11 had the highest number of errors word-initially. Word-final errors were slightly more frequent in the naming test. In addition to Subject 4, Subjects 9 and 13 also made errors word-finally. There are two possible interpretations of the finding that word-final errors were more common in the naming test than in the repetition test. It is possible that the naming errors were phonologically more complex, and subsequently occurred not only word-initially but in other word positions as well. On the other hand, some patients may tend to make errors word-initially and others word-finally. The possible differences between types of aphasia will be discussed in chapter 5.4.2.

The word-initial errors had special, qualitative characteristics. In the repetition test, the Subjects 6 and 11 (but also Subjects 14 and 5) substituted word-initial consonants with /k/. The use of other stops as substitutes was less common. Subjects 5, 6, and 14 also had a high number of word-initial consonant substitutions in the naming test Thus, this error type is in some way related to motor difficulties that arise, for example, in the articulation tests (i.e. diadochokinesis and syllable repetition).

Subject 4's speech contained numerous word-final additions, deletions and substitutions. The vowel /i/ was the most frequent substitute. Sometimes inflections or derivational suffixes were added word-finally, and sometimes final syllables were deleted.

The repetition test was clearly different from the naming and picture description tests, the repetition test being linguistically less demanding. Of the tests, the picture description was the most complex. The subjects did not produce neologisms, verbal or semantic paraphasias in the repetition test. On the other hand, phonologically motivated word substitutions were produced only in the repetition test. There were no clear test-specific differences in types of segmental phonological errors. However, different patients appeared to make different types of segmental errors.

5.4 Discussion: The Nature of Phonological Disturbances

The following discussion will focus on two central issues -- the modality specificity of the observed phonological deficits, and the possibility of different types of phonological deficits.

5.4.1 A Comparison of the Production and Perception Tests

The primary objective of the present comparison is to determine whether or not some subjects have a modality-independent phonological deficit.

Speech Production Tests

In the articulation tests, there were three subjects (5, 6, 14) who had difficulties in all the administered tests. In the literature, the differential diagnosis of dysarthria and speech apraxia has been based on subjects' performance in the alternate motion (Darley et al., 1975) and voice quality tests (Love and Webb, 1986). According to these criteria for classification, Subjects 5, 6, 14, (but also Subjects 11 and 12), displayed dysarthric symptoms. Subject 12 differed from the other speakers in that he failed in alternate motions, but not in sequential motions, which suggests a double dissociation between the two tests.

Subjects exhibiting dysarthric symptoms (difficulties with alternate motions and abnormal voice quality) also made the greatest number of phonological errors in the syllable repetition test. Similar results were also obtained using the following variables: the total number of errors in syllable repetition, the total number of errors in repetition of words and non-words, and performance on the sequential motion test. Patients who had difficulties with these variables can be classified as having speech apraxia.

The patients who had the severest difficulty with sequential motions also had problems with long words. It is a standard procedure to include long words in the test battery for speech apraxia. Data from this study indicated that long words were more sensitive to articulatory difficulties than was the test of sequential motions. Both the tests focused on the difficulties that surfaced with complex sound sequences rather than with more simple articulatory movements. The test of sequential motions might have been more sensitive would it have been administered in a standard way. Thus, in addition to Subjects 4, 8, 9, and 11 who failed in sequential motions, Subjects 2 and

10 appeared to have the same kind of difficulties. Thus, the test of sequential motions and the repetition test measured the same underlying difficulty. Repetition of short (mono- or bisyllabic) items was less sensitive to the articulatory difficulties than the test of sequential motions (i.e. more subjects failed in the test of sequential motions). In the test of sequential motions, the test item was trisyllabic. The repetition of long items (of four or more syllables) was the most sensitive of the tests compared.

Patients with severe articulatory problems (especially, Subjects 6 and 14) did not try to correct their errors. Subject 5 made some corrections, suggesting perhaps that spastic dysphonia is, in this respect, different from other types of dysarthria. Subjects who only failed in sequential motions and in the repetition of long words (Subjects 8 and 10) corrected errors, as did subjects free of articulatory troubles (as verified by the articulation or repetition tests).

In the repetition test, the most important error category was the phonological errors. A good indication of the subjects' overall test performance was the proportion of phonological errors. However, other factors (for example, those related to speech perception) could have played a minor role in the repetition test.

No neologistic answers or semantic paraphasias were found in the repetition test. These errors must be due to some "high" stage of responding that was characteristic of the naming and picture description tests, but not of the repetition test. Thus, the repetition test was linguistically more simple than the naming and picture description tests.

Because of the lack of "pure cases" in the present study, it was difficult to distinguish between patient groups. However, some groups could be postulated. Even if these loosely-formed groups were not completely homogeneous, the patients within each group were more similar to each other than to patients in other groups. One set of patients (Subjects 5, 6, 14, but also 11 and 12 who were less typical of this group) was formed because they shared a clear articulatory trouble (voice problems and difficulties with alternate motions), another group (Subjects 2, 4, 5, 6, 8, 9, 10, 11, and 14) all failed in the more complex articulation tests (sequential motions, long words). A third group (Subjects 2, 3, 7, 9, 11, 13, 15, and possibly 12) had no articulation problems, but failed only in the naming and picture description tests (semantic and verbal paraphasias, neologisms). The classification of patients will be discussed in detail later, in chapter 7.

A Comparison of Production Tests with Perception Tests

Subject 1 was the only patient who had difficulties in both syllable discrimination and in the phonological condition of the word-picture matching test. He also had articulatory problems in repetition of phonetically complex long words. Thus, it remains uncertain whether or not auditory discrimination problems affect speech production. The rest of the subjects (including those with the most severe speech production problems) did not demonstrate difficulties with auditory discrimination. Nevertheless, these speakers may also have had a problem with higher levels of comprehension. Subjects 1, 5, 6, 10, and 11 made frequent errors in the phonological condition of the word-picture matching test. Subjects 1, 2, 9, 17, 18, and 19 made only "phonological errors" in the phonological condition of the word-picture matching test.

A subject's performance in the speech perception tests did not prove to be a prediction for his/her overall performance in the repetition test. Articulatory factors predicted best the performance in the repetition test. It may be the case that the simple analyses conducted in this study failed to reveal the speech perception factors in the repetition test. If this is true, then some subjects may produce errors (e.g. vowel substitutions) where the role of perceptual factors could be detected, given more sensitive instruments.

There are a few studies about the lexical effects in the repetition of non-words where it is assumed that the lexical effect is due to a subject's using lexical knowledge to compensate for an incomplete recognition of an uttered item (Tanenhaus and Lucas, 1987; c.f. also chapters 5.1.2 and 7.2). It has been claimed that these kinds of misrepetitions occur more often when words and non-words are presented in a random mixture in the lists. In order to eliminate this effect, two separate lists were presented to the subjects. One list contained words and the other list contained non-words. The subjects were informed that there were two different lists. Although a relatively quiet setting was chosen for the site of the testing, some background noise was constantly present.

Results from the repetition test are presented in table (5.4.1). When the proportions of words repeated as other words, and of non-words repeated as words were counted, the analysis was based on a subject's overall performance in the repetition test, and the total number of errors was divided by the number of items in the test. The proportion of phonologically related word substitutions was also counted in the acoustically analyzed words of the repetition test (i.e. in a phonetically homogeneous set of bisyllabic words). In this case, the number of items repeated as other words

was divided by the number of phonological errors. It was of interest to relate the proportion of phonologically motivated word substitutions to the total number of phonological errors because the result was an index of the role of speech perception factors in relation to speech production factors in the repetition test. The non-word repetition test was analyzed in closer detail, the variables being non-words repeated as real words, and non-words repeated partly as real words, for example, one part of a "compound" was changed into an existing word. The results were reported in absolute numbers.

Table 5.4.1 Proportion of Phonologically Related Word Substitutions in the Repetition Test

Abbreviations:
subj = subject
acoustic = the proportion of phonologically related word substitutions in the acoustically analyzed words of the repetition test in relation to the total number of phonological errors
word = the proportion of words repeated as other words
non-word = the proportion of non-words repeated as words
whole = the total number of phonologically related words substituted for non-words
part = the total number of phonologically related words substituted for a part of a non-word (usually as either the first or the second part of a "compound")

subj	acoustic			word	non-word	whole	part
1.	4/5	=	0.8	0.027	0.062	3	1
2.	4/12	=	0.33	0.043	0.104	6	4
3.	2/2	=	1.0	0.012	0.021	1	1
4.	6/54	=	0.11	0.103	0.104	3	5
5.	3/39	=	0.08	0.039	0.050	1	1
6.	8/59	=	0.136	0.078	0.167	6	7
7.	0/0	=	0	0.008	0.021	1	2
8.	0/2	=	0	0.008	0.021	0	2
9.	3/11	=	0.27	0.016	0.000	0	2
10.	5/9	=	0.56	0.047	0.083	5	2
11.	4/37	=	0.11	0.090	0.187	8	1
12.	0/3	=	0	0.004	0.021	1	1
13.	0/1	=	0	0.012	0.021	1?	2
14.	11/63	=	0.17	0.063	0.187	10	1
15.	1/3	=	0.33	0.024	0.083	5	1
16.	1/1	=	1.0	0.004	0.062	0	3
17.	0/1	=	0	0.000	0.000	0	1
18.	1/1	=	1.0	0.008	0.021	1	2
19.	4-7?	=	0.57-1.0	0.039	0.021	1	2
20.	1?/1	=	1.0/0	0.020	0.000	0	1

The results showed that the non-word effect existed even when words and non-words were presented in separate lists. If the controls made errors in the repetition of words, their erroneous responses were usually real words. This was not true for the aphasic patients. The result could be explained by assuming that the repetition of a word as a phonologically related word, or the repetition of a non-word as a real word, was a product of chance – a literal paraphasia or distortion that accidentally led to a

word. These types of errors were possibly made by subjects who had the greatest number of phonological errors in the speech production tests. A more plausible explanation for the findings would be that the effect was somehow related to either lexical access (in speech perception) or lexical retrieval (in speech production).

The above analysis was somewhat circular because it was performed by one person only. One major drawback of such an analysis is that the observed number of non-words substituted by existing words may be due to the ear of the listener: distorted speech can easily be interpreted as meaningful. However, all the phonologically related word substitutions cannot be due only to the listener's misinterpretations. Subject 14, whose aphasia was accompanied with dysarthria, frequently repeated non-words as existing words. This patient's reaction to such errors -- laughter or comments -- showed that he realized he had committed errors. For example, the target was *tinkko* and he said *kinkku / ei ole hyvä / kinkku (nauraa) no* 'ham / isn't good / ham (laughter) well'. Thus, the subject had, in fact, perceived a non-word, and his error was a result of a speech production failure.

A closer look at the results of the word-picture matching test may lead to a solution of the production vs. perception problem. In addition to the segmental phonological (i.e. discrimination of minimal pairs) and semantic difficulties, there may be difficulties arising from the phonological form in the lexicon. Thus, some of the patients who failed in the word-picture matching test, but whose difficulties were not captured by the two factors tested (i.e. discrimination of minimal pairs vs. semantically related words), might belong to this group. Figure (5.4.1) presents the results of the word-picture matching test analyzed from this point of view.

Figure 5.4.1 A Re-Evaluation of the Word-Picture Matching Test

Variables:
phon diff = subjects who made phonological errors
sem diff = subjects who made semantic errors
phon unsyst = subjects with "random" errors in the phonological condition of the test

1. phon diff	1	2						9							17	18	19
2. sem diff		2	3				7	9		11		13		15			
3. phon unsyst				4	5	6			10	11	12	13	14	15			

Subjects committing unsystematic errors in the phonological condition of the word-picture matching test (a possible indication of lexical difficulty) were 4, 5, 6, 10, 12, and 14. The unsystematic errors of Subjects 4, 10, and 14 were deletions, whereas Subjects 4 and 6 (and to a lesser extent, Subject 12) had perseveration errors. No generalizations could be made about the errors committed by Subjects 5 and 10 (and

by Subject 13 who was one of the patients with predominantly semantic difficulties). These subjects failed in some of the articulatory and/or repetition tests, and all the dysarthric subjects were included in the group. On the basis of this study's data it was impossible to determine whether the unsystematic errors were a result of accidental features of the small sample of patients, or whether the errors occurred because the lexical effects were actually related to speech production difficulties.

Subjects 9, 11, and 13 made frequent errors in the semantic condition of the word-picture matching test, and also Subjects 2, 3, 7, and 15 had a few such errors. These subjects with semantic difficulties in the word-picture matching test also failed to provide answers in the naming test. Furthermore, their naming errors were usually semantic paraphasias and perseverations of a previous item. No semantic errors were found in the responses of Subject 11. The lack of semantic paraphasias in his speech does not necessarily mean that he did not experience semantic difficulties. Rather, the other symptoms (especially perseveration) were so severe that there was no opportunity for the semantic paraphasias to occur. Subject 13 had verbal paraphasias in both the naming and picture description tests. Subjects 6, 11, and 13 had neologisms in the naming test and in descriptive speech.

At the segmental level, speech production and speech perception tests seemed to be independent. The semantic difficulties accounted by some of the patients arose in both speech production (naming, picture description) and speech perception. It was difficult to draw conclusions about the intermediate levels such as the lexical phonological level, as there was too little data. However, subjects who had unsystematic phonological errors in the word-picture matching test also produced neologistic answers in the naming test.

It is difficult to propose a comprehensive list of the possible components of production and perception that may lie behind the observed errors. In this study, the analysis focuses on the segmental phonological errors. At the segmental level the production and perception mechanisms seem to be modality-specific. At least two main types of deficits were distinguished in speech production: a) patients with "dysarthric" problems (who had voice disorders and who failed in the test of alternate motions) and b) patients who failed only in the test of sequential motions and in the repetition of phonetically complex long words. Patients in both "groups" made segmental phonological errors.

5.4.2 Are there Different Types of Phonological Errors?

It may be possible to distinguish between several types of phonological errors (as there are several groups of patients), but it is also possible that all the segmental errors are similar. Thus, other types of phonological errors may result from syllable or word level deficits. In the following pages, I shall discuss the nature of the errors on the basis of the information obtained from the phonological analysis. In this context, only speech production errors will be discussed.

A major issue in the literature on normal speech production is the size of the motor control unit. This question cannot be directly answered on the basis of the present data, because more detailed phonetic data are needed to carry out such an analysis. Chapter 6 addresses the issue of the phonetic features of the present subjects' speech. In this chapter, we will first determine if there are errors that should be described in relation to phonemes as opposed to articulatory gestures, distinctive features, allophones, or syllables. And finally, we will discuss the features of the phonological errors that contributed to the classification of the aphasic subjects.

In the preceding analysis of the various tests, a very broad definition of "phonological errors" was used so as to catch even the most unexpected types of phonological errors. We will begin with a look at certain error types that may shed light on the role of "phonemes" in describing and explaining errors. Literal paraphasias (i.e. sound substitutions where one sound is substituted by another) are not optimal in this respect. The same error can often be described with reference to any of the units. For example, if *puku* is substituted by *vuku* in aphasic speech, this phenomenon could be accounted for by any solution -- substitution (or even weakening) of an articulatory gesture, a substitution of a distinctive feature, or of a phoneme, or even of a syllable. Furthermore, a phonetic analysis is needed to determine which substitutions are due to the listener's manner of perceiving deviant speech, and which are actual speech production errors.

In the present data, the proportion of literal paraphasias (i.e. paradigmatic sound substitutions) was small in comparison to the total number of phonological errors. Most errors consisted of several sound substitutions. Contextual errors (i.e. syntagmatic sound substitutions) were also frequent: most noticeable were anticipation and metathesis errors that were common in the speech of some patients, but very infrequent in the speech of other patients. There were many anticipation errors in the repetition data of Subjects 5, 6, 8, 11, and 14. In the naming test, anticipation errors were produced by Subjects 6, 8, and 14, and in the picture description test, by Subject

6. Metathesis errors were produced by Subjects 8 and 11 in the repetition test, and by Subject 11 in the naming test. There were no metathesis errors in the (small) sample of descriptive speech.

The errors listed in table (5.4.2) were selected from the data because they clearly revealed the existence of errors that could not be described without reference to the phoneme in speech production:

Table 5.4.2 Phoneme Errors

produced	target	subject	substitution
keekeri	neekeri	5	n > k
pupasi	lupasi	6	l > p
suusi	kuusi	14	k > s
rarsi	varsi	11	v > r
lapu kapula	kapula	10	k > l
kaikalokepit	kainalokepit	8	n > k
kas ... sak-si	sakset	9	s > k
kakstus	kaktus	7	Ø > s

It is necessary to classify these errors as phonemic because they cannot be described equally simply and naturally with reference to articulatory gestures or distinctive features. Often (as in all the above examples) several gestures or features are involved (e.g. place and manner of articulation). Furthermore, these errors cannot be considered to be a result of articulatory strengthening or weakening, nor can they be described in terms of syllables. Instead, the errors must be described in terms of phonemes because they do not involve allophones or sounds. If allophones or sounds were anticipated or subjected to metathesis, the resulting words would always sound inaccurately articulated (as they would be produced with gestures that would better suit another sound environment). However, this sort of distortion is not necessarily present (this will be discussed in more detail in chapter 6).

The errors listed in table (5.4.2) are not the only type of phonological errors, as there may be several other types of deficits that can also be called phonological. According to Blumstein (1973), error categories such as substitution, metathesis, addition, and deletion do not differentiate between types of aphasia. However, this evidence is not conclusive. For example, Nespoulous et al. (1987) have found differences between Broca's aphasics and conduction aphasics: the substitution errors made by the former are simplifications, whereas the substitution errors by the latter group do not follow the markedness hierarchy. The present analysis will not focus on markedness relationships because the listener's perception of abnormal speech may interfere with the transcription of errors, and thereby make reliable comparisons

impossible. However, this does not imply that there are no paradigmatic phoneme substitutions caused by aphasic problems in speech production.

The following pages contain a detailed discussion of the error categories that were used to differentiate between patients applying the error classification outlined in chapter 5.3. The following factors differentiated between patients: (1) the presence of anticipation and/or metathesis errors, (2) the preferential location of the error as word-initial, word-medial, or word-final, (3) the proportion of consonant versus vowel errors, and (4) the presence of neologisms and verbal paraphasias, and the proportion of literal paraphasias versus complex errors.

1. Anticipation and Metathesis Errors

Table (5.4.3) presents the anticipation and metathesis errors found in the data.

Table 5.4.3 Anticipation and Metathesis Errors

The target is given in parentheses. If the patient's target was incorrect, the correct target is indicated by <xx. If otherwise not indicated, the items come from the repetition test. <xx> indicates the examiner's comments. If it was difficult to transcribe the patient's production, questionable sounds were indicated in parentheses. Alternative transcriptions are separated by a slash. The following filled hesitations occur in the patients' productions: *tuota, tota, no, eiku, eikun, voi, voikun, täm, tämä, ei, mutta, joo, ei o hyvä, em minä saa.*

Anticipation Errors

Subject 5: keekeri (neekeri), tilta (silta), tuotti (nootti), u purppu (korppu), pä pämppä (kämppä), k kokeli (tokeni), kääp pääpä (kääpä), sus(e)tti/suntti (rusetti), te tentti (sentti), pu tuota rupasi (lupasi), pep p eiku epäsi (lepäsi), ko ke kokei ko kokero (lokero), tot tot totu toti tontti so-tu-ton koko koko koko tontti koko ... koti tonttu (kotitonttu), kok kok ko ko ko koke?ikakku (sokerikakku), kukka (sukka)

Subject 6: äm eikun pänpä eikum päm voikun älpä ei kun pän ku täm eikun voi voi ,' em minä saa mutta em minä saa (sälpä), pee eet eepu eikun seepra (seepra), mösöpöpö (söpö), parperi (paperi), poippi (koppi), huts eiku kukka (sukka), m e kaakka (taakka), omppu eikun pomppu (korppu), pö pälpempäin (jälkeenpäin), oo attulmati eiku kappulapio (kakkulapio), anna e eikun inna (linna), äännä kokerikattu (sokerikakku), ääpä/pääpä (kääpä), oit eikun tiltti (kiltti), ö kalko (halko), pipesi/vipesi (lipesi), on pupasi (lupasi), mäpihyt ei mäpihytty eiku kun m mäpihyppy ei mutta ei mäpihyppy ei ei mutta mäkihyppy (mäkihyppy), puukkipoika (pyykkipoika, naming), pe-p-eppeles (seppele, naming), pännympäpyjä (käpy, naming), naronat (saranat, naming), tintu (lintu, naming)

Subject 7: kakstus (kaktus, naming)

Subject 8: pseepra (seepra), paitot painotella (painotella), kahsistsematon (kahlitsematon), hammarsharja (hammasharja, naming), kaikalokepit (kainalosauvat, naming), kak(s)tus (kaktus, naming)

Subject 9: sa saks eiku katets ... (katiska, naming)

Subject 10: lapu kapula (kapula), sees-ti (teesi)

Subject 11: sipusi (kipusi), kokero (lokero), kika (pika), soo kookeri kaa kaakku (sokerikakku), kölki (tölkki), sylsy (hylsy), sulsi (pulssi), rarsi (varsi), rorsu (norsu), saasu (kaasu), seesi (teesi), silki eiku pilpi kilpi joo (kilpi), kökki eiku kökkö ei (mökki), kelikaanit (pelikaani, naming)

Subject 14: mm pumpu (rumpu), suusi (kuusi), pu lulppa (tulppa), peeppa ei o hyvä no (seepra), teestyy (seestyy), poppi (koppi), t'ootti (nootti), kukka ei ei sukka (sukka), sorlsu (norsu), s santsi (kansi), sänsä/säntsä (känsä), totitonttu (kotitonttu), sylssy (hylsy), l tuuttuu (luuttu), kalko (halko), o op(p)opis ei o hyvä to popotsi (roposi), tanta (ranta), tentti (sentti), pernppälsi (lepäsi), tanttu (lanttu), käntky (sänky, naming), kirtala (kitara, naming), aattituuta (<lattialuuta, harja naming), puppeppoista (pyykkipoika, naming), katetti (kanootti, naming), uureparppu (huuliharppu, naming), [illegible]ta (kota, naming), kukellusmene (sukellusvene, naming), tuuntelluvlaite (<kuuntelulaite, stetoskooppi naming), kuonopoppa (kuonokoppa, naming), utsetti (rusetti, naming), pa(r)ppi (harppi, naming), irbopooppi (mikroskooppi, naming), pumppa(m)pii (turbaani, naming)

Subject 16: papisi (vapisi)

Metathesis Errors

Subject 4: pinkka eiku tota pik penkka (penkki), mirkka (merkki)
Subject 5: ruiku (<?riuku, harppi, naming)
Subject 6: (p)yysä (syylä), pirspi (sirppi), ääsi (sääli)
Subject 8: rokelo (lokero), helikopreti (helikopteri, naming), sanarat (saranat, naming), lappunat (nappulat, naming)
Subject 9: kas kas eiku sat sak-si (sakset, naming)
Subject 10: sees-ti (teesi)
Subject 11: kiippi eiku kii ki ki (piikki), saapi (paasi), kuuppo (puukko), sänkä (känsä), sumppi (punssi), kamppi eikun kamppi nojoo (pankki), tepo (peto), kesikelä (kesäkeli), ka ta sa kase (sakset, naming), <ma> laima kaima (maila, naming), <sa> e <joo> sanara (saranat, naming), ?vanaja (majava, naming)
Subject 14: sanara (saranat, naming)

Let us first turn our attention to Subject 8's anticipation errors. As was concluded in chapter (5.4.1), Subject 8 belonged to the group of patients who had difficulties only in the sequential motion test, in the repetition of long items, and in descriptive speech. Subject 8 differed from the other subjects of that group in that he had a very high proportion of phonological errors in the picture description test, as compared to the repetition and naming tests. In the repetition test, the long items proved to be the most difficult for this subject. For this reason, one can suspect that difficulty in descriptive speech may arise from the long stretches of speech to be produced without pausing (e.g. phrases instead of words). Results of phonetic measurements of normal speech support this hypothesis. The duration of a segment depends on the length of the word: the shorter the word, the longer the segment. In connected speech the segments are shorter than in isolated words.

Subject 8's phonological errors (both anticipations and phoneme perseverations) were assimilatory. The item *kaikalokepit* could be interpreted either as an anticipation or as a perseveration. This subject made more anticipation errors than phoneme perseveration errors. The substituted consonant was either word-initial or occurred in the second syllable (or on the border of the first and second syllables). The anticipated

consonant was either a stop, fricative (/s/), or tremulant (/r/) that occurred either in the second, third or fourth syllable. The anticipated consonant could be located on either side of the syllable boundary, and it could be a single consonant or one part of a consonant cluster. The anticipation could occur more than once, and it could either substitute another sound, or it could be added to the word (e.g. *kahsistsematon* < *kahlitsematon*). The change was not necessarily a reduction or a simplification of the word form; on the contrary, the result of the change could be a phonotactically inadmissible cluster.

The errors made by other subjects who had the same type of aphasia as Subject 8 (i.e. they had problems in the test of sequential motions and in the repetition of long items, but they did not have difficulties in the test of alternate motions) were similar to those made by Subject 8.

Subjects 5, 6, 11, and 14 made frequent anticipation errors, and most of these mistakes can be described by the following generalization[1]:

For bisyllabic words, an obstruent that occurs on the border of the first and second syllables substitutes the word-initial consonant. For longer words, any obstruent can serve as a substitute for a consonant that occurs earlier in the word.

There were a few exceptions to this generalization. First, the anticipated consonant was not always an obstruent, e.g. *pu lulppa* (<*tulppa*), *rarsi* (<*varsi*, expected *sarsi*), *rorsu* (<*norsu*, expected *sorsu*). Sometimes a vowel was anticipated, for example *poippi* (<*koppi*).

Besides anticipation errors, the subjects also made other types of mistakes (e.g. *silki* <*kilpi*). Some of these mistakes were literal paraphasias that may have resulted from articulatory weakening or strengthening. These errors will not be discussed because a reliable analysis would demand the use of phonetic measurements. However, two errors are noteworthy, *kokerikattu* < *sokerikakku*, and *mäpihytty* < *mäkihyppy*, as they resemble some metathesis cases. It has been proposed (Shattuck-Hufnagel, 1987: 22) that the anticipation and metathesis errors are related. With metathesis errors, the subject keeps the substituted sound in mind, whereas with anticipation errors he/she forgets the substituted sound. Although this hypothesis could be true, it is very

[1] In the repetition test, obstruents were favored because of the acoustic analysis (they were easier to segment than sonorants). Thus, it could be suspected that the selection of the items might bias the results. However, the subjects made similar errors in both the repetition and naming tests. In the repetition test, the systematic alternation of phonetic features may have facilitated the error analysis. It was easier to detect the regularities of the error types when there was a homogeneous and sufficiently large sample of short and phonetically simple test items.

difficult to test. One could consider the metathesis errors to be a milder form of the anticipation errors. There were also errors whose anticipated consonant was something other than an obstruent. These could be considered attempts at correction and, thus, a "milder" error of the same type (e.g. *pu lulppa* < *tulppa*). The most severe errors were those involving both anticipation and phoneme perseveration. In such errors a word-medial consonant substituted both word-initial and word-final consonants, and the error resulted in a word form in which all the consonants were similar (e.g. *peeppa* < *seepra*). The examples in table (5.4.4) reveal the articulatory nature of these errors.

Table 5.4.4 Anticipation Errors with "Self-Correction"

kääp pääpä	'kääpä'	Here the subject began with the correct form but failed to articulate it.
l tuuttuu	'luuttu'	This example also indicated that the target was correct.
soo kookeri kaa kaakku	'sokerikakku'	Again, the original target was correct.

The inherent difficulties in the articulation of these words were revealed by an analysis of the "false starts" which were, in fact, the correct beginnings.

The generalization about the nature of anticipation errors was similar for all the patients, regardless of alternate motion difficulties. The only difference was that for patients with alternate motion difficulties, the anticipation errors were very common and occurred even in bisyllabic words. For subjects without alternate motion difficulties but with sequential motion difficulties, the anticipation errors occurred only in long items of complex phonetic composition. For subjects with alternate motion difficulties, the assimilation errors were more total than for subjects without alternate motion difficulties. For the subjects exhibiting alternate motion difficulties, the assimilation often resulted in a word form with similar consonants only. For this reason it seemed reasonable to consider the errors of the two patient groups to be a result of a shared underlying error mechanism, but differing in severity.

The metathesis errors also failed to reveal a clear distinction between the two "groups" of subjects. The metathesis errors were most common for Subjects 8 and 11, but the speech of Subjects 5, 6, and 14 also contained such errors. Some of these errors involved geminate consonants, e.g. *kiippi* < *piikki* and *kuuppo* < *puukko*. In the four instances where Subject 11 produced these forms, the resulting form was phonotactically acceptable. However, one of the errors made by Subject 6 was different: *pirspi* < *sirppi* (on the basis of Subject 11's errors, we would have expected

a phonotactically acceptable form *pirssi*). Due to the small number of examples, no generalizations could be drawn about these two types of metathesis errors.

The word *saranat* elicited a metathetical form in three subjects, and they produced *sanara(t)*. On the basis of the present data it is difficult to say why exactly the resulting form would be easier than the original one. One could propose, for example, that the sonority hierarchy of the consonants is a factor here. In this context, the sonority hierarchy refers to the order of the consonants in a word form, not in a syllable. Thus, the more sonorous consonants would become later in the word. However, the forms *lappunat* < *nappulat* and *helikopreti* < *helikopteri* were contrary to this suggestion. In the metathesis errors, both vowels and consonants were interchangeable, but in all the errors either two consonants (e.g. obstruents or liquids) or two vowels exchanged places.

Initially the anticipation errors of Subjects 5, 6, and 14 appeared to be different than the anticipation errors of other subjects. However, after a closer inspection, no clear qualitative difference surfaced in this analysis, and the difference was thus attributed only to severity. A superficial comparison of the present data with the descriptions of slips of the tongue (e.g. Shattuck-Hufnagel, 1983) gave the impression that phoneme substitutions were more common in slips of the tongue, whereas complex errors and contextual errors predominated in aphasia. Thus, there may be qualitative differences between the errors made by aphasics and the errors occurring in slips of the tongue. Dressler (1982) has presented evidence to support this qualitative difference in errors.

2. Word-Initial, Word-Medial and Word-Final Errors

The analysis of the errors revealed a difference in their locations: some patients made more errors word-initially, whereas other patients made more errors word-finally. Blumstein's (1973) results showed a clear difference between Broca's aphasia and Wernicke's aphasia in this respect. The former group made more errors word-initially, and the latter group made their errors word-finally. Blumstein did not, however, discuss this finding. The finding has two interpretations: either the difference reflects different stages of the speech production process (i.e. word-initial errors are closer to the motor end of the process, and word-final errors to the lexical end of the process), or the errors are a result of the same basic problem and the difference is one of severity, i.e. the more severe the deficit, the more complex the errors. Furthermore, we could assume that a severe deficit would result in errors that occurred in all positions

of both short and long words, whereas a milder deficit would result in errors that occurred in long words word-medially or word-finally, as those subjects without alternate motion difficulties made their errors in long words of complex phonetic composition.

In order to find out whether or not word-initial and word-final errors are due to different error mechanisms, subjects with word-initial and word-final errors will be compared. All, and only those items will be analyzed that were misproduced by the subjects. In order to obtain a sufficient sample of errors, two subjects will be compared simultaneously. There were only two subjects (4 and 9) with a reasonable number of word-final errors, and subsequently two comparisons will be made. In the repetition test, the effect of position was clearest for Subjects 4 and 6 (the former made more word-final errors, the latter made more word-initial errors). The errors made by these two subjects will be compared. Another comparison will be made between Subject 9 (who made errors word-finally) and Subject 14 (who made errors word-initially). Table (5.4.5) presents the comparison of errors of Subjects 4 and 6, and 9 and 14, respectively.

Table 5.4.5 Position of the Errors in the Words

This table compares the errors of subjects who demonstrated clear differences in the "preferential" word positions for errors. All, and only such items are included in the comparison where both the subjects made phonological errors. There are no other selection criteria, so that the tables give a representative picture of the errors. The words are organized according the length of the target, from monosyllabic words to compounds.

The patients' comments and filled pauses are in brackets. Alternative transcriptions are indicated by a slash.

Subjects 4 and 6

target	4	6
Repetition		
vie	vai vian	ie
rumpu	rumpi rumpu	umpu
teettää	tää tii	eettää
kukko	kok?i	'ukko
luuta	luuti	luuta/'juuta
koti	kuti	koti/oti
soolo	suo lö suo-li	okjoolo
sälpä	selvi	äm (eikun) pänpä (eikun) päm (voikun) älpä (ei kun) pä (ku täm eikun voi voi ... em minä saa mutta em minä saa)
kilpi	kel	ilpi
kokko	ko ko	okko
kämppä	kämppe/kämppi	ämppä
loota	loote/looti	oota/uoota

liina	liima	iina
tulppa	tuu tuu (mikä se)	kulppa
koko	ku kul kuku	oko
ele	(mikä) ill	ole
tulee	pulo	ylee
seepra	tee siipra	pee eet eepu (eikun) seepra
teesi	tiisön	iesi
tölli	töllit/töllet	önni
seestyy	siisti	iistyy
sello	selli	kello/jello
tossu	tossut	oossu
kasa	kas-s-sa? (kuinka se) kassik	'aza/pasa
koppi	kup (eiku) kop	poippi
kelo	kel kelli kelli	elo (eno?)
setä	seti	pö etä
tylsä	kyrsy	pir (e eikun) tylsä
syylä	syyly syylä	(p)yysä
sirppi	siippi	pirspi
korppu	kurppi kur kur-ppe	omppu (eikun) pomppu
helppo	hilppo	aelppo
käki	ka ki käki	väki
lääke	lääki	ääke
kapula	kapa	apula
keräsi	kirs	köräsi
lokero	lukiin	okeero
paperi	paperri	parperi
halveksunta	hal hal halki	alveskunta
karikkoinen	karri karri karri-ni	karikkone
kehystämätön	kiha kii kehi	s esyttämätön
kellertävä	kelli ki-i ka	paellertävä
luultavasti	luus luulte luul	tuultavasti
hulivili	ke	ulivili
kakkulapio	kakku la lapi-ja lapiji	attulmati kappulapio
kesäkeli	kesi si	esäkeli
kirkonkellot	kirro kir kirri	irkonkellot
kotitonttu	ku kut kute/kuti ku	(l)opitonttu
lelupalikka	li li-pa	pa lerupalikka
lottovoitto	luttu	ottovoitto
papupata	pappu	makupata

Naming

kampa	kr kr ... kamppu	ampa
kukka	kukkare	(titten) ka (k)ukka
harja	(se on tämne ee) vaasi laas laa	(paö päs on) puuta
seppele	(se on se on tämmöne) semp seppele	pe p eppeles
hammasharja	(se on) ham hampa haro hara	(ja) kammasharja
pyykkipoika	pyy pyy	(ja) puukkipoika
kainalosauvat	kane kan ... kan ... ka ... kane kanek kankkius	(ja titten poika kävelöö) kaunakepillä (eikun) kae

Subjects 9 and 14

target	9	14
Repetition		
teettää	tiittää	hirttää/irttää
teema	tiima	eema ... keema (ei olkoon) ... vleema (ei ei ole hyvä)
kuulo	kuuno	kuul (ei ole)... luullo
merkki	mertti	pikki
takka	tagga	alkka
valssi	valssu	valtsi
ehkä	ehtä	ketsä
sokeri	sokeli	soterli
kahlitsematon	kahlishat kahlis kahlitsema	katlimnenmanton
kallistuminen	kallistumaa-na	kan-tit-tum-min-nen
kehystämätön	kesty kesystä lä mä kevystä kevystää	tehtsytlä (ai) ... elkkylmä ... seskummatton ... tissulttammetton
taivutteleminen	taivutteliminе	tammuttennemminen
tornimainen	torrimainen	tornimmannen
valheellisuus	valheellis-su valheellisuus	valkeillituus
ystävällisyys	ystevällityysi	us-täm-mällintyys
hulivili	kuiveli	al(v)ivili
kapakala	napakala	pak(k)akatla
mäkihyppy	mäkihyppi	mökkis hyppy
sokerikakku	sokerikampku	kotelinka(p)kku

It was difficult to determine the difference in the nature of errors for bisyllabic items without counting the error types (especially deletion or distortion of the word-initial consonant for Subject 6, and substitution, distortion, or deletion of the word-final vowel for Subject 4). The difference became very clear when longer items were compared. Subject 4 rarely succeeded in producing more than the first syllable or syllables (which were correct). Subject 6 produced the long item with some errors that often occurred word-initially, or near the beginning of the item. Subject 9 resembled Subject 4, whereas Subjects 5, 6, 11, and 14 resembled Subject 6. Subject 9 made fewer repetition errors than did Subject 4.

It was as if the initiation of the movement were difficult for Subjects 6 and 14. According to the hypothesis by Joanette et al. (1980), the difficulty of Subject 4 might be interpreted as an instability of the internal representation of the phonological form, or a difficulty in activating it. This led to both literal paraphasias, difficulties in producing the ends of the items, and some phonetic disintegration (e.g. vowels foreign to the Finnish system). There were remarkable differences in Subject 4's performance in different tests. The disturbance was the severest in spontaneous speech and naming, moderate in repetition, and the mildest in reading. He read slowly, syllable by syllable, but he made few errors. Out of thirty verbs in an action naming test, five

responses were considered to be correct. However, in only one example the reported answer was completely correct (this was the only monosyllabic verb of the test). Subject 4 produced the first syllable(s) of the target in twenty-four out of twenty-five false responses, but he could not complete the word. When the same list of verbs was administered to the subject one week later to be read aloud, the number of correct responses was twenty-five.

Subject 4's difficulty was partially compensated for by different types of external support. The repetition of words was supported by the auditive model which was less effective than the visual support available in reading. In repetition the errors made by Subject 9 resembled those of Subject 4. However, in the naming test, Subject 9 sometimes gave the right name, but he began to self-correct his responses. This subject acted as if he did not recognize the correct word form (e.g. when trying to name the pelican he said *mutta ei muista / en mitä tätä että mikä tän nimi on / pelek pelik kaani kääni kooni eiku (laughter) vai muistanko mä / peli / peli peli pelikaan pelikää kää kaali eiku peli / pelu pelikaati / ei se taia ihan oikein tulla / penni pelikaali*). This is apparently a variety of anosognosia that shall be referred to here as phonological anosognosia. Still, as the correct name occurred in the sequence of approximations, Subject 9 must have had the right target in mind. The phonological form had not disappeared from his lexicon, but the source of the problem was elsewhere. He had a complex syndrome, and his phonological difficulties were accompanied with semantic difficulties. His slight articulatory difficulty may (at least in principle) be either a separate mild component of his aphasic syndrome, or an obligatory concomitant of this syndrome.

Subjects 4 and 9 both had many series of approximations. Subject 9 made most of his approximations in the naming test, and none in the repetition and picture description tests. His attempts at self-correction were not very successful.

3. Vowel and Consonant Errors

According to the characteristics of the phonological errors, the difference between subjects' performance could be partly attributed to the proportion of vowel versus consonant errors. Table (5.4.6) presents the proportion of consonant and vowel errors in the repetition and naming tests for Subjects 4, 5, 6, 9, 11, and 14. These subjects were selected because they made at least five consonant or vowel errors.

Table 5.4.6 Proportion of Consonant and Vowel Errors in the Repetition and Naming Tests

(C = consonant error, V = vowel error)

	naming		repetition	
subj	C	V	C	V
4	0.57	0.43	0.09	0.91
5	0.83	0.17	0.71	0.29
6	0.88	0.13	0.82	0.18
9	0.80	0.20	0.55	0.44
11	1.00	0.00	0.98	0.02
14	1.00	0.00	0.90	0.10

All subjects made more vowel errors in the repetition test than in the naming test. Thus, some vowel errors may be perceptual in nature. However, the subjects who had the highest proportion of vowel errors in repetition also made some vowel errors in naming. Vowel errors were relatively frequent for Subjects 4, 9, and 5. In contrast, Subjects 11 and 14 had very few vowel errors. Subjects 4 and 9 had severe difficulties with the repetition and naming of long items: they tended to produce the first (and, perhaps, the second) syllable correctly but subsequently "forgot" the end of the item. The errors of Subjects 6 and 14 occurred word-initially. Table (5.4.7) presents the location of errors. The analysis was based on the acoustically analyzed words of the repetition test.

Table 5.4.7 Distribution of the Repetition Errors

The analysis was based on the acoustically analyzed words of the repetition test. Most test items were bisyllabic. C1 refers to the word-initial consonant, V1 to the initial syllable vowel, C2 to the consonant(s) between the first and second syllables, and V2 to the vowel of the second syllable. No target had a consonant following V2, but if the subjects added something to the end of the word, it was counted as an error in V2 even when it was a consonant added to V2. The proportions indicate the number of errors in the given position in relation to the total number of phonological errors in the sample.

subj	C1	V1	C2	V2
4	0.03	0.23	0.20	0.54
5	0.54	0.27	0.16	0.03
6	0.79	0.08	0.12	0.01
9	0.12	0.50	0.31	0.06
11	0.76	0.04	0.33	0.09
14	0.41	0.10	0.45	0.04

For Subjects 6 and 11, word-initial consonants were the most prone to error, and the highest proportion of their errors were made in this environment. Subject 14 committed errors most often in the word-medial consonants. Only Subject 4 made many errors in the word-final vowel.

There were also some uifferences between the types of errors. The consonant errors were divided into weakening errors (deletion, the changing of a stop to a fricative maintaining the same place of articulation, etc., c.f. Lass, 1984) and substitution errors (e.g. p > k, s > t, m > n, p > m, l/n confusions). For the word-medial consonants, there were also a number of lengthening and shortening errors, as well as either additions or omissions of a nasal or liquid preceding a stop (e.g. lpp > pp, t > nt). The error types are presented in tables (5.4.8) and (5.4.9).

Table 5.4.8 Types of Word-Initial Consonant Errors

The absolute number of errors is reported.

subj	weakening	substitution
4	1	1
5	13	23
6	49	10
9	0	2
11	4	36
14	10	23

Table 5.4.9 Types of Word-Medial Consonant Errors

The absolute number of errors is reported.

subj	weakening	substitution	lengthening	shortening	cluster
4	0	4	3	8	1
5	3	5	0	1	2
6	2	4	1	0	0
9	0	2	2	0	1
11	1	9	0	5	3
14	0	17	18	0	7

Weakening errors were common in the word-initial position. This type of error was particularly characteristic of Subject 6. There were few l/n confusions in the word initial-position. Subjects 5 and 6 made most of their substitution errors in word-medial consonants, and these were l/n confusions, whereas the substitutions by Subjects 11 and 14 occurred between obstruents. Subjects 4 and 11 generally shortened word-medial geminates, whereas Subject 14 generally lengthened word-medial consonants. Table (5.4.10) presents the classification of vow l errors.

Table 5.4.10 Types of Vowel Errors in the First Syllable

(">" = change to, dipht = diphthong)

subj	> high	> low	> short	> long	> dipht	> back	other
4	12	3	0	1	0	1	0
5	8	0	1	0	5	2	0
6	1	0	0	1	1	1	2
9	2	0	1	0	5	0	0
11	0	0	0	1	1	0	0
14	2	0	3	0	2	3	0

There were few qualitative differences between the first syllable vowel errors. Subjects 5 and 9 substituted long mid-vowels with their corresponding diphthongs (ee > ie, öö > yö). Diphthongization is common in some Finnish dialects, and it parallels a historical sound change which is no longer productive in standard Finnish. Many of the changes from front vowel to back vowel occurred after a velar consonant /k/, and these were phonetic rather than phonological change: the beginning of a (short) vowel sounded back, but the quality of the vowel changed, and the final part of the vowel sounded like the front vowel (e.g. y > uy). The most common error type was the raising of a mid-vowel (ee > ii, öö > yy, o > u).

Subject 4 typically made word-final errors, whereas the other subjects made very few errors in this position. Two error types predominated in this data. The most common was the substitution of /i/ (a common ending of Finnish nouns) for the vowel of the second syllable. Subject 4 also often added consonants /t/ or /n/ or the vowel /a/ to the end of the word. These are common suffixes in Finnish.

Vowel errors occurring in the first syllable will be discussed in chapter 6. The words of the repetition test were selected so that there were numerous obstruents and resonants /l/ and /n/. Substitutions between obstruents (p > k, s > t etc.) and between /l/ and /n/ were relatively common in the data. However, these types of errors should be analyzed in phonetic detail to distinguish between the perceptual factors biasing the transcription and the subjects' production difficulties. Subjects may differ in preferences for error types. For example, Subject 11 (who was the most acute of the patients) often substituted the word-initial consonant with /k/. Subject 14 made numerous anticipation errors where /p/ was a common substitute for other obstruents. In a few items, he also substituted affricates for /s/ (for example, *kača* instead of *kasa*, and *pätsi* instead of *pässi*). However, on the basis of the present data, it was impossible to determine whether these differences were accidental or more interesting, that is, due to the acuteness of the brain damage, its size, or lesion location.

4. Neologisms and Verbal Paraphasias

Segmental errors and neologisms were typical for different types of aphasia. The segmental errors were associated with difficulties in alternate and sequential motions, whereas neologisms and verbal paraphasias were associated with semantic errors. Kohn (1985) considered neologisms to be caused by a deficit at an earlier stage of the production process than the phoneme errors. Some patients with naming difficulties made frequent neologisms, but on the basis of the present data it was impossible to determine whether there was a dissociation between neologisms and semantic paraphasias. It may be that neologisms are closer to the lexicon and lexical retrieval, and the phoneme errors are closer to the motor end of the production process. However, subjects with numerous word-final errors did not have neologisms. Thus, there are two types of "lexical phonological" errors, neologisms and word-final omissions. Phonological anosognosia may be a third lexical phonological error type. Table (5.4.11) presents the neologisms and verbal paraphasias found in the data.

Table 5.4.11 Neologisms and Verbal Paraphasias

In the subjects' answers, the subjects' explanations and filled pauses are enclosed in parentheses. The target and its English equivalent are also given in parentheses.

Neologisms

Subject 2: masyrsmy (majava 'beaver'; unclearly articulated)
Subject 5: sarkovoo-ita (kitara 'guitar')
Subject 6: puulo (mikrofoni 'microphone'), pois po (eikun) poispuuta pö (eikun) pootö (mustekala 'cuttlefish')
Subject 10: (siinäki taas yhden, yhtä rimputettaa) <joo> (mut en tiä mikä se o) vaakuneko (harppu 'harp'; unclearly articulated, laughs simultaneously)
Subject 11: kole ko ko kole (puujalat 'stilts'), kurvi (merihevonen 'sea horse'), perkyrikoona (pingviini 'penguin'), herko (eei ei, no perkule) kenouviinit (eiku ei ei) (yksisarvinen 'unicorn')
Subject 13: rapuli (eiku) rapula (helikopteri 'helicopter'), balkki (pingviini 'penguin')
Subject 14: paparba (majava 'beaver'), ävrivättää (maissi 'Indian corn')

Verbal Paraphasias

Subject 13: lammas 'sheep' (naamari 'mask'), kirkas 'bright' (tulivuori 'volcano'), varvas 'toe' (sarvikuono 'rhinoceros'), koivuja 'birch trees' (puujalat 'stilts'), huhmari 'pounding mill' (länget 'collar for a horse'), riikinkukko 'peacock' (pyramidi 'pyramid'), salkku 'portfolio' (rusetti 'bow, knot')

Both nonfluent subjects (Subjects 5, 6, 14) and fluent subjects (Subject 13) produced neologisms. Some of the neologisms produced by the nonfluent patients may have been instances of extreme phonological errors (possibly a circumlocution with phonological errors) that the examiner failed to recognize (e.g. *puulo* <?*kuulo* 'hearing'

instead of 'microphone'). For this reason, no firm conclusions could be made based on these errors.

The neologism made by Subject 2 was articulated hesitantly and, thus, it was difficult to transcribe. However, this response could be interpreted as a contamination of several words that were simultaneously activated during the naming task (*majava* 'beaver' + *marsu* 'guinea pig' + *myyrä* 'vole' > *masyrsmy* instead of *majava* 'beaver'). There was yet another error that could be considered a contamination in the data, namely (*heli)koottori* = *kopteri* '(heli)copter' + *moottori* 'motor' which was produced by Subject 9. The errors made by Subjects 11 and 13 were articulated fluently and they seemed to be real, "pure" neologisms. It was difficult to "explain" such forms as *balkki* or *perkyrikoona* as a response to a picture of a penguin (*pingviini*). Subject 13 also had some verbal paraphasias that obviously should be considered "random" selections from the lexicon. Some errors were difficult to classify (e.g. *koivuja* 'birch trees' for 'stilts' may have been a circumlocution or a semantic paraphasia).

On the basis of the present data it is difficult to determine if the different error types (neologisms, verbal and semantic paraphasias) all refer to different levels of the word-finding process that can be disturbed selectively in aphasia. No double dissociations were found between these error types. It was possible that the error types were different manifestations of the same underlying difficulty, or they may have resulted from combinations of several independent deficits. These error types were particularly characteristic of the fluent patients.

There are at least two aspects of phonology that suffer in aphasia, the production of phoneme sequences and the lexical phonological representation. In the discussion of the results from the speech perception and production tests, we referred to certain indicators of lexical processing. Two problems were discussed: (1) the repetition of non-words as real words, and (2) unsystematic phonological errors in the phonological condition of the word-picture matching test. Neologisms and verbal paraphasias may also refer to lexical difficulties. A comparison of patients with lexical difficulties as determined by the above variables, is presented in figure (5.4.2).

Figure 5.4.2 Lexical Phonological Errors

Abbreviations:
non-word = numerous non-words repeated as real words
phon unsyst = numerous unsystematic errors in the phonological condition of the word-picture matching test, i.e. not confusions of minimal pairs
neologisms = neologisms in naming and picture description
verb par = verbal paraphasias in naming and picture description
omission = word-final omission of sounds and syllables
anosognosia = phonological anosognosia

The numbers refer to subjects.

1. non-word	2	4		6		(10)	11			14	(15)
2. phon unsyst		4	5	6		10	11	12	13	14	15
3. neologisms	2		5	6		10	11		13	14	
4. verb par									13		
5. omission	4				9						
6. anosognosia					9						

Subjects 4 and 9 had a tendency to omit the ends of the words when repeating and naming long words. Subject 9 had phonological anosognosia. These results do not "fit" into the other results presented in figure (5.4.2), even if Subject 4 has difficulties with three of the above variables. This may imply that there are several types of lexical phonological deficits.

5.4.3 Conclusion

In this chapter, the central issue has been about the characterizing of the phonological aspects of the aphasics' speech production and perception. We have concluded that:

(1) Phonological deficits are not always associated with "dysarthria" that was characterized by voice disorders and by certain types of nonfluent articulation (e.g., difficulties with alternate motions).

(2) The phonological segments of speech perception and speech production can be selectively disturbed. There are subjects with phonological speech perception problems (accompanied possibly by mild speech production problems), and subjects with a phonological speech production problem (without speech perception problems).

(3) Several types of production deficits can be classified as "phonological".

(4) There are segmental errors in speech production that must be classified as phonemic (i.e. it is unnatural to describe these errors with reference to articulatory gestures, distinctive features, allophones, or syllables).

(5) Anticipation errors are articulatory. This is indicated by the errors in which the patient begins with a correct syllable but fails to accomplish the complex sequence of articulatory movements. The most characteristic errors were anticipations of voiceless obstruents (p, t, k, s). In the most severe deficit, the word-medial obstruent was anticipated and substituted for the word-initial consonant. In a milder deficit, the anticipations only occurred in long words.

(6) Some patients often omitted the word-final sounds or syllables of long words.

(7) Some patients made more vowel errors than other patients.

(8) Some patients made more word-initial distortions than other patients did.

(9) A more detailed error classification (e.g. a classification of the errors into weakening, substitution, shortening and lengthening errors) may reveal additional differences between the subjects.

(10) One patient had phonological anosognosia which referred to a particular type of phoneme substitution error.

(11) Some patients made neologisms and verbal paraphasias in the naming and picture description tests, and unsystematic phonological errors in the word-picture matching test.

(12) The semantic errors of speech perception and speech production dissociated from the phonological errors.

(13) According to the present data, the semantic difficulties were modality-independent. Other error types also appeared to be a result of modality-independent deficits, and they were classified as lexical phonological disturbances (neologisms, verbal paraphasias, unsystematic errors in the phonological condition of the word-

picture matching test, possibly also word-final omissions and phonological anosognosia). There seem to be several types of lexical disturbances.

There seemed to be many different types of errors. The more detailed the analysis, the more differences were detected between the subjects. This was particularly true when comparing vowel and consonant errors in bisyllabic items. On the basis of the present data it was impossible to conclusively define the factors contributing to the different error types. The linguistic implications of the error types will be discussed in chapter 7.2. In aphasiology, it is usually assumed that the differences correspond to different lesions. However, differences in age, education, history of language use, and personality also must be considered as contributing factors.

6 Listening Experiment and Acoustic Analysis

6.1 Introduction

A phonetic analysis should provide information about the underlying factors that contribute to sound substitutions. The role of the listener's way of perceiving deviant speech should be estimated, and the relation of phonetic variation to sound substitutions should be studied in greater detail. In this study, the phonetic analysis consisted of two experiments: a listening test and an acoustic analysis. These two experiments were independent in the sense that the words analyzed in the two experiments were not the same. The listening experiment focused on the listener's judgments of articulatory fluency. The speaker's correct and incorrect responses were compared in different tests (naming and repetition). In the acoustic analysis, the formant frequencies and duration of the eight Finnish vowel phonemes (both short and long) were measured in the first (stressed) syllable.

According to the linguistic interpretation of aphasia data, it is assumed that patients with Broca's aphasia (and anterior lesions) have a motor speech production disorder (that is distinct from dysarthria). Patients with Wernicke's aphasia (and posterior lesions) show a phonological (i.e. premotor) speech production disorder. Some patients have both a motor and a phonological deficit (Blumstein, 1981). There may be problems with this interpretation of the data. According to Blumstein (1973), all the literal paraphasias (in Broca's, Wernicke's, and in conduction aphasia) are of the same type: unmarked sounds tend to be substituted for marked sounds. MacNeilage, Hutchinson and Lasater (1981) have re-analyzed the results of three detailed speech apraxia studies, and their results support the motor difficulty hypothesis. According to this hypothesis, motor difficulties cause the markedness effects observed in speech apraxia. However, there are results according to which different types of phoneme substitutions can be distinguished in aphasic speech.

In the acoustic analyses of aphasic sound substitutions, there is evidence for two error types: phoneme substitutions and distortion errors (c.f. chapter 3.2). Kent (1983: 84) has proposed that apractic errors in articulatory positioning and response sequencing might be explained by a theory of speech motor control in which (1) temporal schemata regulate the sequencing of movements and (2) spatial targets are specified within a space coordinate system of the vocal tract. The schemata are means by which abstract linguistic units such as phonemes can make contact with the physical events of articulatory control. MacKay (1970) has proposed that sound

substitutions in slips of the tongue are phonemic, i.e. the units that are anticipated or substituted are phonemes and not, for example, allophones.

If there are two types of errors -- linguistic errors and motor errors -- the motor errors should be characterized by increased phonetic variation in both the listening experiment (more dissension in transcriptions and ratings for less fluent articulation) and an abnormally high standard deviation in durations and formant frequencies, whereas the linguistic errors should not show an increase in phonetic variation. If two types of errors can be distinguished, we should also be able to find two groups of patients, one group with a motor problem, and another group without motor involvement (according to the four measures). Furthermore, the acoustic analysis will provide data for a comparison of the temporal and spatial aspects of articulation. There may be errors that are due to a difficulty in controlling the temporal aspects of articulation, and errors that are due to a difficulty in controlling the spatial aspects of articulation. Shinn and Blumstein (1983) have presented evidence to establish that spatial aspects of articulation remain intact in aphasia.

According to Love and Webb (1986: 134-5), only bilateral brain damage results in a severe involvement of speech musculature. Aphasic patients usually have unilateral brain damage. It is a common clinical observation that many patients recover their articulatory deficits (to a remarkable extent) during the first few months following the onset of aphasia. It is not self-evident that this recovery is due to the compensatory reorganization of the motor systems. However, according to MacNeilage et al. (1981), the motor problem of the aphasic patients "resolves into phonologically predictable strategies". The existence of such compensatory strategies would explain why the errors are phoneme substitutions in which unmarked phonemes (motorically simpler sounds) substitute for marked phonemes. The methodology of the current study does not allow for an analysis of possible compensatory mechanisms. The present data only allow for an analysis of remaining difficulties when the compensation is incomplete.

Increased variation in vowel durations is often interpreted as an explicit measure of damage to the motor systems (e.g. Duffy and Gawle, 1984: 169). This measure is independent from the proportion of phonological errors. If the subject has a motor problem, it is sensible to assume that the phonological errors are related to this motor problem. This can be tested by calculating the correlation between the amount of variation in segment durations and the number of phonological errors.

Lecours and Lhermitte (1973) proposed explicit criteria for distinguishing between phonetic and phonological deficits. The criteria relied on the listener's judgements about the nature of aphasic speech. It is important to determine what it is about

aphasic speech -- what are the specific features that give an impression of nonfluent versus fluent articulation? Is it merely increased variation in all speech production? To what extent is it due to voice disorders, and what are the more specific factors involved? The present study focuses on formant frequencies and vowel durations. These measures provide only a partial answer to the questions. A comprehensive understanding of the mechanisms of articulatory nonfluency can only result from a more comprehensive phonetic analysis.

Some "substitutions" may also be due to the listener's false identification of the aphasic speaker's intention. In most of the misidentified items, the listeners should provide different transcriptions, and rate the articulation as poor. However, the production may also be off-target in such a way that it gives rise to similar (false) identifications by all the listeners. In such cases, the comparison of ratings and transcriptions may be informative.

The rating experiment provides a direct way of comparing the linguistic classification (where two types of disorders are distinguished) with the "motor theory" (where there are different types of motor errors). If the two stages of speech production (the premotor, phonological stage and the motor stage) exist, then two types of errors should appear in the rating experiment: (1) errors due to motor difficulty should result in a variation in transcriptions and rating for nonfluent articulation, whereas (2) errors due to premotor difficulty should result in relatively similar transcriptions by all the listeners and in ratings for fluent articulation. If all the literal paraphasias were due to a motor difficulty there would be no errors of type (2). These theories do not predict a difference between naming and repetition.

Of particular interest is the nature of the errors made by "fluent" subjects. Some theorists such as Luria (1973) and Hardcastle (1987) claim that completely fluent patients with production difficulties do not exist. What lies behind the fluent aphasics' articulatory troubles is impaired feedback monitoring. If Luria and Hardcastle are right, all errors made by aphasics should be hesitantly articulated. The phonetic analysis should reveal which patients have a motor control problem. However, it is not clear how the increased variation for durations should be related to the possible loss of feedback from the articulators. It is also possible that some of the errors are pure phoneme substitutions. The question remains whether or not such errors are also produced in tests other than the repetition test. In repetition the pure phoneme substitutions can be patients' misperceptions.

6.2 The Rating Experiment

The aim of the rating experiment was to test the reliability of the clinical classification of aphasia into the fluent and nonfluent types, as well as the success of the two-stage view of speech production in predicting the nature of the errors made by the speakers -- are the errors of nonfluent speakers distortions, and the errors of fluent speakers phoneme substitutions? The naming and repetition tests are compared in order to control for the possible sources of phonetic variation. The transcriptions also served as a measure of reliability of the phonological analysis found in chapter 6.3.

6.2.1 Subjects

Ten subjects were included in the rating experiment. Of the aphasic patients, three were considered (predominantly) fluent, (9, 12, 13), three were clearly nonfluent (5, 6, 14) and two were neither typically fluent nor nonfluent (4, 11). Here, fluency was determined on the basis of phonological criteria (c.f. chapter 5). The fluent subjects had more difficulty in the naming and picture description tests, and less difficulty in the repetition test. The phonological errors typical of these subjects were neologisms and verbal paraphasias. The nonfluent subjects had difficulties with alternate motions. Subjects 4 and 11 had less difficulty with alternate motions but they failed in the sequential motion test. Two of the aphasic subjects were female, one of them had fluent aphasia, and the other one nonfluent aphasia. Also two controls (16, 17) were included in the experiment, one male, and the other female.

6.2.2 Listening Tapes[1]

Five hundred words were analyzed, i.e. fifty words per speaker. The words were selected by the experimenter so as to provide a balanced set of data of both (relatively) successful and unsuccessful pronunciations by the subjects. It was impossible to check for the exact nature of the variation in transcriptions because different words were selected from different speakers. If the same words had been selected for all speakers, it would have been impossible to vary the correctness of the answer. Twenty of the words were taken from the confrontation naming test, twenty from the repetition of real words, and ten from the repetition of non-words.

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[1] Listening tapes were made at Haskins Laboratories under NICHD Contract NO1-HD-5-2910.

Non-words were included in the experiment because literal paraphasias often resulted in non-words that could be rated differently from real words by the listeners. An attempt was made to balance the words for frequency, length, and phonetic composition. Furthermore, effo t was made to select the speakers' best productions (especially of the nonfluent patients) as the correct answers. As the incorrect answers, literal paraphasias (those that did not sound distorted) were preferred. If these were not found, the experimenter selected other incorrect answers (neologisms, verbal paraphasias, distortions).

The words were selected according to the following criteria (the number of syllables was always based on the real productions by the subjects, not on the target words):

a) naming: a total of 20 tokens per patient

There were ten bisyllabic and ten trisyllabic answers. In each group, five items were real words (correct answers) and five were non-words (i.e. either articulatory distortions, literal paraphasias or neologisms).

b) repetition of real words: a total of 20 tokens per patient

There were ten bisyllabic and ten longer answers. Five words in each group were correct repetitions and five were non-words (i.e. errors).

c) repetition of non-words: a total of 10 tokens per patient

There were five correct and five incorrect repetitions (preferably six phonemes long). For each subject, an attempt was made to balance the length of the correct and incorrect answers.

In selecting the correct answers (a and b), word frequency was noted: both high and low frequency words were analyzed. However, frequency could not be varied systematically because some patients were only able to correctly produce the most common words. For those patients who made very few mistakes, all the incorrect answers were included. If, for example, only three bisyllabic incorrect answers were found in the repetition test, then two longer, incorrect answers were included (instead of the bisyllabic ones). In this case, also three bisyllabic and seven longer, correct answers of the repetition test were analyzed. It was difficult to find the required number of correct answers for some patients, especially in trisyllabic words. In such a case, bisyllabic words (both correct and incorrect answers) were substituted for the trisyllabic words.

An attempt was made to control the frequency of the items produced by different speakers (both relatively frequent and infrequent items were included) because the listeners may be affected by word frequency. When the patient says a frequently occurring word, it may be easier for the listener to predict what is being said. Thus,

the listener would not be required to pay close attention to the accuracy of the production, and the frequent words would be rated relatively fluent. Word frequency was estimated on the basis of the Frequency Dictionary of Finnish.

The same criteria were used for selecting the controls' words as had been used for selecting the patients' words. However, there were very few incorrect answers in the control data.

Table (6.2.1) gives the number of different types of words selected for each subject.

Table 6.2.1 Types of Words in the Listening Experiment

		naming		repetition (words)		repetition (non-words)	
subj		OK	wrong	OK	wrong	OK	wrong
5	short	5	5	5	5	5	5
	long	5	5	5	5		
14	short	5	5	10	10	5	5
	long	5	5				
6	short	7	7	5	5	5	5
	long	3	3	5	5		
11	short	5	5	5	5	5	5
	long	5	5	5	5		
4	short	7	5	8	8	5	5
	long	3	5	2	2		
13	short	5	5	10	6	6	4
	long	5	5	4			
9	short	5	5	5	5	5	5
	long	5	5	5	5		
12	short	5	5	5	5	5	5
	long	5	5	5	5		
16	short	10		9	1	9	1
	long	10		10			
17	short	10		9	1	8	2
	long	10		10			

The items were randomized and recorded on tapes. Only one occurrence of a word (or a non-word) was allowed on one tape. In order to keep the number of tapes as small as possible, the similarity of the items was judged on the basis of the actual productions. In two instances very different literal paraphasias of the same target were allowed on one tape. Also, different naming responses (semantic paraphasias) for the same target were allowed on one tape. Five tapes were made containing hundred items each. The tapes were balanced for words vs. non-words (on the basis of the target) and speaker (each tape had ten items from each speaker). Each item consisted of a given token recorded twice in succession with a 500 ms pause between repetitions, followed by nine seconds of silence before the next item. There were twenty-five practice items at the beginning of each tape. The word list for each tape is found in appendix (6).

On Subject 6's tape, there was a continuous background noise (obviously coming from a lamp) that was difficult to filter out. Subject 11 spoke quietly. It is possible that these facts had a slight effect on the results obtained, and this will be discussed later in connection with the results.

6.2.3 Raters and Rating Sessions

The total number of listeners was 125, i.e. twenty-five listeners per tape. Twenty-five listening sessions were organized in a quiet laboratory at the Department of Phonetics, at the University of Helsinki. The number of listeners in one session varied from one to thirteen. The listeners who volunteered were liberal arts undergraduate students from the University of Helsinki. Table (6.2.2) provides some information about the raters and the rating sessions.

Table 6.2.2 Information about Raters and Rating Sessions

tape	1	2	3	4	5	combined
number of sessions	6	4	8	2	5	25
listeners:						
male	5	6	1	3	2	17
female	20	19	24	22	23	108
age:						
mean	22	26	22	23	23	23
variation	19-30	19-42	19-29	19-26	20-33	
years of study:						
mean	2.3	3.2	2.6	2.3	2.7	2.6
variation	1-8	1-11	1-8	1-6	1-10	

The listeners were asked to record (according to the Finnish orthographic system, they were advised not to use the IPA system) the words and non-words they heard -- ignoring the meaning of the item -- and rate these words and non-words for the fluency of articulation on an answer sheet (normal-abnormal, scale 1-5). The answer sheet and its English translation are presented in appendix (7).

6.2.4 An Analysis of the Answers

The analysis covers the amount of variation in transcriptions and the rating for articulation. The variation in transcriptions was described in terms of relative entropy

$$\text{entropy} = H = -A \sum_{i=1}^{l} P_i \log_{10} P_i$$

where A= $1/\log_{10}2$; relative entropy = H/maxH (Vasama and Vartia, 1973: 100-101). P_i is the relative frequency of a transcription variant, and l is the number of different transcription variants. Relative entropy was 0 when there was consensus among all raters, and it was 1 when all the raters provided different transcriptions. The ratings were characterized by the median for each item on the tapes. When the median was 1, the raters judged the articulation to be normal, but when the median was 5, the raters considered the articulation to be extremely inaccurate.

A comparison of the speakers was made using the following variables: (1) the amount of variation in transcriptions, and the rating for articulation, (2) the test-specific differences, and (3) the correct and incorrect answers.

6.2.5 Results

The data were subjected to an analysis of variance. The analysis of relative entropy and means of the medians provided very consistent results. According to the principles of statistics, the medians of the ratings should not be subjected to an analysis of variance. In the present study this principle was violated because it was suspected that the ratings might give more reliable results than the transcriptions. The results should be interpreted with caution, especially if they differ from the transcription results.

Statistically significant main effects were observed for both subject, test, and correctness. According to the "medians", the interaction between subject and test approached significance. Otherwise, the interactions appeared not to be significant. The results of the statistical analysis are reported in appendix (8). In the following pages, the results will be discussed in more linguistic detail.

Ratings and Variation in Transcriptions

A comparison of speakers for variations in transcriptions (means of relative entropy) and ratings for articulation (medians of the median) revealed a continuum, where on one end were the controls, and at the other end some of the nonfluent subjects. A scattergram of the medians of the ratings and the means of relative entropy for

variation in transcriptions indicated that there was a linear relationship between the two variables. The results are presented in figures (6.2.1) and (6.2.2).

Figure 6.2.1 Variation in Transcriptions

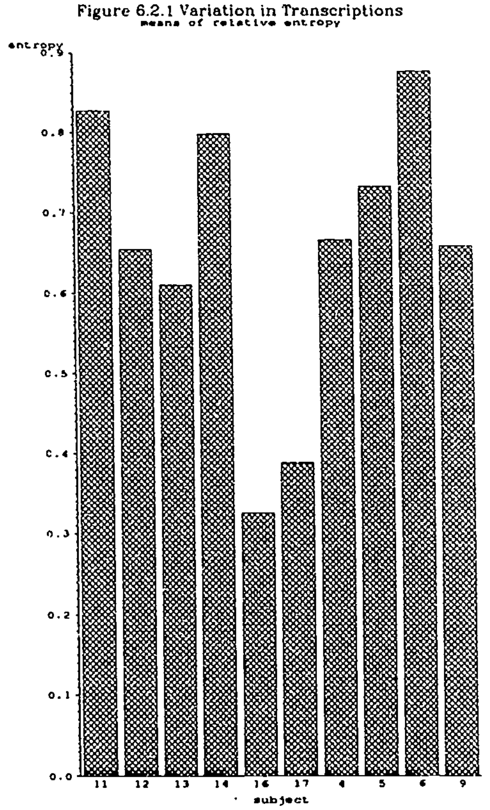
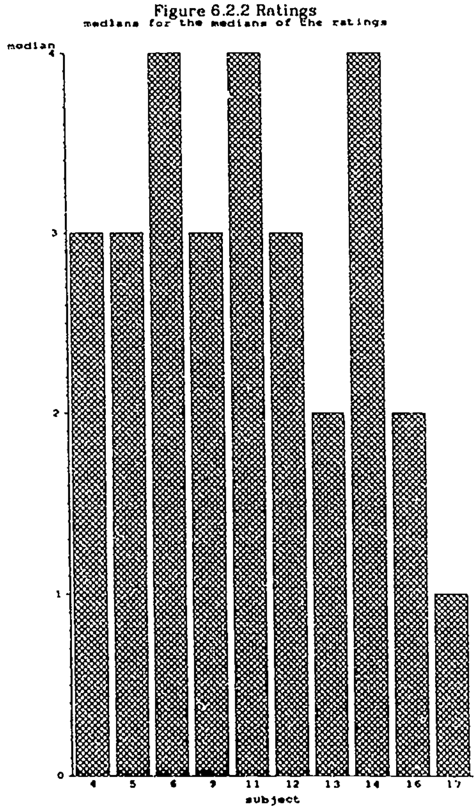


Figure 6.2.2 Ratings



According to the transcriptions, only the controls clearly differed from the aphasics. The median of the ratings was a robust measure, but even according to this measure, a slight difference between fluent and other aphasics was found. When the subjects were dealt into three groups -- controls (16, 17), fluent aphasics (9, 12, 13), and nonfluent aphasics (5, 6, 14) -- a significant difference was found between the groups (analysis of variance for relative entropy, df=2, SSE=12.86, f=122.02, p<0.0). The relative order of the subjects was almost the same according to both the relative entropies and the medians. There were a few differences between the results obtained with the two variables. For example, using the transcriptions, Subject 11 appeared to be more nonfluent than when evaluated by the ratings. One possible explanation for this is that he produced some words relatively silently, which may have increased the amount of variation in the transcriptions. The listeners were able to take into consideration the silent voice and adjust their ratings for articulation.

Test-Specific Differences

Tables (6.2.3) and (6.2.4) present the data organized according to the different tests and according to the correctness of the answers.

Table 6.2.3 Variation in Transcriptions

(means of relative entropy per subject)

subject	naming		repetition (words)		repetition (non-words)	
	corr	incorr	corr	incorr	corr	incorr
6	0.87	0.89	0.85	0.90	0.90	0.88
11	0.77	0.85	0.84	0.82	0.82	0.90
14	0.81	0.90	0.73	0.73	0.79	0.86
5	0.65	0.80	0.60	0.74	0.90	0.85
4	0.57	0.71	0.52	0.78	0.78	0.71
9	0.53	0.72	0.53	0.76	0.66	0.84
12	0.67	0.76	0.48	0.66	0.62	0.79
13	0.71	0.65	0.39	0.68	0.74	0.58
17	0.43	-	0.24	0.40	0.53	0.79
16	0.37	-	0.21	0.50	0.45	0.24

Table 6.2.4 Ratings for the Correct and Incorrect Answers in the Different Tests

(medians of median per subject; as there was an even number of items in some conditions, the median may have two values)

subject	naming	(words)	repetition (non-words)		repetition	
	corr	incorr	corr	incorr	corr	incorr
6	4	4	4	4	4	4
11	3+4	3+4	4	3+4	3	4
14	4	4	3	4	4	4
5	3	4	3	3	4	4
4	3	3+4	3	3	4	3
9	2	3	2	3	3	3
12	3	3	2	3	3	3
13	3	3	1+2	2	3	3
16	2	-	1	1	2	2
17	1	-	1	1	1	1+2

A visual inspection of the tables reveals a clear difference between the tests, especially for the correct answers. An analysis of variance for the relative entropy showed that the differences were statistically significant both when the data were analyzed as a whole (df=2, SSE=1.367, f=9.01, p<0.0001) and for the correct answers (df=2, SSE=1.658, f=9.44, p<0.0001). The rating results were not subjected to a statistical analysis but they showed the same tendency. The differences were clearest between naming and repetition of real words, and between repetition of real words and non-words. According to both variables, the variation in transcriptions and the median of ratings,

the named words were articulated less fluently than the repeated words. The test-specific differences were the clearest for the control subjects and some fluent aphasics (Subjects 12 and 13).

Variation in naming is caused by the "hesitancy" that occurs when the subject searches for a word. There was a clear difference between the controls and the aphasic subjects. Subject 13 most resembled the control subjects. It is possible that the slightly greater "hesitancy" on the part of the fluent aphasics (as compared to the controls) was qualitatively similar to the naming "hesitancy" of the controls. As to the repetition of non-words, the listeners always rated non-words less fluent than real words. Thus, the listeners may perceive (and rate) nonexistent items differently than items that do exist in the lexicon. Another plausible explanation refers to the speakers. The effect may be explained by the extra processing needed to articulate items that are novel and do not exist in the lexicon. Also erroneous items may be articulated more hesitantly than correct items.

Correct versus Incorrect Answers

The examiner judged an answer's correctness on the basis of its phonological correctness. The results were presented in tables (6.2.3) and (6.2.4). According to the relative entropy, the difference between incorrect and correct answers was statistically significant (c.f. above). The ratings provided further support to the difference between correct and incorrect answers.

When the correct answers were analyzed, the subjects' order on the continuum of speakers (with controls at one end, and nonfluent aphasics at the other) resembled the order obtained when the data were analyzed as a whole. According to the ratings, the only clear difference was between the controls and the aphasics. According to the transcription variations, the nonfluent patients and Subject 11 seemed to form a group that differed from the other speakers. The difference between the aphasic patients and the controls was also clear. For control subjects, the means of relative entropy ranged from 0.32 to 0.37, and for aphasics the means of relative entropy ranged from 0.55 to 0.86.

When the incorrect answers were analyzed, the order of the speakers on the continuum was different than in the previous analyses. According to the variation in transcriptions, only Subject 16 was clearly different from the other speakers. However, the controls made very few mistakes (i.e., two errors were made by Subject 16, and three by Subject 17). In general, the incorrect items produced by the two controls were

more fluent than those produced by the aphasic patients. However, the difference was not very striking, and there appeared to be different types of errors. The differences in articulatory fluency between the subgroups of aphasic patients were even less clear.

For the correct answers, test-specific differences were very clear. In contrast, for the incorrect answers the difference between the tests did not prove to be a factor. In both the naming and repetition of real words, there was a clear difference between the incorrect and correct answers. However, the difference can be accounted for in two ways – the incorrect answers are non-words, and they are incorrect. In the repetition of non-words there was a difference between correct and incorrect answers which was statistically significant (analysis of variance for relative entropy, df=1, SSE=0.262, f=5.15, p<0.0254). As a rule, the subjects' correct answers were judged to be more fluent than their incorrect productions. However, for some speakers there was no difference between the correct and incorrect answers, and the correct answers could even be rated as less fluent than the incorrect answers. We can conclude, that the listeners evaluate words as more fluent than nonexistent items, and this effect is stronger than the differences in articulatory fluency for correct versus incorrect items. The nature of the errors may be different in the different subgroups of aphasic patients. A more exhaustive comparison of correct and incorrect items may reveal the nature of the differences in more detail.

Another source of information comes from a closer analysis of the different transcriptions provided by the listeners. Such an analysis could reveal differences between different classes of sounds, e.g. vowels and consonants. The present data were not very suitable for this analysis because different items were selected from the speakers. However, the transcriptions of the controls' errors were analyzed in order to see what these errors were like. The controls made three errors (that were noticed by the examiner) in the repetition of non-words, Subject 17 made two errors and Subject 16 made one error. Subject 16's mistake was heard in the same way by most of the raters. The target was *nerikutto*, 24 raters had recorded *nelikuttu*, and one *nelikuttuh*. This can be interpreted as the repetition of a non-word as a word because both *neli-* and *kuttu* exist, and can be thought to form a nonsensical compound. One of Subject 17's errors resembled the mistake made by Subject 16. However, there was more variation in the listeners's transcriptions of this error. The target was *outakouro*, and the most common transcriptions were *outakoulu* (13 listeners had provided this transcription), and *outakouru* (recorded by 8 listeners). In these forms, the nonsensical second part of the compound is substituted with an existing word *koulu* 'school', or *kouru* 'gutter'. There were also three other transcription variants. The other error made

by 17 was somewhat different. The target was *unkura* and 7 listeners recorded it in this way, but 18 listeners recorded *onkura*, which is a non-word. In this case, Subject 17's production of the vowel /u/ may have been "off-target".

There were two errors made in the repetition of real words, one by Subject 16 and the other by Subject 17. Subject 16 repeated *tiili* as *tilli* (20 transcriptions, three listeners had heard *pilli*, one *dtilli*, and one *illi*). Subject 17 repeated *kyyti* as *pyyti* (22 transcriptions, two heard *tyyti*, and one *pyytin*). Thus, these errors appeared to be relatively "pure" sound substitutions, i.e. we can assume that the speaker intended to utter *tilli* and *pyyti*. The experimenter did not hear errors in the naming test for the comparison group, and we can thus tentatively assume that errors in repetition were related to perception (either a misperception by the subject tested, or by the listeners rating the subjects).

6.2.6 Discussion

The subjects' order was similar in the various comparisons. Patients who were classified as fluent were closer to the controls on a speaker continuum, and the other aphasics differed more from the controls. This was in accordance with the common clinical distinction between nonfluent and fluent aphasia. However, all aphasic speakers were rated less fluent than the controls. Thus, the speech of the fluent aphasics was not fluent in the phonetic sense. The phonetic variation in naming seemed to be related to the retrieval of the word form from the lexicon. Non-words were rated as less fluent than were real words, which may also be explained with reference to the lexicon: the items that exist in the lexicon are either easier to perceive, or easier to produce, or perhaps both. Words with sound substitutions were not judged to be as fluent as correct answers. This was because the listeners could have perceived non-words differently from real words. However, there was also a difference between correct and incorrect non-words, the latter being less fluent. There seemed to be different types of errors, and the analysis did not reveal if all words with phonological errors were articulated less fluently than correct items. In the following discussion, three major points will be examined: (1) the fluency versus nonfluency dichotomy, (2) the nature of sound substitutions, and (3) the reliability of the transcriptions of aphasic speech.

One of the aims of the listening experiment was to experimentally test the validity of defining the fluency vs. nonfluency dichotomy in articulatory terms. A statistically significant difference was observed between these two patient groups, and both the results from the listening experiment and from the error classification (fluent patients had semantic errors, whereas nonfluent patients had segmental phonological errors; fluent patients made no errors in the repetition test, whereas nonfluent patients made an equal number of segmental phonological errors in the repetition, naming, and picture description tests) provided consistent results. Thus, we can conclude that the speech of the nonfluent aphasic patients is less well articulated than the speech of fluent aphasic patients. However, this does not mean that the speech of the fluent aphasics would not differ from the speech produced by the control subjects. On the contrary, the speech of the fluent patients was evaluated to be less fluent in comparison to the control subjects' speech. The most likely interpretation for these findings is that there are several types of phonetic variation: certain types are typical for nonfluent aphasic patients, and certain types are typical for fluent aphasic patients. The fact that test-specific differences were revealed even in the control data points to the lexical nature of certain types of phonetic variation. The relation of phonetic variation to phonological errors will be discussed in detail in chapter 6.4.2.

In connection with descriptive speech, fluency was analyzed on the basis of grammatical criteria. In this respect, the most useful measure was the average number of all words in a unit ("all words per unit"). In counting "all words", fillers, false starts, and repetitions were included in the word count, and a unit was defined as a simple sentence with one finite verb. Of the subjects included in the listening experiment, Subjects 11 and 14 were classified as nonfluent, whereas Subjects 4, 9, 12, and possibly 13 and 16, were classified as fluent. In the literature (e.g. Paradis, 1987), grammatical fluency is often determined on the basis of utterance length. In the present data, Subjects 11, 12, 13, and 14 produced the greatest number of subordinate sentences. For the nonfluent subjects (Subjects 11 and 14), both the main clauses and the subordinate sentences were short, whereas the fluent subjects (Subjects 12 and 13) produced longer subordinate sentences. Thus, the criterion used in classifying subjects as fluent and nonfluent has a slight effect on the results. However, both unit and utterance length provided relatively similar results.

A comparison of grammatical and phonological criteria for determining fluency did not provide completely consistent results. Subject 4 was very fluent according to

grammatical criteria, but he made many phonological errors. On the other hand, Subjects 5 and 6 were clearly nonfluent according to the articulatory/phonological criteria, but did not differ from the controls according to the grammatical criteria. However, Subjects 9, 12, and possibly 13, were fluent according to both sets of criteria. The grammatical fluency of Subject 4 was mainly due to the great number of false starts and corrections in his speech, but he was not classified as nonfluent even when the "empty elements" were eliminated from the word count. .

On the basis of the present analyses, the articulatory or phonological criteria, and the grammatical criteria appeared to give slightly different results concerning the classification of aphasia as fluent and nonfluent. It is likely that these two aspects of language production are independent of each other. However, the grammatical aspects of fluency should be studied in greater detail before drawing final conclusions.

According to the present results, fluency was not directly related to the severity of aphasia. For example, Subject 4 had severe aphasia (severity rating "2", c.f. table 4.2). The listeners judged his speech to be relatively fluent, and he also produced long utterances (even if he seldom succeeded in uttering complete words). The nonfluent patients (e.g. Subjects 6 and 14) had less severe aphasia (severity rating "3"). Subject 9 also received severity rating "3", but his aphasia was classified as fluent according to both articulatory and grammatical criteria, and the error classification also supported this classification.

The Nature of Sound Substitutions

One important question was whether or not one could gather evidence from phonological errors to support the hypothesis that phonological deficits were independent of the speech production motor processes. Because of the literal paraphasias, real words were changed to non-words that were perceived differently from real words by the listeners. The listeners provided more varied transcriptions for non-words than for real words, and non-words were also rated as less fluent than real words. It was also possible that non-words were articulated as poorly as named words because they were not a part of a speaker's lexicon. Results from the present experiment did not conclusively solve the question of the phonological deficits.

For the control subjects and for most of the patients, there was significantly more variation in the named words than in the repeated words. One can interpret this fact in two ways: (1) whatever difficulty the speaker had in performing the test, it was reflected in his speech production as an increase in the phonetic variation, or (2) the

increase in variation indicated a motor difficulty in finding the right word (i.e. that the lexical phonological representation was somehow motor in nature, or that it was more closely related to motor speech production than to the other aspects of the lexicon). In the latter case, there should not be an increase in the amount of variation for the semantic paraphasias. Among the phonologically correct answers there were some semantic paraphasias. For the one semantic paraphasia produced by the control Subject 16, the median for ratings was 1 and all the raters had transcribed the word in the same way. The same was true of one semantic paraphasia by Subject 9. The semantic paraphasias produced by nonfluent patients were rated less fluent than those produced by fluent patients and controls. This may be because their speech production problem affected all the words that were articulated to an equal extent. Lack of phonetic variation in semantic paraphasias means that the various types of cognitive difficulty do not increase phonetic variation in words. Thus, the phonetic variation observed in named words stems from some specific source that could be the phonological form in the lexicon or is a result of the speech-language interface, i.e. the way in which the phonological forms make contact with the motor speech production system.

A detailed look at other types of errors, for example, verbal paraphasias and neologisms, could shed light on the source of phonetic variation. The listening results combined with an acoustic analysis would make it possible to explore the possible differences between the sound substitutions in the repetition test, some being substitutions and some being misperceptions, and some misproductions. In this study, the repeated non-words and the named words were less fluent than the repeated words. Non-words are not represented in the lexicon. Thus, in this respect, the repetition of non-words obviously differs from the repetition of real words. When repeating existing words, the lexical item to be produced may already receive its activation during speech perception. In naming, the speaker must activate the lexical item to be produced. The activation (and selection) of the phonological form in speech production may lead to phonetic variation. This may be interpreted as support for the different sources of phonetic variation (e.g. the activation and selection of the phonological form, the production of items that are not in the lexicon), and as evidence against the motor nature of the lexical representation.

The incorrect non-words were articulated less fluently than the correct non-words. This indicated that some hesitation may be associated with the production of a phonological error. However, the fact that one control subject had more variation in the correct rather than in the incorrect repetitions of real words can be cited as

evidence for the argument that there are different sources of phonetic variation and different error types.

A qualitative analysis of the listening results would shed light on the differences between error types. The speakers and the ratings that their productions received could not be compared systematically because different words were taken from the speakers. The examples of phonological errors discussed under "transcription reliability" will demonstrate the possibilities of such an analysis.

Transcription Reliability

Two measures of variation were used in the current study, relative entropy of transcriptions, and rating for normality of articulation. A closer look at the results would allow for an estimation of the transcription reliability, and, thus, it would provide an estimation of the reliability of the phonemic error analysis of chapter 5.4.2.

The relative entropy of transcriptions may not directly reflect the nature of the patients' difficulties, even if it reveals the test-specific differences in normal speech production. The human ear may be more sensitive than the transcriptions. In the transcriptions, the existence of certain letters and the lack of other letters may lead people to artificial choices and thus restrict their possibilities in expressing everything that was heard. However, there may be instances in which the human ear fails. Some types of variation may be reflected more reliably in the transcriptions than in the ratings. It is possible that people sometimes categorically perceive deviant sounds, rating them as fluent, but there is variation in the way in which people transcribe these sounds. A problem with randomized listening tapes is that the listeners are uncertain about the identity of the speakers, and consequently some misperceptions may result from a failure in vocal tract normalization (Lieberman and Blumstein, 1988: 177-179).

The present experiment made use of a five point rating scale. There were twenty-five practice items in the beginning of each tape. There were examples of both excellent and very inaccurate articulations among the practice items. Nevertheless, different listeners may interpret the intervals of the scale in slightly different ways, and the listeners may also base their ratings on different features of abnormal articulation. The present data did not reveal the factors underlying the rating and transcription results.

Variation in transcription depends upon the training of the transcribers. Also transcribers' expectations have an effect on the results (Oller and Eilers, 1975). The

raters in this experiment were informed that they would hear words and non-words produced by normal and aphasic speakers. These listeners were untrained, and did not have previous experience in transcription. The use of experienced transcribers (and raters) would have affected the results, but it is unlikely that the differences between speakers or conditions would have changed.

There are some experiments that address the question of variation in speech perception under less than optimal listening conditions (e.g. Hirsh, Reynolds, and Joseph 1954). Lack of articulatory fluency may have the same effect as masking by white noise or filtering – it increases the variation in transcriptions. Data collected from this study did not allow for a qualitative error analysis because different words were selected from different speakers. For this reason, it remains uncertain whether or not the effects of the articulatory type of "noise" on the transcriptions differ from the white noise added to the tape-recordings in, for example, the experiments by Miller and Nicely (1966, c.f. Clark and Clark, 1977). Whatever the effect of noise, conditions for the patients and controls should not differ such that the comparison would be unreliable. The following examples provide further information about transcription reliability.

The phonological errors produced by Subject 12 (one of the most fluent aphasics according to the error types, c.f. 5.3) were included in the rating experiment. In the repetition of words there were two instances of consonant substitutions (target *kyky* was repeated as *pypy,* and target *kyy* as *pyy*). In *kyky* the listeners transcribed the word-initial consonant as /p/, and a majority (23 of 25) transcribed the word-medial consonant as /p/, and finally two other listeners had interpreted it as a /t/. Twenty-two listeners had transcribed the vowels of the first and second syllables as /i/, two listeners had interpreted them as /e/, and one as /y/. In *kyy* twenty-four of twenty-five listeners had transcribed the word-initial consonant as /p/, but only one had interpreted it as /t/. There were also two instances of word-final vowel substitutions: target *tossu* was repeated as *tossi*, and target *norsu* was repeated as *norsi*. In *tossu*, the subjects transcribed the word-final vowel as /i/ (either short or long). In *norsu*, eighteen listeners transcribed the word-final vowel as /u/, four subjects reported it as an /i/, two as /y/, and one did not hear a vowel at the end of the word. If the majority view is taken as the point of reference, the transcription of the consonants was quite reliable, but for vowels, the transcriptions had a bi-modal distribution in two instances. In the repetition of non-words, Subject 12 made one metathesis error (*turipekko* was repeated as *puritekko*). The listeners transcribed the word-initial consonant as /p/, and a majority (22 of 25) transcribed the consonant in the third

syllable as /t/, but the other transcriptions contained Ø and a /j/. Thus, irrespective of the great amount of variation in transcriptions, the phonemic error analysis (of consonant errors, at least) can be considered relatively reliable for the controls and fluent aphasics.

The nature of the nonfluent errors could not be determined in the present analysis. Two of the subjects had voice disorders (Subjects 5 and 14). Since these subjects were not rated as the most nonfluent, it was obvious that the voice disorder did not account for the rating results. However, it was difficult to estimate the role played by their voice disorders in relation to the rating results. The recordings of Subject 6's responses contained background noise, and Subject 11 produced some words in a silent voice. The acoustic analysis will provide further information about the factors underlying the rating results.

6.3 Acoustic Analysis of the Vowel in the First Syllable

The rating experiment produced a speaker continuum with the most nonfluent patients on one end, and the controls on the other. The subjects' order on the continuum corresponded well to the results obtained from the phonological error analysis – the nonfluent subjects made segmental phonological errors, whereas the most fluent subjects did not make phonological errors. However, several factors could influence the rating results: it was not quite clear to what extent the ratings (especially for the most nonfluent patients) were influenced by factors such as abnormal voice quality, and background noise on the tape, or by the quiet voice of the speaker. Also, the normal listener's perception of abnormal speech may have affected the results (for example, the non-word effect was - in part - attributed to the listener).

It would be a tremendous task to determine the phonetic features upon which the ratings were based: one would need to study both the steady states and transitions of vowels, and the different types of consonants. Different classes of sounds may be distorted differently, and in turn these distortions may be interpreted differently by normal listeners. A comprehensive analysis with a representative set of phonetic features is beyond the scope of this study. The two major objectives of the present experiment were: (1) to point out what types of information can be obtained from a phonetic analysis, and (2) to provide more precise information about the nature of phonetic variation. The target of the analysis was the vowel of the first syllable. The reasons for selecting this vowel are as follows:

1) It is well established that vowel formants (especially F1 and F2) serve as cues in the perception of vowel quality.

2) Comparison data from normal speech is available for Finnish vowels.

3) The vowels of English-speaking aphasics have been recently analyzed (Keller, 1978; Ryalls, 1986). Thus, the results on Finnish and English can be compared.

4) In Finnish, the vowels have a phonological opposition of length. This provides us with an opportunity to investigate the validity of claims by Blumstein et al. (1980) who proposed that different error types can be differentiated on the basis of the VOT in English.

5) An increased standard deviation for vowel durations is considered to be an indicator of a motor control problem (e.g. Duffy et al., 1984: 169).

Two vowel features have been analyzed -- formant structure (F1, F2, and F3) and duration.

Ryalls (1987) summarizes the recent research on vowel duration in aphasic speakers: according to several studies the vowel durations of aphasics are longer than normal. Ryalls' own results indicate that vowel durations are somewhat increased in aphasia, especially in the speech of patients with posterior lesions.

The results of Gandour and Dardarananda (1984) are especially interesting to us because they studied the length opposition of vowels. The authors claim that, for both nonfluent and fluent native Thai-speaking aphasics, the timing of vowel duration for signaling the contrast between short and long vowels remains relatively intact. Furthermore, Gandour and Dardarananda contend that vowel duration is not increased in aphasic patients' speech, but it is increased only in the speech of dysarthric patients.

Two studies provide information about the vowel quality in English-speaking aphasic patients: Keller (1978) and Ryalls (1986). According to Keller, the vowel figure (F2 versus F1) is somewhat flattened along the F1 axis. Keller concludes that this results from articulatory postures that are more open than in normal speech. Ryalls claims that the averages of F1 and F2 do not differ from the control data.

In the present study, variation was calculated for both the vowel durations and frequencies of F1, F2 and F3. Results from the earlier studies indicate that increased variation can be expected for both duration and formant frequencies. Ryalls' findings show that this is particularly true for anterior aphasics, as well as for posterior aphasics. According to Tikofsky (cited by Ryalls, 1986) there is less variation in dysarthric speech than in normal speech. Studies of normal speech have shown that in careful and slow speech, the stressed vowels are relatively long, produced with high intensity, and without contextual assimilation. Such vowels are less centralized than vowels in colloquial speech (e.g. Delattre, 1969; Iivonen, 1988). For nonfluent

aphasics (with signs of dysarthria), the vowel quality may also be affected by the speech problem, and one possible consequence of such a problem is the centralization of vowel quality (Ziegler and von Cramon, 1983).

If there is a high correlation between ratings for abnormal articulation and the amount of variation revealed in the acoustic measures (or if the order of the subjects in the continuum is the same according to both the listening results and the acoustic analysis), the most interesting interpretation of the listening experiment has been confirmed, i.e. that the ratings were based on variables of articulation (in a narrow sense). Otherwise, more attention should be paid to the "uninteresting" factors, such as the various sources of noise in the listening experiment.

In the acoustic analysis, the different patient groups were also compared to test whether or not there were differences between fluent and nonfluent patients.

6.3.1 Research Material

6.3.1.1 Words Analyzed

An analysis is made of one hundred and five words per speaker. The acoustic analysis was based on the words of the repetition test. A sample was selected of predominantly bisyllabic words containing all the Finnish vowel phonemes in the first syllable, and the consonants /p/, /t/, /k/, /s/, /l/, /n/ (both single and geminate) initially and between the first and second syllables. The data included at least six examples of each vowel phoneme (both long and short). Tables (6.3.1) and (6.3.2) provide additional information about the analyzed words. Even when the surrounding sounds and the structure of the word affect the duration and the quality of the vowels, the effect should be the same for all subjects, and consequently, the subjects can be compared. The words were randomly distributed among the words of the repetition test.

Table 6.3.1 The Acoustic Analysis – Phonetic Composition of the Words

The numbers indicate the number of items of the type in question.

The environment of the vowel:

	word-initial	word-medial single	gem.	clusters
p	17	7	7	pr 1, mpp 1
t	28	7	9	nt 2, st 1, ntt 1
k	29	9	10	sk 1
s	16	9	5	lss 1, st 1, sk 1
l	9	14	7	lss 1
n	5	6	6	nt 2, ntt 1
m	1	1	0	0

Vowels analyzed:

	short	long
i	6	6
y	7	6
e	6	6
ö	6	6
u	9	8
o	8	6
ä	7	6
a	6	6

Structure of the words:

CVCCV	30	CVVCCV	4
CVVCV	26	CVVCCVV	2
CVCV	25	CVVCVCV	2
CVVCCV	11	CVVCCVV	1
CVCCCV	4		

Table 6.3.2 The Words Included in the Acoustic Analysis

tilli, tippa, linna, pika, tina, kissa
liina, liika, piika, piina, piikki, tiili
kyky, kyllä, syli, pytty, pyssy, kylä, tyttö
pyykki, syylä, tyyli, kyyti, tyyni, tyyppi
tunne, kukko, tuttu, pupu, tulli, sukka, tuli, nunna, pulssi
tuuli, kuusi, luuta, luulo, suunta, suunta, luuttu, puukko
kello, keppi, sello, kelo, peto, setä
teettää, teema, neekeri, seepra, teesi, seestyy
mökki, tönö, köli, pöllö, tölli, söpö
pöönä, köökki, tööttää, söötti, töölö, lööperi
konna, koti, kokko, koko, tonni, tossu, tonttu, koppi
soolo, soosi, toosa, loota, nootti, soopa
kämppä, käki, käpy, kämppä, pässi, käsi, nätti
sääli, käännä, lääke, pääsi, sääski, kääpä
nappi, kasa, takka, taka, tapa, kassa
taakka, kaasu, kaato, paalu, kaappi, paasi

6.3.1.2 Subjects

Data from the male subjects were analyzed. Female subjects were omitted because of the difference in formant positions. Furthermore, there were few female subjects and thus little data were available for comparison.

6.3.2 Analysis of the Data

SPS-02 was used to analyze the data (for technical details, c.f. Karjalainen, 1980). Vowels were segmented, and then the vowel durations were measured. Then the three lowest formants (F1, F2, F3) were subsequently measured. The FFT spectrum was calculated from the middle of the vowel by the Hamming window, and the formants were measured using the cursor. The formant positions were determined visually by the experimenter.

The segmentation criteria used in this study were adopted from Lehtonen (1970) who had taken his criteria from Peterson and Lehiste (1960) and Elert (1965). The criteria aim at a definition of articulatory segments on the basis of the information from the acoustic signal. When a vowel was located between voiceless consonants, the vowel duration was measured as the time from the onset of vocal cord vibration to its cessation. When determining the segment boundary between a voiced consonant and a vowel, the position of maximal change in the speech wave served as the segmentation criterion.

6.3.3 Results

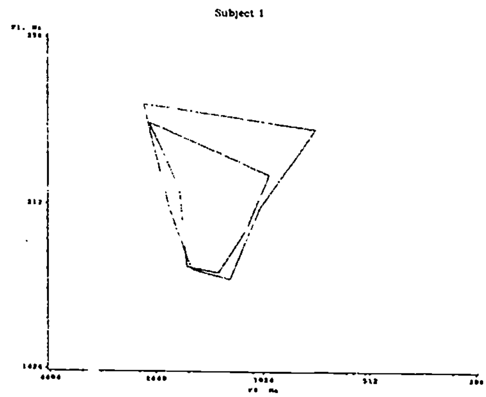
6.3.3.1 Formant Frequencies

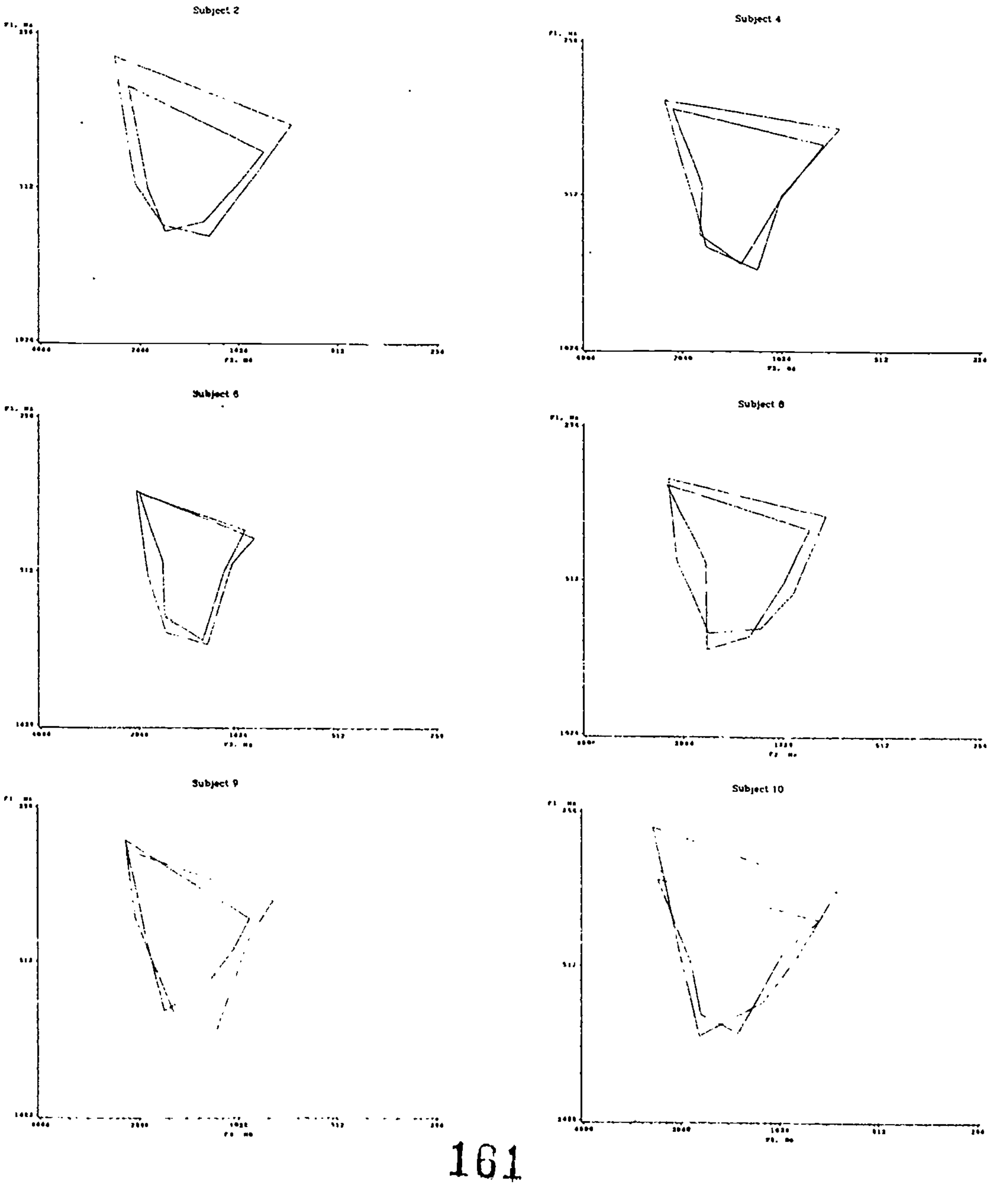
Do the Means for the Aphasic Patients Differ from those for the Comparison Group?

This study incorporated two sets of data for comparison, the data collected from normal subjects in the present study and the data presented by Wiik (1965). There were no remarkable differences between these two sets of data. However, according to the present results, the difference between the short and long vowels /u/, /i/ and /y/ were less clear than in Wiik's data, and the vowels of this study generally were

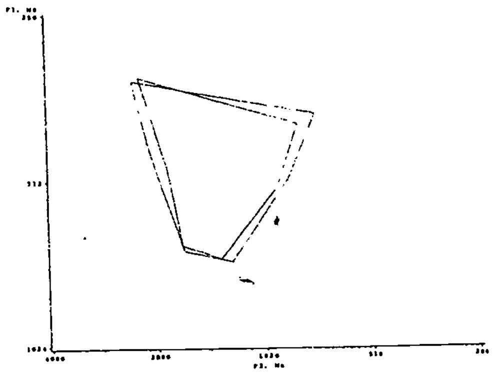
Figure 6.3.1 Means for the Formant Frequencies

The formant frequencies for short and long vowels were plotted on a diagram (the inner diagram presents the short vowels, and the outer diagram presents the long vowels; vowels /y/ and /ö/ were deleted from the figures). The aphasic speakers should be compared with the comparison group (Subjects 16, 18, 19, and 20).

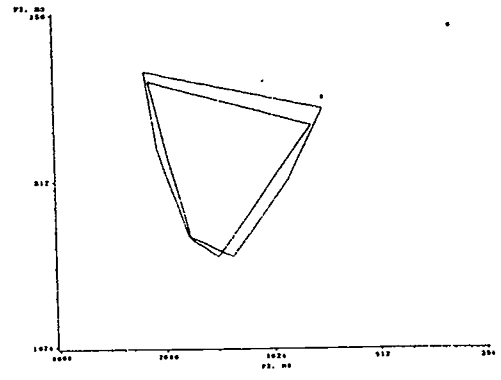




Subject 11



Subject 12



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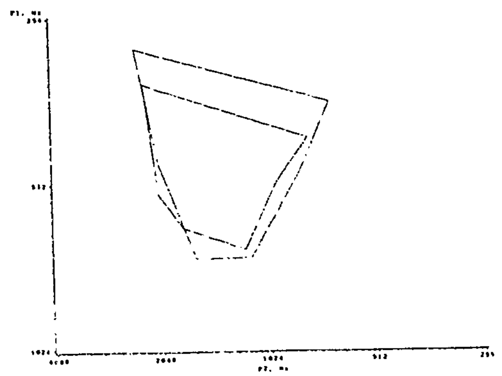

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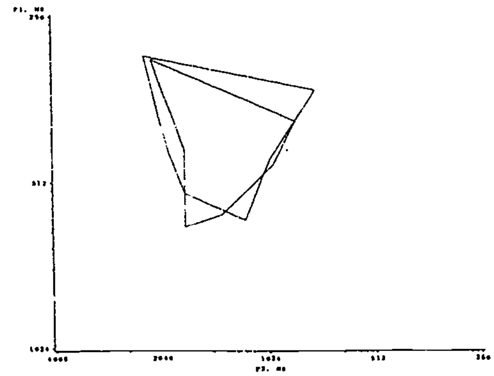

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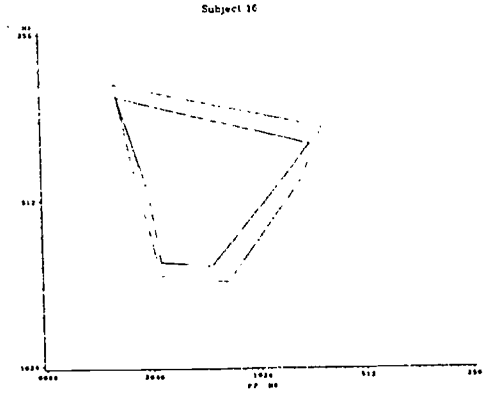
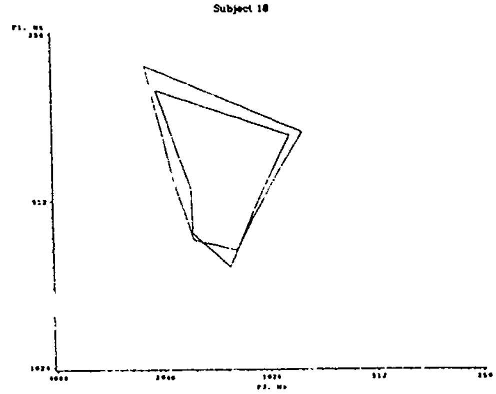
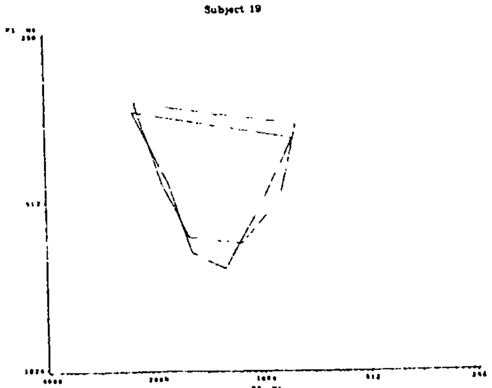


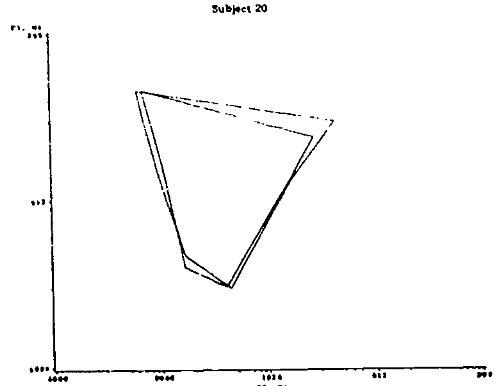
Subject 18



Subject 19



Subject 20



more centralized than in Wiik's data. For this reason, in the present study, the primary comparison data were collected from the comparison group included in the study. Errors were deleted from the data base, and thus the major analyses were based only on correct repetitions. A comparison of the correct and incorrect answers is found at the end of this chapter. The greatest number of errors occurred with the vowels /e/, /y/, and /ö/. When the vowels of the comparison group were plotted on a formant chart (F1 versus F2), there was overlap between /i/ and /y/, and between /e/ and /ö/. Here, other features than F1 and F2 also appeared to affect the recognition of vowel quality. The results are presented in figure (6.3.1). The formant frequencies for F1, F2, and F3 are listed in appendix (9).

The size of the articulatory tract has an effect on the actual frequencies. Due to such factors, the place of the vowel diagram in the vowel chart should change, and for this reason, a detailed comparison of the vowel figures is not reliable. However, the vowel charts (figure 6.3.1) of many aphasic patients showed an increased variation for the means as compared to the normal speakers. This was indicated by the irregular shapes of the vowel diagrams. Subject 6 produced the most clearly deviant results. His vowels were centralized. Centralization was determined visually by the experimenter, and the judgement was based on both F1 and F2. In less carefully articulated colloquial speech, the vowels are more centralized than in formal, more carefully articulated speech. However, the result for Subject 6 appeared to be abnormal. This assumption is supported by the rating results – Subject 6's speech was evaluated to be the most nonfluent.

Was there an Increase in Variation?

There are many ways to calculate the amount of variation. Ryalls (1986) analyzed and compared several repetitions of the same word. Thus, the effect of the surrounding sounds was eliminated. In the data of this study, due to the different contexts of the vowels, the amount of variation was substantial, and there were differences between the vowels. However, the context was identical for all speakers (concerning the correct productions). Ryalls used standard deviation as a measure of variation. However, it is better to use the coefficient of variation. The formants are not independent of F0: the higher the F0 frequency, the higher the other formants. The higher the frequency, the more variation (according to std).

The coefficients of variation are presented in table (6.3.3). These were calculated on the basis of the correct answers.

Table 6.3.3 Coefficients of Variation for Formant Frequencies

The analysis is based on correct answers.

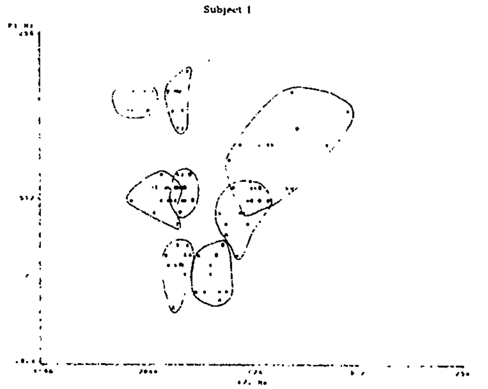
subject	F1 (Hz)	F2 (Hz)	F3 (Hz)
1.	0.091	0.076	0.056
2.	0.086	0.061	0.042
4.	0.093	0.056	0.040
6.	0.110	0.065	0.047
8.	0.076	0.064	0.041
9.	0.082	0.071	0.051
10.	0.072	0.052	0.038
11.	0.084	0.064	0.038
12.	0.069	0.059	0.041
14.	0.077	0.069	0.055
15.	0.106	0.076	0.054
16.	0.058	0.066	0.059
18.	0.072	0.053	0.036
19.	0.051	0.084	0.043
20.	0.068	0.044	0.034

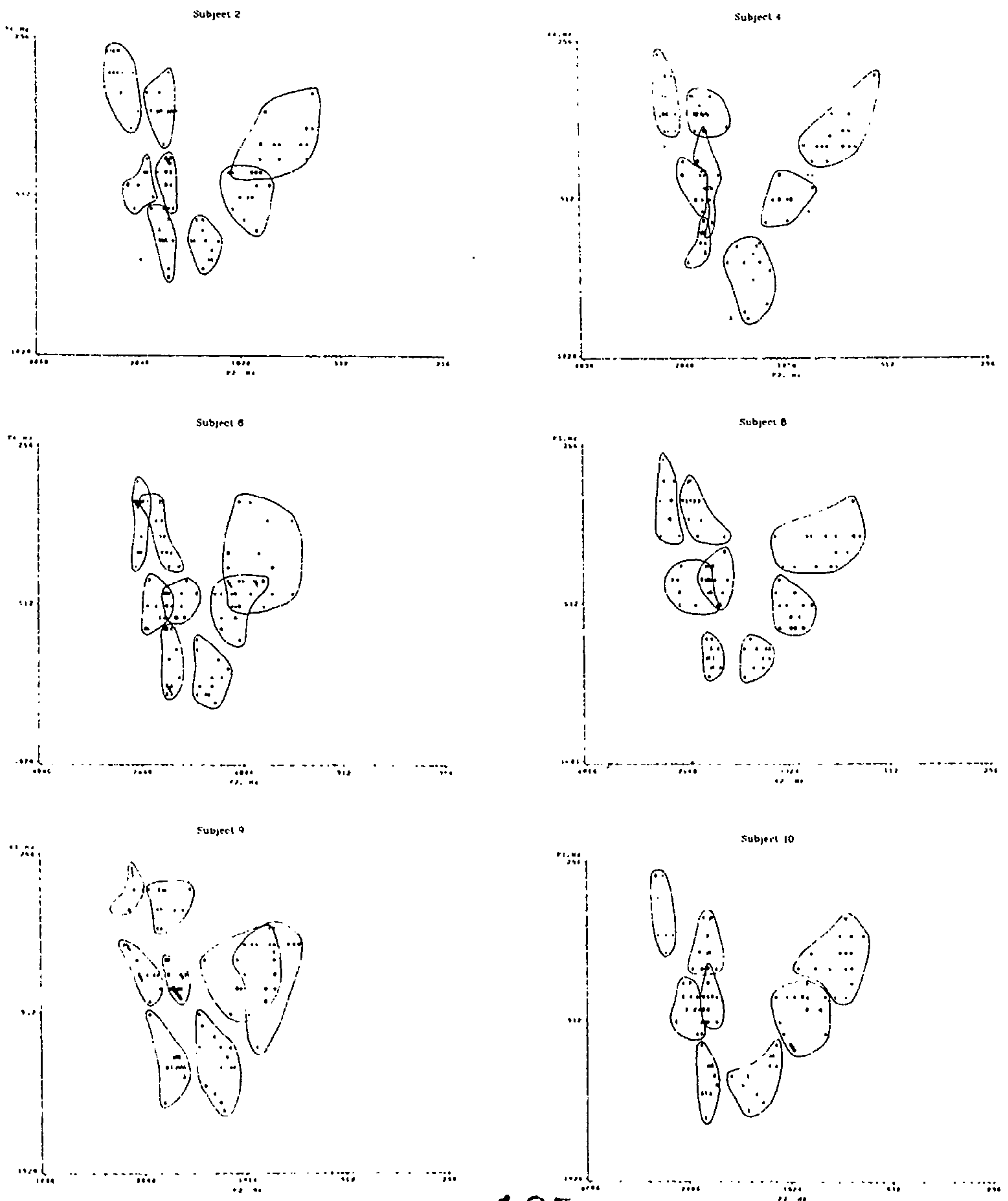
The F1 variation was increased for Subjects 1, 2, 4, 6, 9, 11, and 15, but this was not reflected in the F2 or F3. It is difficult to explain why the increased variation would not appear equally in all formants. Even when it is difficult to distinguish a F0 from a F1, this difficulty does not account for the difference between the control subjects and the aphasic patients.

The data are presented in figure (6.3.2). Subjects 1 and 9 had the clearest deviations. For them, the variation of vowel /u/ was exceptionally wide.

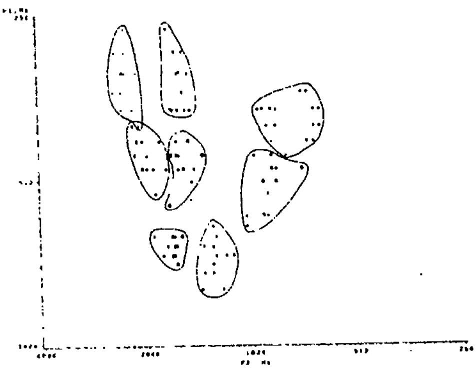
Figure 6.3.2 Variation for Formant Frequencies

The scattergrams present the distribution of the subjects' vowels. The correct vowels are printed in black, and the incorrect productions are printed in grey.

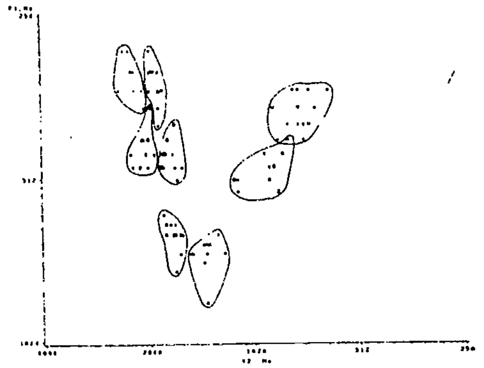




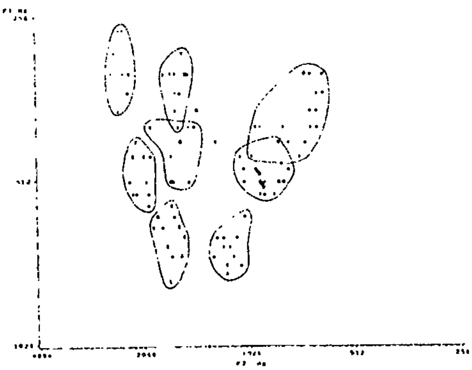
Subject 11



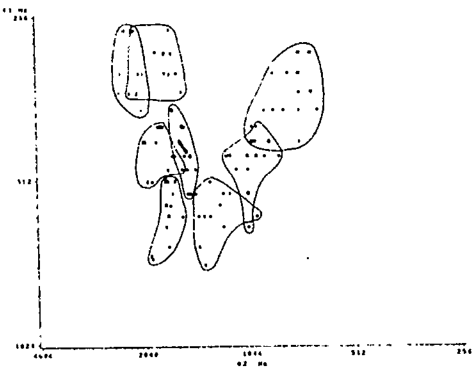
Subject 12



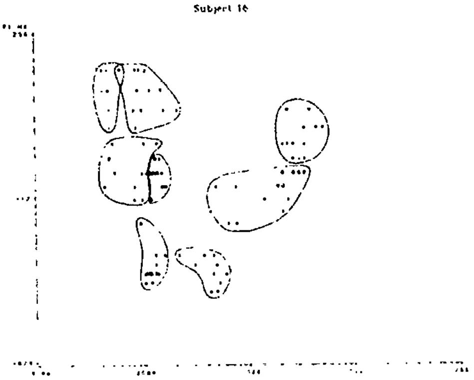
Subject 14



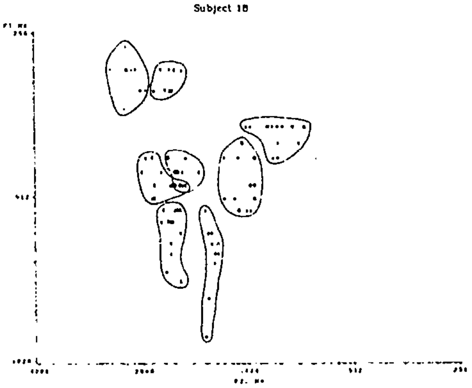
Subject 15



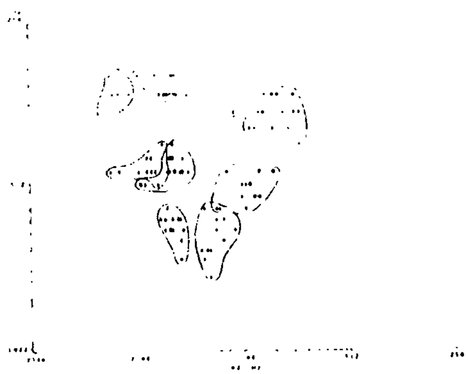
Subject 16



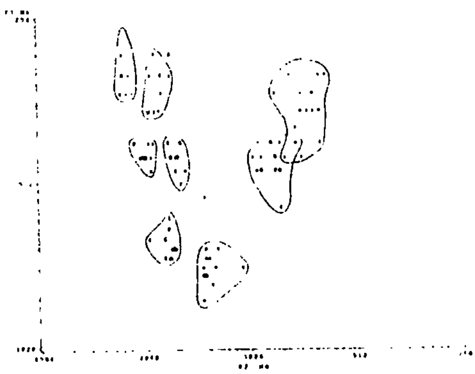
Subject 18



Subject 19



Subject 20



About the Nature of Qualitative Vowel Errors

Errors that sounded like diphthongs were not analyzed because correct diphthongs were unavailable for comparison. When single deviant items are analyzed, the possibility of measurement errors should be taken into consideration. The aim of the comparison was to see whether or not the transcriber's misperception of the target could account for some or all of the phoneme substitution errors. If the misperception hypothesis is correct, the errors should fall between the phoneme categories on the formant chart. Subjects 2, 4, 6, 9, 14 and 20 had vowel quality errors. A list of these errors is found in appendix (10).

Each subject's correct and incorrect answers were plotted on a vowel chart. The figures were visually analyzed by the author. The research question was whether the erroneous vowel fell into the phoneme category for the vowel in question, or whether it seemed to fall in the area between the phoneme categories that were determined roughly as those areas where the correct productions were located on the vowel charts. When the erroneous vowels did not fall into the phoneme category, it was possible that the listeners were making misperceptions. Erroneous vowels are marked in grey in figure (6.3.2).

In most of the qualitative vowel errors the target seemed to be substituted by a "phoneme" other than the target. The total number of qualitative vowel errors in the data was 31, and 26 of these appeared to be "pure phoneme substitutions". Of the five exceptions that did not fall within the phoneme categories (and that sounded like errors), three were made by speaker 14, and two were made by speaker 9. Both subjects also made other errors that resembled phoneme substitutions. The analysis of the errors supports the hypothesis put forth in chapters 5.3.2 and 6.2.6: (some of the) vowel errors in the repetition test may be misperceptions.

How Formant Frequencies are Influenced by Surrounding Sounds

The main source of variation in formant frequencies were traced to the surrounding sounds. The surrounding sounds have two different types of effects on the Finnish vowel formants (Wiik, 1965).

Vowel /e/ in the first syllable may have two variants, although in Wiik's material no difference was found between the two environments (Wiik, 1965: 65). The two variants have different F2 frequencies. F2 frequencies are higher in words ending in a front vowel (e.g. *sekä*) and lower in words ending in a back vowel (e.g. *seka*). There

were five words of this type in the data (*setä, kello, sello, kelo, peto*). A comparison of F2's in these words revealed that only two subjects (Subjects 8 and 18) had higher F2s in *setä* than in words *kello, sello, kelo,* and *peto.*

The formant frequencies of a vowel are dependent upon the surrounding consonants. This is especially clear in short /u/, /o/, and /a/. Their F2 is relatively higher when the vowels occur between /j/, /d/, /t/, /s/, or /n/ and relatively lower when the vowels occur between /p/, /m/, or /v/ (Wiik, 1965: 72, 76-77, 79). In the present data, there were two words *pupu* and *tuttu* in which the effect of the surrounding consonant could be studied. The F2 of *tuttu* was higher than the F2 of *pupu* for all speakers except 2 and 16. Subject 16 produced the same F2 for both these words.

There was insufficient data to evaluate the contribution of surrounding consonants to the vowel quality. No differences between the aphasics and the controls were found in the comparison of the few available words.

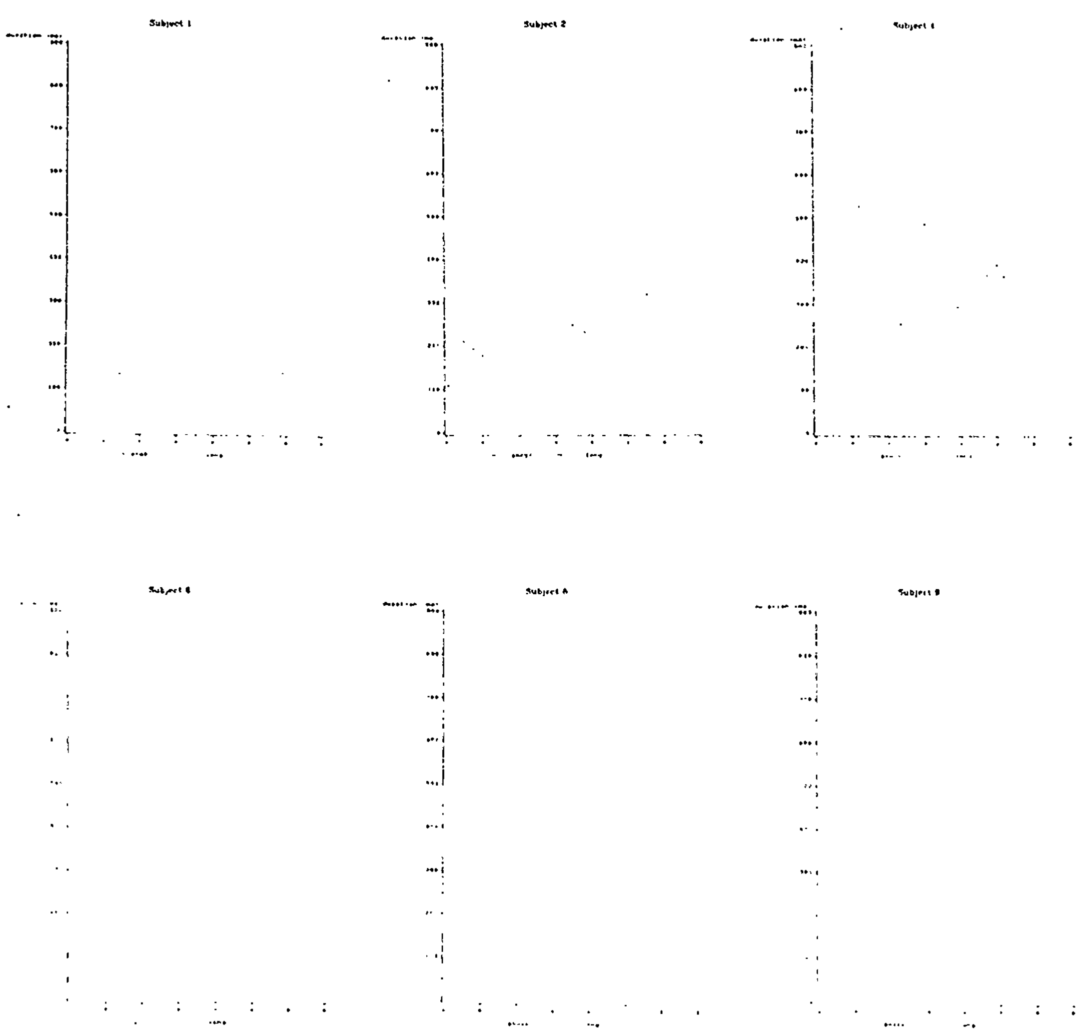
6.3.3.2 Duration

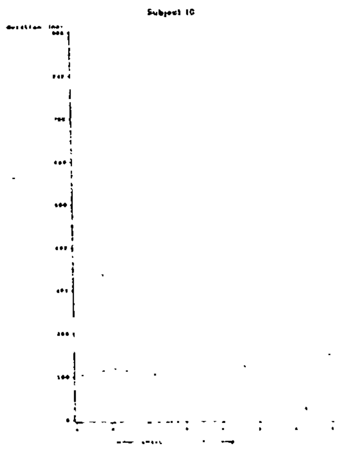
Did the Vowel Duration Increase?

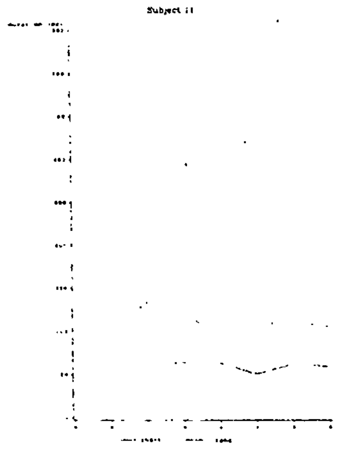
Figure (6.3.3) presents the means for the vowel durations. The durations are listed in appendix (11). On the basis of visual inspection, three subjects differed from the others. The vowels of these three subjects were, on the average, longer than the vowels in comparison data. This difference was very clear for Subject 4, but less clear for Subjects 6 and 14 (the duration of long vowels was increased for these subjects).

Figure 6.3.3 Vowel Durations

The figures compare the durations of short and long vowels (a, e, i, o, u, y, ä, ö). The upper line refers to the long vowels, and the lower line refers to the short vowels.




Subject 10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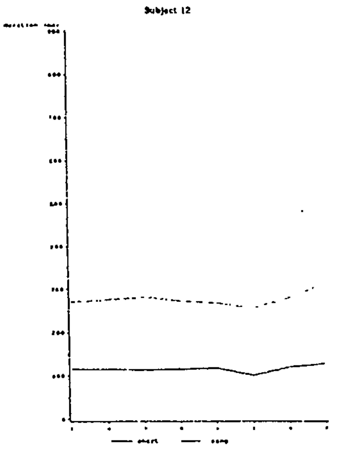
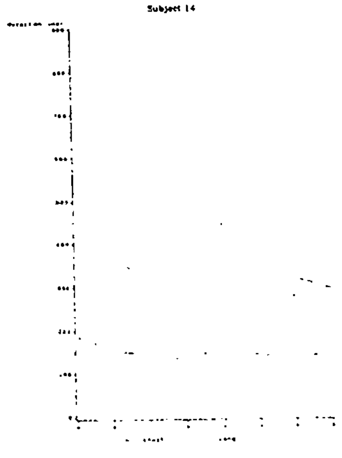
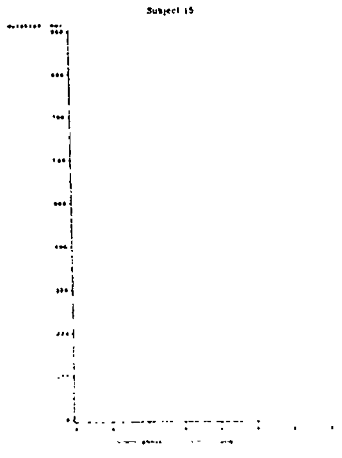
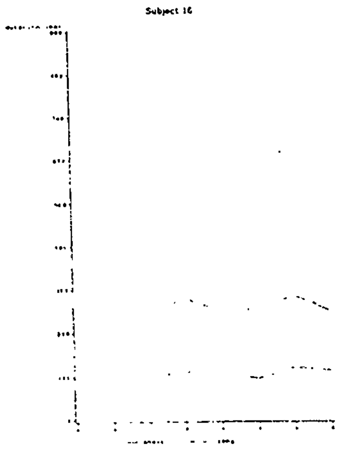
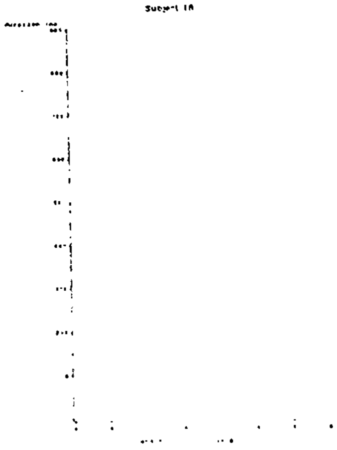
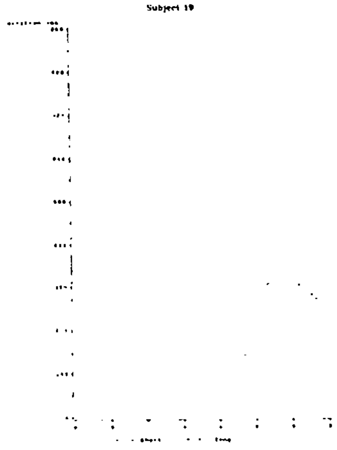

Subject 12

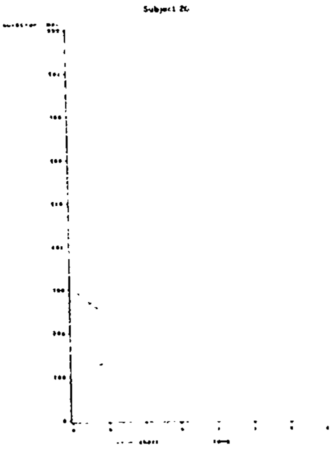

Subject 14


Subject 15


Subject 16


Subject 18


Subject 19


Subject 20

Did the Coefficient of Variation for Vowel Duration Increase?

The coefficient of variation for vowel duration was calculated for each subject. The standard deviation for each vowel (short and long vowels separately) and for each speaker was calculated and divided by the mean duration of each vowel. The variation score for each subject was the mean of these coefficients of variation. The scores are presented in table (6.3.4).

Table 6.3.4 Vowel Duration: Means of Coefficient of Variation

The standard deviation for each vowel phoneme (short and long vowels separately) was calculated and divided by the mean duration of each vowel phoneme. The variation score for each subject was the mean of these coefficients of variation.

subject		subject	
1.	0.175 ms	11.	0.259 ms
2.	0.212 ms	12.	0.163 ms
4.	0.313 ms	14.	0.217 ms
6.	0.210 ms	15.	0.217 ms
8.	0.164 ms	16.	0.168 ms
9.	0.262 ms	18.	0.166 ms
10.	0.221 ms	19.	0.129 ms
		20.	0.165 ms

In the aphasic data, the mean for the coefficient of variation was usually higher than it was in the control data. The only exceptions were Subjects 8 and 12 who did not differ from the controls.

Is Length Opposition Preserved?

On the basis of the means for durations, the length opposition was preserved in the speech of the aphasic patients. Another way of looking at this issue is to measure the length of long vowels in relation to short vowels. According to Lehtonen (1970) the relation in normal speech is approximately 1:2.2. In slow or formal speech, the long vowels lengthen more than the short vowels, but the relation is, even in this case, less than 1:3. Marjomaa (1982) has compared vowel duration under varying tempo conditions, and according to his results the relation is 1:2.3 in slow speech. Lehtonen's and Marjomaa's results were obtained from words produced in a sentence frame. Table (6.3.5) relates the duration of the short and long vowels in the present data (which consist of isolated words).

Table 6.3.5 The Duration of Long Vowels in Relation to Short Vowels

subj		subj		subj	
1.	1:1.9	9.	1:2.6	15.	1:2.0
2.	1:1.6	10.	1:1.9	16.	1:2.5
4.	1:2.2	11.	1:1.9	18.	1:2.4
6.	1:1.8	12.	1:2.4	19.	1:1.9
8.	1:2.1	14.	1:2.3	20.	1:2.2

Subjects 2 and 6 were the only subjects who seemed to differ from the comparison group. Their vowel ratios were smaller than would be expected.

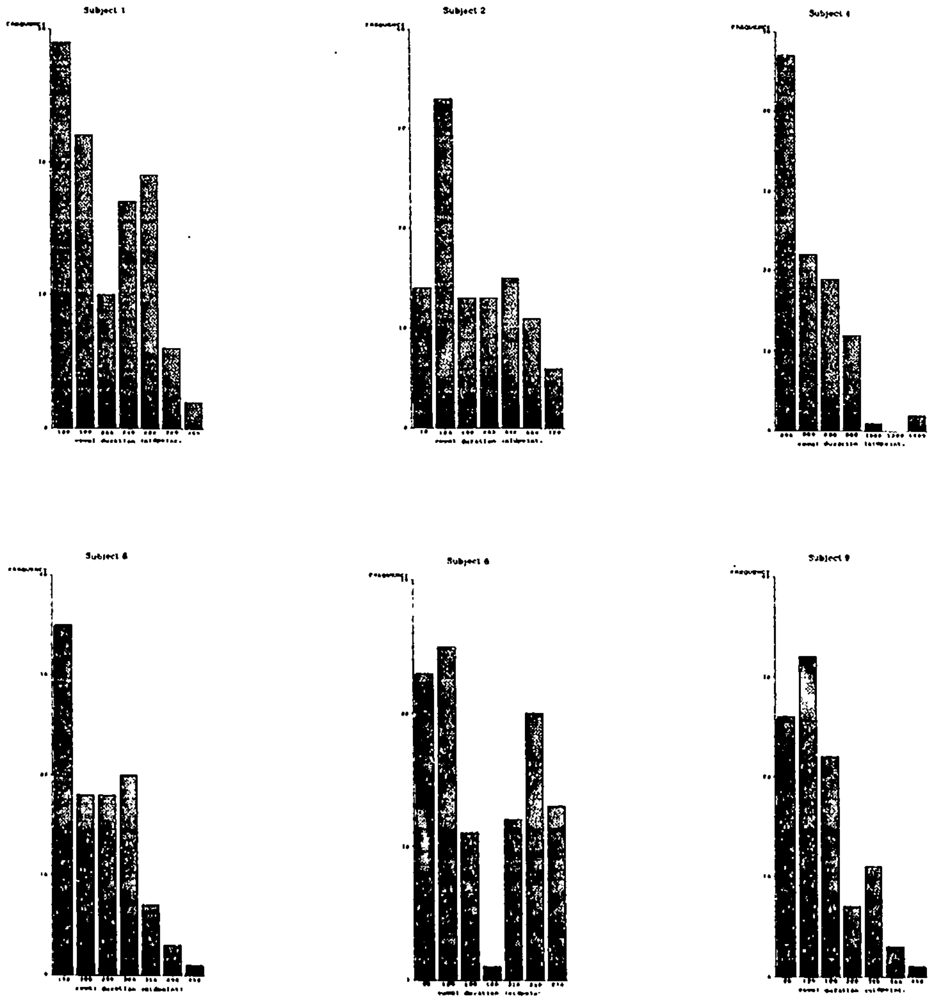
Wiik (1965) examined the possible distributional differences for the variation of durations in Finnish and English. According to Wiik, the distribution in Finnish is bi-modal. Figure (6.3.4) presents the distributions for the subjects of the present study. The charts were drawn on a computer that was programmed to divide the duration distribution into seven classes. Thus, for some speakers one class was 50 ms, for some one class was 200 ms, depending on the duration of their vowels (which could range from approximately 30 ms to 400 ms, as for Subject 15, or from approximately 150 ms to 1500 ms, as for Subject 4). This produced some problems in the comparison of the figures, especially for Subject 4 and for other subjects with lengthened vowels.

Two speakers (8 and 18) had a clearly bi-modal distribution of vowel duration. Of the remaining speakers, the majority displayed a tendency for bi-modal distributions, but this was not very clear. No tendency for bi-modal distribution was observed in the data for Subjects 4 and 11, and the tendency was also very weak for Subjects 2, 12, and 14. It is possible that there is a relation between the amount of variation in a speaker's vowel durations, and the existence of a bi-modal distribution -- the more variation, the less likely a bi-modal distribution. Marjomaa's (1982) results show that in slow speech the distribution is less clearly bi-modal than in normal or fast speech. Especially the peak for long vowels is unclear in slow speech. In the present study, the controls also did not demonstrate a clear bi-modal distribution, and this may be related to the fact that, in general, segment durations are greater in isolated words as compared to connected speech.

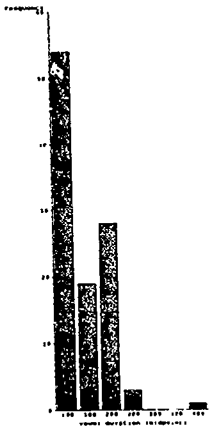
In order to further characterize the nature of the abnormal variation, the experimenter checked the speakers' vowel pairs (i-ii, e-ee, etc.) for the occurrence of a "margin" between the longest short vowel and the shortest long vowel. The analysis was motivated by the Blumstein et al. (1980) findings where two types of deficits of VOT were found. Table (6.3.6) presents the average duration of this margin, as well as its median, and the shortest and longest margins. The numbers were counted pair-by-pair and summarized in the table.

Figure 6.3.4 Distribution of Vowel Durations

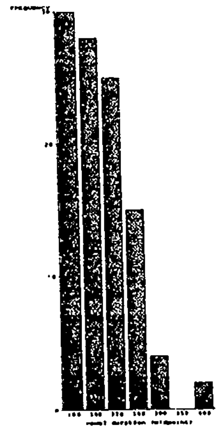
The vowel charts were drawn on a computer that was programmed to divide the duration distribution (ms) into seven classes. The aphasic speakers' distributions should be compared with the control subjects' (Subjects 16, 18, 19, 20) distributions that were bi-modal.



Subject 10



Subject 11



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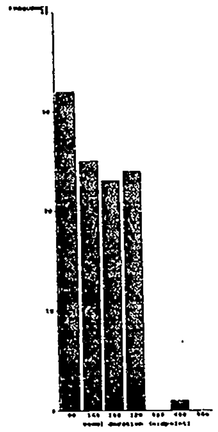
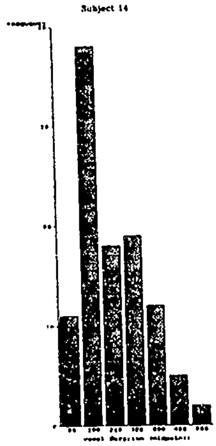
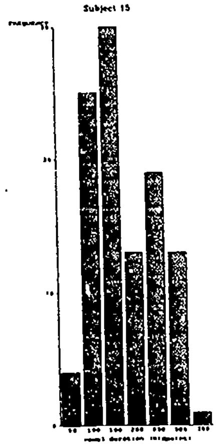


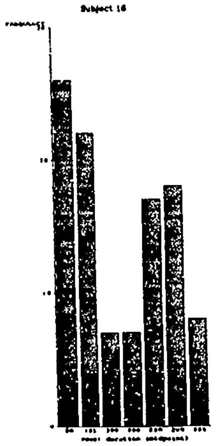
Subject 14



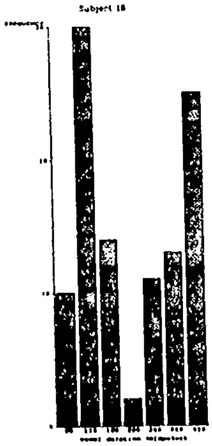
Subject 15



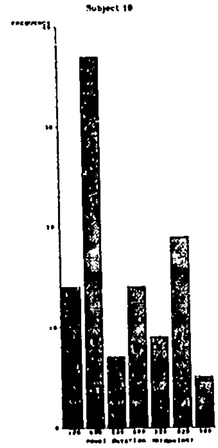
Subject 16



Subject 18



Subject 19



Subject 20

Table 6.3.6 Longest Short Vowels versus Shortest Long Vowels

The experimenter checked the pairs of vowel phonemes (i - ii, a - aa, etc.) for a margin between the shortest long vowel and the longest short vowel. The means, medians and variation of the duration of the margin (ms) are reported.

subj	mean	median	shortest and longest margins
1.	26	23.5	-72, 90
2.	28	28.5	-34, 85
4.	-70	43	-926, 255
6.	0.87	1	-56, 69
8.	48	55	-9, 84
9.	34	22	-22, 177
10.	-12	35.5	-335, 56
11.	-18	-1	-35, 28
12.	87	91.5	41, 116
14.	49	69.5	-74, 148
15.	21	24	-45, 70
16.	72	75.5	31, 100
18.	85	94.5	32, 110
19.	61	71.5	3, 94
20.	68	79	27, 93

The aphasic subjects were very clearly different from the comparison group (except for Subject 12 who did not differ from the controls). For example, there was no overlap between the short and long vowels in the comparison group. For this reason it was of interest to look carefully through the data, subject by subject, and phoneme by phoneme. Subjects 4, 6, and 9 had the greatest difficulties in realizing the length opposition. Also Subjects 8, 10, and 11 showed clear difficulties in producing the length opposition.

Table (6.3.7) presents the data (means of the margin in ms) for different vowels.

Table 6.3.7 Duration of the Margin between Short and Long Vowels

The duration of the margin between short and long vowels has been determined phoneme by phoneme, and speaker by speaker. The mean duration of the margin for each vowel has been calculated.

vowel	comparison group	aphasics
a	106.5 ms	64.8 ms
e	84.0	90.8
i	102.5	78.4
o	102.5	84.7
u	80.0	10.9
y	110.5	-4.6
ä	111.7	115.2
ö	88.7	69.3

The subjects found it difficult to realize the length opposition in high labial vowels (which are produced by lip protrusion). The open vowel /ä/ was the easiest to produce. However, even if the realization of the length opposition was abnormal, the

subjects did not make clear errors (which may relate to the way duration is perceived by normal listeners). The generalizations that can be made about the errors seem to refer to articulatory variables rather than to markedness (according to which /y/ and /ö/ should be the most difficult vowels in Finnish). It has been noted that coarticulation in fast speech is particularly great for /u/, and this may be due to the smaller motility of lips as compared to the tongue (Stevens and House, 1963).

The Influence of the Surrounding Sounds on the Realization of the Length Opposition

A vowel's duration can be affected by the surrounding consonants. According to Lehtonen (1970), vowels between two sibilants are the longest, vowels between two stops are the shortest, and vowels between a sibilant and a stop are of intermediate length. In order to study the effect of the surrounding consonants on vowel duration, the vowels between two stops (context 1) were compared with the vowels in the surrounding /slr-V-ptk/ and /ptk-V-s/ (context 2). The different word structures (CVCV, CVCCV, CVVCV, CVVCCV) were separated in the analysis. Only completely correct answers were included.

In the comparison data, the effect of the surrounding consonants was as predicted. There were some exceptions, but in these cases one of the structures consisted of two or three items only and consequently, the result was not reliable.

When the effect of consonant surrounding was analyzed, Subjects 6, 10, 14 and 15 were not different from the comparison group. For Subjects 1, 8, 9, 11, and 12, the consonants had very little effect on the vowel duration, in fact, less than was expected. The results obtained from Subjects 2 and 4 were difficult to interpret. In fact, the results were surprising because the most clearly nonfluent subjects were in the same category as the comparison group, but subjects with hardly noticeable articulatory difficulties (increased variation in F1 and vowel duration) differed from the comparison group.

Even though some subjects differed from the comparison group, we can conclude that the source of increased variation in vowel durations can not be traced to a specific environmental influence.

The Influence of the Word Structure on the Realization of the Length Opposition

The structure of the word affects the duration of a given vowel token. According to Lehtonen (1970) vowels in word structures CVCV and CVVCCV are somewhat shorter than the same vowels in the structures CVCCV and CVVCV. These structures have been compared to see if the word structure accounts for the increased variation in durations. Table (6.3.8) presents the results of this comparison. The pairs where the relation is as predicted are marked with (+) and opposite instances with (-).

Table 6.3.8 Word Structure and Vowel Duration

Vowels in word structures CVCV (1) and CVVCCV (4) are somewhat shorter than the same vowels in the structures CVCCV (2) and CVVCV (3). The pairs where the relation is as predicted are marked with (+) and opposite instances with (-).

subject	1 : 2		3 : 4	
1.	1 : 1.0	+-	1 : 0.9	+
2.	1 : 1.0	+-	1 : 0.8	+
4.	1 : 1.4	-	1 : 0.8	+
6.	1 : 1.0	+-	1 : 0.8	+
8.	1 : 0.7	+	1 : 0.9	+
9.	1 : 1.0	+-	1 : 0.6	+
10.	1 : 0.8	+	1 : 0.9	+
11.	1 : 0.8	+	1 : 0.9	+
12.	1 : 0.9	+	1 : 0.8	+
14.	1 : 0.9	+	1 : 0.8	+
15.	1 : 0.9	+	1 : 0.8	+
16.	1 : 0.8	+	1 : 0.8	+
18.	1 : 0.7	+	1 : 0.8	+
19.	1 : 1.1	-	1 : 0.9	+
20.	1 : 1.2	-	1 : 0.8	+

The vowel in the word structure CVCV should be shorter than the same vowel in the word structure CVCCV. However, this was not even the case in the comparison data. The duration of the vowel in CVCV words may have undergone a change. At least in the Helsinki area, the vowel in CVCV words is often lengthened (informal observation). Thus, this result does not relate to the nature of aphasic speech, but rather to the speaker's native dialect. In principle, the present finding can also be accounted for by assuming that the length opposition is realized differently in isolated words than in words produced within a sentence frame. However, this in an unlikely solution. The vowel in the word structure CVVCCV should be shorter than the vowel in the word structure CVVCV. This was true for all speakers. The vowel of word structure CVVCCV was exceptionally short for patient 9 who produced all words in the repetition test with an intonation typical to lists (stress placed on the last syllable).

For this reason, the vowel of the last syllable was exceptionally long in comparison with the vowel of the first syllable.

Speakers with syllable segregation may lengthen vowels before a syllable boundary. For this type of a speaker, vowels in CVCV and CVVCV structures should prove to be longer than vowels in the two other structures. There was very slight evidence for this in the CVCV structures produced by Subject 4.

The Nature of Length Errors

The experimenter discovered very few errors in length. Six speakers made duration errors. There were two types of such errors: a short vowel heard as a long vowel, or a long vowel heard as a short vowel. Only one type of error was made by each speaker. Subjects 4, 6, and 11 lengthened vowels, whereas Subjects 9 and 14 shortened vowels. The errors of Subjects 6 and 11 resembled substitutions, as these mistakes did not fall within the "margin" between the short and long vowel. Subjects 9 and 14 had a tendency to shorten vowels, and their mistakes fell within this "margin". It was not possible to predict the error types on the basis of the amount of variation in durations. The result was somewhat preliminary, as only Subject 14 had several errors, but the other subjects had only one or two errors.

6.3.4 An Interpretation of the Results

6.3.4.1 A Summary of the Results of the Acoustic Analysis

The acoustic analysis focused on several variables. The present summary in figure (6.3.5) reviews those variables based on correct responses that revealed differences between the patients. The nature of the errors will be discussed in chapter 6.3.4.2. According to these variables, Subjects 4 and 6 had the greatest difficulties – having problems with the spatial and temporal aspects of speech. Subjects 1 and 15 had increased variation in F1, whereas Subjects 9 and 11 had difficulties with the temporal aspects of speech. As different patients had difficulties with the spatial and temporal aspects, these two factors appeared to dissociate in aphasia. However, additional variables must be taken into consideration (e.g. consonant duration) to establish the existence of dissociation.

Figure 6.3.5 A Comparison of the Variables of the Acoustic Analysis

There were a few variables in the acoustic analysis that revealed differences between the subjects. These variables measured both spatial characteristics of vowel articulation – F1 variation ("F1 var") and amount of vowel centralization – and temporal characteristics of the vowels – variation in vowel duration ("var in dur"), vowel lengthening, and overlap between the durations of short and long vowels ("dur overlap"). According to these variables, there were observable differences between the control subjects and the aphasic speakers. Among the aphasics, there were both subjects who did not differ from the controls ("normal range"), and subjects who showed very clear deviations ("subjects who deviate").

variable	subjects who deviate	normal range
1. var in F1	1 4 6 15	12
2. centralization	6	
3. var in dur	4 9 11	8 12
4. lengthening	4 6 14	
5. dur overlap	4 6 9	

Distorted vowels are often considered to be characteristic of dysarthria (Darley et al., 1975; Ziegler and von Cramon, 1983). The present data support this conclusion. Subject 6 had the most prominent vowel centralization and, according to the listening results, he was also the most nonfluent speaker. Ziegler and von Cramon (1983) interpret their results on vowel reduction primarily in terms of reduction in muscular activity. The present results are in agreement with this interpretation -- the surrounding sounds did not seem to affect the aphasic speakers' vowels more than the vowels of the normal speakers. However, the data for testing the effect of surrounding sounds were scanty, especially for the nonfluent patients with numerous phonological errors. Reduction of muscular activity may also be associated with vowel lengthening, although there seem be other, independent factors that also influence the vowel durations.

The increase in variation for segment durations could be interpreted as a motor involvement in the aphasic syndrome (Duffy and Gawle, 1984: 169). Subjects 4, 9, and 11 had the greatest variation in vowel durations. Most aphasic patients had a greater coefficient of variation than did the controls. Only Subjects 8 and 12 resembled the controls in this respect. This result is difficult to interpret because of the differences between Subjects 8 and 12. Subject 12 was clearly "fluent" without difficulties in the sequential motion test and without phonological errors in the repetition test. His errors were primarily semantic paraphasias. Subject 8, however, had few difficulties with the repetition of bisyllabic words, he failed in the sequential motion test, he had difficulties with the repetition of long words, and he made a considerable number of phonological errors in the picture description test. If longer words had been included in the acoustic analysis, then phonetic variables such as the coefficient of variation for

vowel duration may have revealed deviations in the speech of Subject 8. Subject 14 was judged to be nonfluent, but according to the acoustic measures, his speech did not show an increase in phonetic variation. In his case, an analysis of consonant features would have been helpful. This is indicated by the fact that Subject 14 made only consonant errors, yet vowels were the only sounds to be analyzed acoustically. Thus, a phonetic analysis of those features that prove most problematic for the subject may be the most informative. For the most nonfluent patients (with dysarthric symptoms), the analysis of the first syllable vowel provided good results, but the analysis of consonants would obviously shed more light on "apractic" problems.

6.3.4.2 The Nature of Sound Substitutions

It was predicted that if the vowel errors were due to a perceptual miscategorization by the listener, the erroneous vowels ought to fall outside the phoneme categories. However, this was the case only for some of the errors committed by Subjects 9 and 14. These subjects also made duration errors where the erroneous vowel fell between the typically short and long vowels. However, in a majority of the cases, both errors in vowel quality and errors in vowel duration resembled substitutions. The errors of vowel quality looked especially like substitutions. The "substitution" errors in duration were observed in the speech of Subjects 6 and 11. These mistakes may also be due to a decreased speech tempo which was misinterpreted by the listener.

An important theoretical question is whether the substitutions are allophonic substitutions rather than phonemic substitutions. In order to draw firm conclusions about the nature of substitutions, the errors must be analyzed in more phonetic detail. Consonant errors should be included in the analysis because the comparison of the repetition and naming tests established a difference between the proportion of consonant versus vowel errors in the tests. There were more vowel errors in the repetition test, and there is reason to assume that many of the vowel errors in the repetition test were in fact misperceptions. A more comprehensive listening test could also prove helpful for solving the problem of perception versus production aspects of the substitution errors.

The usefulness of the rating results can be demonstrated by comparing items that were produced by one speaker but were rated differently by the listeners. The errors by Subjects 4, 6, and 14 were usually rated less fluent than their correct items. When comparing the items that were common to the rating experiment and the acoustic analysis, it appeared to be the case that vowel errors were often rated to be nonfluent.

Thus, consonant and vowel errors may receive different ratings. The listening experiment performed in the connection with the present study can serve as a model for several listening experiments where different variables are varied. For example, items of a determined phonetic composition could be compared for several speakers, or the error types could be systematically alternated.

6.4 Results of the Phonetic Analysis

6.4.1 Acoustic Variables behind the Rating Results

The rating experiment produced a speaker continuum with the control subjects at one end, and the most nonfluent patients at the other end. Fluent aphasics (Subjects 12 and 13 who had predominantly semantic errors, c.f. chapter 5) were closer to the controls than were the other aphasic subjects. Subjects 6, 11, and 14 were rated as the most nonfluent.

The acoustic analysis of the first syllable vowel did not uncover all the factors behind the rating results. However, the most nonfluent speakers (Subjects 6, 11, and 14) differed from the others with respect to some acoustic variables. Subject 6 was the only speaker whose vowels were clearly centralized. This speaker also had an increase in variation for F1 and for vowel duration. Subject 11 had an increase of F1 variation. Subject 14 produced lengthened vowels. Subjects 4 and 9 (who, according to the results of the rating experiment, were between the most nonfluent and the fluent patients) differed from the controls for more phonetic features than the most nonfluent Subjects 6 and 14. The proportion of vowel errors was high for Subjects 4 and 9 (c.f. chapter 5.4). As only vowels were analyzed acoustically, it was natural than the subjects with the greatest number of vowel errors also showed the most obvious deficits according to the acoustic analysis. The most fluent of the patients (Subject 12) did not differ from the controls. The variation for F1 and for vowel duration was within normal limits in his speech, and no other deviations were found.

In the listening experiment, all patients were evaluated as less fluent than the comparison group. For all subjects, the named items were less fluent than the repeated words. A part of the increase in nonfluency in aphasic speech may be accounted for by the same factors that underlie normal variation in articulatory fluency. The acoustic analysis supported the hypothesis: according to the variation for durations and F1, the fluent subjects did not differ from the control subjects. Fluent aphasics' nonfluency

seemed to reflect other factors than a problem with speech motor control. Before the characteristics of different types of nonfluency can be defined, there must be a more comprehensive study of the phonetic features involved.

There were approximately fifty items common to both the rating experiment and the acoustic analysis. The comparison of these items may shed light on the features that form the basis for the ratings. We can hypothesize that there will be an abnormally long vowel in items with poorer rating results (and higher relative entropy). The comparison of durations revealed that items containing a very short vowel (78 - 97 ms) or a very long vowel (467 - 628 ms) were often rated as more nonfluent than other items produced by the same subject. The items with very short vowels in the first syllable (especially those produced by Subject 9) had the main stress on the second syllable (intonation typical to word lists) and were rated as nonfluent. Subject 12 articulated one item especially slowly, and this item was also rated as nonfluent. Even if abnormal vowel duration seemed to have a negative effect on fluency ratings, there were a few exceptions to this generalization.

Subject 6 was rated the most nonfluent (the median of the ratings was 4, and the mean of relative entropy was 0.88). He was the only subject who centralized his vowels. The effect of vowel centralization was compared in seven items. For two of these items, the median of the ratings was 3 (somewhat abnormal articulation), and for five items it was 4 (clearly abnormal articulation). The vowels of the two items with the rating 3 were less centralized than the vowels of other items. The most centralized vowels were not among the seven items compared. For this reason it remained uncertain as to what extent vowel centralization accounted for the rating results. However, the effect of vowel centralization seemed to be substantial.

One of the items produced by Subject 16 sounded nasalized, and it was rated as nonfluent. Thus, there were obviously many phonetic features contributing to the rating results. For example, intonation and voice quality may also play an important role in the ratings. Especially for patients with frequent phonological errors, the nature of the errors and the fact that they are non-words may produce the impression of nonfluency or indistinctness. However, the listeners judged even those subjects who failed to show an increase in phonetic variation (according to acoustic measures) to be somewhat nonfluent. In conclusion, a more comprehensive acoustic analysis is needed.

6.4.2 Explaining the Segmental Errors

In chapter 3.2, various explanations for phoneme substitutions were presented. Reasons cited were misperceptions either by the normal listener, or by the patient, real literal paraphasias, or contaminations. In the following pages, these causes will be evaluated as explanations for the observed errors.

Literal Paraphasias

The comparison of the transcriptions provided in the rating experiment indicated that the phonological analysis of aphasic errors may be unreliable. The entropy for transcriptions was great, especially for the most nonfluent speakers. In order to obtain detailed and reliable information about speech production, an experimental analysis of the phonetic characteristics of the errors should accompany the detailed phonological error classification.

Anticipation and metathesis errors cannot be explained as listeners' misperceptions. Errors where the patient started with the correct target, but stopped in the middle of the word, were informative as to the underlying source of the errors. In the new attempt, the subject changed the correct beginning to a false one. In these cases it was very obvious that the patient had the right target in mind but, due to the articulatory complexity of the phoneme sequence, he had to replace the complex sequence with something more simple. Such phonological errors were rated as less fluent by the listeners than the correct answers, but these ratings were poor obviously because the incorrect items were non-words. It seems very unlikely that the aforementioned errors would involve allophones instead of phonemes, but this can be checked experimentally. Phonological errors may also be articulated more hesitantly than correct answers for other than articulatory reasons.

The phonological errors elicited in the speech production tests differed in several respects. Firstly, some patients had word-initial errors, whereas others had word-final errors. Furthermore, the proportion of vowel errors varied, as well as the types of consonant errors. Phonological anosognosia (typical of Subject 9) is yet another error type (c.f. chapters 5.4.2 and 7.2). The types of literal paraphasias were discussed in chapter 5.4.2., and they will also be taken up in chapter 7.2.

Perceptual Factors

When interacting, both aphasic patients and normal listeners make misperception errors. Aphasic patients may have a perception deficit due to the brain damage, and normal listeners may have difficulties in interpreting the abnormal speech produced by the aphasic patients. The patients' speech perception abilities were evaluated in the perception tests, and these results provi led a basis for estimating the role of perceptual factors in the patients' production errors (especially those in the repetition test). Only one subject (Subject 1) had auditory discrimination problems according to several tests. The perception difficulties (that were revealed by the syllable discrimination and auditory word-picture matching tests) usually did not result in the production of literal paraphasias in the repetition test. It was more common for patients with perception problems to produce phonologically motivated word substitutions. The controls also occasionally made these sorts of errors. Several factors may be assumed to contribute to these errors -- a hearing impairment, background noise, etc. From a theoretical point of view, the lack of perceptual sound substitutions in the repetition test may be explained by referring to the lexicon – people try to make sense of the items they hear. Semantic paraphasias were never produced in the repetition test. The lack of semantic errors means that the lexical representation's phonological form is more important in the repetition test than is the semantic representation associated with the phonological form.

The perception of abnormal speech by normal listeners may account for a number of "literal paraphasias" (i.e. phoneme substitutions). The results of the rating experiment provided a basis for estimating the role of such misperceptions. The relative entropy for the proportions of different transcriptions was great, especially for the nonfluent aphasics. This meant that the transcriber was likely to make transcription errors, and thus, direct conclusions about production mechanisms should not be based solely on such transcriptions. A more detailed analysis of these perceptual errors was beyond the scope of the present study. We could also assume that subjects with speech perception problems should have frequent phonological errors the in repetition test, but fewer mistakes in the naming test. No such patients were observed in the present study. However, an acoustic analysis of vowel errors revealed many instances in which the erroneous vowel fell into the phoneme category of the vowel that it was perceived to be like. These errors (that were all elicited in the repetition test) could very well be misperceptions by the subject (most of whom were aphasics but some errors were found also in the control data). The differences

between classes of sounds (for example, vowels and consonants) should be studied in more detail.

We can conclude that the auditory discrimination problems were only indirectly reflected in speech production. In contrast, subjects with lexical-semantic perception problems (i.e. difficulties in the semantic condition of the word-picture matching test) suffered from a corresponding deficit in speech production (i.e. they made semantic paraphasias in the naming and picture description tests).

The Articulatory Hypothesis

A strong interpretation of the articulatory hypothesis states that the phoneme substitutions are due to a listener's perceptual problem. The aphasic patient's phonological intention may be correct, but the patient has difficulties in controlling his articulatory movements (for example, the durations of his sounds are abnormal and show a high standard deviation). The listener occasionally "misinterprets" the aphasic speaker's sounds which acoustically do not resemble the intended phoneme, but instead resemble a closely related phoneme.

Assuming all errors were due to misinterpretations by the listener, then the amount of variation should directly predict the proportion of phonological errors -- the more variation, the more errors. However, there is one exception -- variation that results in categorical perception. The listening experiment did not pick up this type of variation.

In the phonetic analysis, the amount of variation in speech production was estimated in the following four ways. For the listening experiment (1) by the median of the ratings and (2) by the relative entropy for proportions of different transcriptions, and for the acoustic analysis (3) by the coefficient of variation for F1, and (4) by the coefficient of variation for the duration of the first syllable vowel. The following comparison of the above-mentioned measures of variation, and the proportion of phonological errors, is based on the correct answers. The strong non-word effect observed in the listening experiment is the reason for excluding the incorrect answers. All non-words (both correct non-words and literal paraphasias resulting in non-words) were consistently evaluated as less fluent than existing words. All non-words formed a relatively homogeneous group in the listening experiment. For these non-words, there was less difference between speaker or test than was found in the case of correct answers.

In the listening experiment, the two measures of variation mentioned above gave very consistent results. The small differences observed may be accounted for in the following ways -- the amount of variation in transcriptions may be a product of the writing system itself. Some sounds will be transcribed in the same way because there are no letters available for expressing the small differences observed. The median of the ratings is also not totally reliable. The listeners may base their ratings on different variables, and they may also interpret the rating scale in slightly different ways.

The acoustic variables mentioned above (the coefficient of variation for vowel duration and F1) did not provide totally consistent results. The subjects having the most problems with vowel durations did not have problems with F1. Obviously there were several independent acoustic variables, each being an indicator of a specific type of speech production problems. A further variable that differed from the aforementioned variables, was the degree of vowel centralization (as measured by F1 and F2). However, the variation observed in vowel durations was of special interest because it has been used as a measure for immaturity in speech motor control.

Table (6.4.1) presents the comparisons of the ratings for fluency with the number of errors in the repetition and naming tests. The comparison was based on only those patients who were included in the listening experiment.

Table 6.4.1 Phonetic Variation and the Number of Errors

The numbers refer to the subjects. The severity of their speech production problem is compared using the relative entropy for transcriptions ("trans"), listeners' evaluation of articulatory fluency ("rating"), the coefficient of variation for vowel durations ("dur") and F1 ("F1"), and the proportion of phonological errors ("err"). The phonetic variables of both the listening experiment and the acoustic analysis were based on correct answers. The subjects placed highest on the scales had the highest relative entropy for transcriptions, were rated the most nonfluent, had the greatest amount of variation, and made the greatest number of "phonological" errors in the repetition and naming tests.

naming			repetition of words				
trans	rating	err	trans	rating	err	dur	F1
6	14, 6	14	6	11, 6	14	4	6
14		4	11		6	9	4
11	11	5	14	14, 5, 4	4	11	11
13	5	6	5		11	14	9
12	4, 12, 13	11	9		5	6	14
5		9	4	9, 12	9	12	12
4		12	12		12		
9	9	13	13	13	13		

In general, the results obtained supported the articulatory hypothesis: patients demonstrating the greatest amount of variation also made the greatest number of errors. In particular, Subjects 12 and 13 were classified as the most fluent speakers in

the rating experiment, and they produced the least amount of errors. However, these subjects made more errors in the naming test than in the repetition test, and their speech was also evaluated as more fluent in the repetition test as compared to the naming test. Subject 12 also failed to show an increase in variation according to the acoustic analysis. Subject 13 was not included in the acoustic analysis.

It was impossible to accurately predict the number of phonological errors on the basis of the amount of phonetic variation. This was indicated by the fact that the order of the subjects varied to some extent. In this respect, Subjects 4 and 11 were two of the most interesting speakers. The speech of Subject 4 was evaluated as rather fluent in spite of the high number of errors. Patient 4 made a great number of vowel errors which may be treated differently than consonant errors in the ratings. Subject 11, on the other hand, made fewer phonological errors, and was rated as rather nonfluent. Subject 11 was in a very acute stage of aphasia. Articulation in acute aphasia may be different from articulation in a more stable form of aphasia where the articulatory mechanisms of the other cerebral hemisphere have been made available. Subjects 4 and 9, who made their phonological errors word-finally, resembled more the fluent subjects than did those patients with word-initial phonological errors.

When the three tests -- the acoustic analysis, the rating experiment, and the phonological analysis (proportion of errors) -- were compared for the nonfluent speakers, the results of the acoustic analysis differed from the other two tests. The amount of variation was dependent upon the acoustic measure used. The listener's evaluation of the articulation was based on different acoustic variables: sometimes the articulation was rated as poor because of nasal voice quality, sometimes because of inter-word pauses, etc. In spite of these differences, the subjects classified as the most fluent and nonfluent were the same according to all the indexes of articulatory fluency.

The fluent patients made fewer errors in the repetition test than in the naming test, and these subjects were also rated more fluent in the former, rather than the latter test. The nonfluent subjects had the same ratings in the naming and repetition tests. The controls were also rated as more fluent in repetition than in naming, even though they made more errors in the repetition test than in the naming test. Thus, the amount of phonetic variation did not directly predict the proportion of phonological errors for the control subjects. When the listener's evaluations of the errors made by the control subjects were analyzed in greater detail, the errors seemed to fall into several different error types.

There was no direct causal link between the phonetic variation observed in the correct productions and the types of phonological errors. However, there seemed to be phonetic differences between normal speech and the speech of the subjects with frequent phonological errors. Several types of articulatory nonfluency appeared to exist. The question of fluency becomes increasingly complex when not only articulatory nonfluency, but also, for example, grammatical aspects of nonfluency are taken into consideration.

Lexical Confusions

MacNeilage et al. (1981) referred to "lexical confusions" as an alternative explanation for aphasic phonological errors. Some examples of this type were found in the data. The following contamination error was produced by Subject 9 in the naming test. The target was *helikopteri* 'helicopter':

helikoottori ei koottori loottori loottori moottori
'no' 'motor'
koottori = kopteri + moottori (/l/ in *loottori* may come from *heli*)

This type of error was the most difficult to interpret because the subjects' original target could not be accurately reconstructed.

Other errors may also have referred to an aspect of the processing of the phonological form other than the strictly segmental aspects discussed above. Neologistic answers and verbal paraphasias obviously referred to some aspect of lexical retrieval. Word selection appeared to be random in verbal paraphasias. The neologisms were difficult to interpret, but these errors may have been lexical contaminations where the targets remained unknown. In neologisms, phoneme substitutions may accompany the lexical contaminations. Another explanation for the neologisms is that there is a "random string generator" (Buckingham, 1987). The neologisms found in the present study obeyed the phonotactic constraints of Finnish. The only subjects who produced word forms which did not obey the phonotactic constraints of Finnish were those who had articulatory problems.

The subjects differed with respect to the occurrence of phonological errors word-initially and word-finally. Such differences may refer to different stages of lexical retrieval -- the more "motor" related the speech production problem, the more frequent the word-initial errors. In addition to neologisms and contaminations, two types of lexical phonological errors were found -- deletion of word-final syllables and phonological anosognosia.

In the study of lexical errors, circumlocutions are another type of error that need be investigated. Subject 1 had the most circumlocutions, and the majority of these errors were made in the naming test. An example of this is the following: for 'unicorn' which is *yksisarvinen* in Finnish, Subject 1 said *satuhevonen* 'fairy-tale horse', thus retaining the same number of syllables and the same structure of the ideal answer. Of interest is the frequency of such circumlocutions. Unfortunately, there were too few circumlocutions in the present data to warrant further investigation.

6.4.3 Explaining the Phonetic Variation

The following indexes were applied to aphasic speech in order to reveal an increase in variation: in the listening experiment, the median of the ratings, as well as the relative entropy for different transcriptions; in the acoustic analysis, the coefficient of variation for F1 and for vowel duration. There was increased variation in both the correct and incorrect answers. When acoustic measures were used, the most fluent subject (with a parietal lesion and with few phonological errors) did not differ from the control subjects. The listening experiment indicated a clearer difference between the aphasic and control subjects. A more detailed phonetic analysis could reveal additional differences between fluent and nonfluent subjects.

The variation of vowel durations is often used as an indicator for motor control problems (e.g. Duffy and Gawle, 1983). The results obtained using this measure agreed with the other results from the phonetic experiments. For the most fluent speaker, the coefficient of variation for vowel duration was within normal limits. However, Subject 8 (who had "apractic" speech errors in descriptive speech) did not differ from the control subjects with respect to variation for vowel duration. This result has several interpretations: (1) The "apractic" speakers' articulation may be "fluent". (2) When the standard deviation of vowel durations is used as an index of articulatory fluency, the measure should always be determined in those items where the subject makes phonological errors (i.e. as far as Subject 8 is concerned, the vowel duration of the long items should have been measured in the repetition test). (3) The measure may not be a good indicator of motor control problems. The present data did not provide a basis for deciding between these alternatives.

The presence of a speech motor control problem may explain why the speech of a few subjects was consistently evaluated as poorly articulated. The order of the nonfluent subjects in a fluency scale was dependent upon the phonetic feature under investigation. It has been proposed that the spatial and temporal aspects of articulation

are controlled independently (Kelso, Tuller, and Harris, 1983: 145). In the present study, Subject 6 had a severe problem in spatial aspects of articulation (vowel centralization), but he had only a mild problem with the temporal aspects of articulation as compared to the other nonfluent patients. Ziegler and von Cramon (1983) have interpreted vowel centralization as resulting from a decrease in the motility of articulators.

A comparison between the amount of phonetic variation in speech production and the proportion of phonological errors suggested that patients having numerous phonological errors also had an increase in phonetic variation. The errors cannot be explained merely with reference to articulatory gestures (such as lip movements or velar movements), but usually the simplifications can best be described in terms of phonemes. For aphasics, however, the abnormal realization of the length opposition may point to some stage of speech motor control where the gestures play a role -- high, rounded vowels produced with lip protrusion were the most affected.

According to Luria (e.g. 1973) and Hardcastle (1987), the fluent patients' speech production problems were caused by impaired feedback monitoring. This theory does not account for the present findings. It does not explain why named words were not articulated as well as repeated words. All the variation found in the rating experiment could not be due to motor control problems (i.e. a damage to the motor systems).

The named words may have been articulated less fluently than the repeated words because in naming, the subject must activate the phonological form stored in the lexicon, whereas in repetition the form has already received its activation during the perception process. The activation process is reflected in the phonetic output as nonfluency (of a particular type, the nature of which is unknown).

The most nonfluent patients made word-initial errors. There were also patients who made predominantly word-final errors. The subjects with word-final errors also made more vowel errors than other subjects, and they produced neologisms in the naming and picture description tests. The word-initial and word-medial errors of long and phonetically complex items that were elicited in the repetition test may be signs of speech apraxia. Speech apraxia is often defined as a problem of the motor control in articulating complex phoneme sequences. The patients whose errors typically occurred word-finally may have a lexical retrieval problem. Alternatively, word-final errors may be due to difficulties in activating the lexical item or in keeping the activation level high enough during the time demanded by the production mechanism (as proposed by Joanette et al., 1980). The severity of the activation problem may vary -- the more severe the problem, the more severe the errors. If the severity theory

is true, then neologisms and contaminations are the most severe errors, whereas omissions of the word-final syllables are less severe. Phonological anosognosia was one form of the lexical difficulties. The lexicon is one area where further research is warranted. If further dissociations between the different types of lexical errors will be found in future studies, then it will be shown that the components of lexicon can be selectively affected. Results from the rating experiment indicated that some types of phonetic variation may be best explained with reference to the lexicon, and there obviously are different types of phonetic variation.

7 Patient Classification

The patient groups discussed in the previous chapters were not completely homogeneous. There was also an overlap between the groups, and it was possible for one subject to belong to several groups at the same time. In some cases it was difficult to decide whether errors should be considered to belong to one or to two different error types (i.e., whether the errors differed in quality or in severity). If more subjects had been examined then it obviously would have been possible to divide the present patient groups into sub-groups. In the present study, only those groups who could be separated by phonological variables were discussed.

7.1 Groups in the Present Data

When analyzing the speech samples in terms of linguistic and phonetic variables, the subjects often seemed to fall along a continuum, with nonfluent patients at one end, and fluent patients and controls at the other. Some generalizations about patient classification were apparent from the data. This classification was not tested statistically because the analysis involved a small number of patients and a great number of variables. Several ways of classifying patients were compared. The patients could be classified according to the most dominant speech deficit. If there was no double dissociation between the analyzed variables, the subjects could be "forced" into a group. When more variables were taken into consideration, the groups were more indistinct. In other words, there was considerable overlap between the groups.

The first step was to divide the patients into three groups based on their performance in the articulation tests. The result was the following classification: (1) subjects with voice problems and with alternate motion difficulties, (2) subjects who failed only in the sequential motion and repetition tests, and (3) subjects who did not fail in the articulation tests. When the repetition, naming, picture description, and speech perception tests were analyzed, the above-mentioned groups were characterized with more features. Subjects who had difficulties in the sequential motion test also had a tendency to make errors in the repetition of long, phonetically complex words. Of the two tests – repetition and sequential motions -- the former was more sensitive in detecting phonological difficulties. The third group consisted of patients who did not have problems with the articulation or repetition tests, but who did fail in the naming and picture description tests. The qualitative analysis of naming and picture

description errors revealed new error types: neologisms, and verbal and semantic paraphasias. These error types were characteristic of those subjects who did not have difficulties in the articulation or repetition tests. These subjects tended to have more difficulty with the semantically related items of the word-picture matching test (as compared to unrelated and phonologically related items).

Data from fifteen aphasic patients are too small for determining whether or not the analyzed phonetic and linguistic variables can be selectively affected. Nevertheless, double dissociations of some variables were detected (e.g. phonological vs. semantic errors in the word-picture matching test). Such dissociations provide a solid basis for patient classification. However, it was more characteristic of the present data that a certain error category was either present or absent (e.g. voice disorder, semantic paraphasias in the naming test). Some of the analyzed variables were apparently independent of each other, but many variables also characterized different manifestations of the same underlying difficulty. In this respect, the present study only forms a basis for more comprehensive studies in the future.

The following paragraphs summarize the most important results as they relate to patient classification.

1. Subjects without Problems in the Articulation or Repetition Tests

Subjects 1, 3, 7, 13, and 15 passed the articulation tests. Another feature common to these subjects was that they made similar errors in the word-picture matching, naming and picture description tests. The characteristic error types were semantic difficulties in the word-picture matching test, and semantic paraphasias and neologisms in the naming and picture description tests. These error types provided a basis for a positive definition of this patient group. On the basis of their performance in the naming and word-picture matching tests, Subjects 2, 3, 7, 9, 11, (12), 13, and 15 were placed in the same group. Subjects 9, 11, and 13 had the most difficulty with the semantic condition of the word-picture matching test. Subjects 2, 3, 7, and 15 also had more difficulties in the semantic condition than they had in the other conditions of the test.

When the classification was made solely on the basis of types of naming errors, picture description and word-picture matching errors, Subjects 2, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, and 15 formed one group. Subjects with severe articulatory trouble were included in this group, and only Subjects 1, 4, and 8 were excluded. Although Subject 1 had difficulties in auditory discrimination, he otherwise had only mild difficulties (articulation problems with long words, and difficulties with naming that resulted in

circumlocutions). Subject 4 obviously had such severe phonological or word finding difficulties in the naming and picture description tests that no "semantic" errors could be found. In fact, it was mentioned in the medical files that he possibly suffered from multi-infarct dementia. Subject 8 passed the standard aphasia testing so well that he was almost as normal[1]. His main difficulties were articulatory, and they were manifested in spontaneous and descriptive speech (not in isolated words if the words were not exceptionally long). Thus, it was an open question as to whether his problem was aphasia proper. At any rate, the problem was very severe, and it prevented the subject from returning to his previous job.

When more restrictive criteria of patient classification were used, either Subject 12 (who did not make phonological errors in the articulation or repetition tests, and who produced the longest story in the picture description test), or Subjects 9 and 13 (who had semantic paraphasias and neologisms in naming and descriptive speech) could be considered very typical, fluent aphasics. When Subjects 9, 12, and 13 made a phonological error in the repetition test, they corrected it themselves (as did the controls). Also in the naming test these subjects usually corrected their own phonological errors. Due to the small number of mistakes, it was difficult to evaluate the role that word length played in the production of errors, but as far as the present data were concerned, word length appeared to have a negligible effect. According to the phonetic analysis, the coefficient of variation for F1 and for vowel duration were not increased in Subject 12's speech. In the listening experiment, Subjects 13 and 12 were rated as the most fluent aphasics.

Subjects 9 and 13 had a temporal lesion, and Subject 12 had a parietal lesion (with subcortical involvement). Thus, the differences between these fluent patients lied in the location of the lesions. There are different types of fluent aphasia, Subject 12 having one type of fluent aphasia, and Subjects 9 and 13 having another type of fluent aphasia. When the above-mentioned, large set of patients (twelve) was considered, no generalizations as to lesion localization could be made (it varied from frontal to temporal and parietal, and several patients also had subcortical involvement).

2. Subjects with Voice Disorders and with Problems in Alternate Motions

A few patients even had difficulties on the simplest speech production tests. For example, Subjects 5, 6, and 14 were the most characteristic of this group as they all

[1] Information about the subject's performance in the Western Aphasia Battery was obtained from a speech pathologist.

had difficulties with the alternate motion test. Subject 5 was diagnosed as having spastic dysphonia, and Subject 14 also had a voice disorder. These basic motor and phonation difficulties were manifested in all speech production tests. Subject 14 was very representative of this group, because he made relatively few other than articulation errors. Subjects 11 and 12 also had some problems of this type. Subject 12 whispered the last item in the series of alternate motions. If his behavior was considered pathological, it evidenced the double dissociation between alternate and sequential motions. However, this evidence was not quite convincing. Subject 11 was tested only 1,5 months post-onset, and his syndrome was very complex. For this subject, features of fluent aphasia were very clear in naming, but he also had articulatory/phonological difficulties that were less dominant than naming difficulties and could, therefore, be assumed to resolve over time. However, when Subject 11 was tested, he made many phonological errors unlike those of the other patients (c.f. below).

Subjects 5, 6, 11, and 14 made numerous phonological errors in the repetition, naming, and picture description tests. Word length played an important role in these subjects' errors -- the more complex the phonetic composition of an item, the more prone the subject was to commit a phonological error. A closer analysis also revealed differences between the subjects. Subject 5 differed from Subjects 6 and 14 in that she had somewhat more "non-answers", the repetition deficit was a little milder (she reproduced incorrectly about 30 % of the bisyllabic targets, whereas Subjects 6 and 14 made errors in more than 50 % of the targets), and in the naming test there was no clear difference between bi- and trisyllabic targets (however, compounds were more difficult than shorter items). Subject 11 often failed to repeat or to name the longer items. The subjects did not try to correct themselves (Subjects 5 and 6 tried more often than Subject 14, and Subject 11 in 30 % of the items of the repetition test but not in the naming test), the few attempts were not successful.

Anticipation errors were typical for these subjects, although Subjects 5 and 11 did not make these sort of mistake in the naming samples. Deletion and substitution errors were also common word-initially (especially for Subject 6 in all the tests, and for Subject 11 in the repetition test) or word-medially (especially for Subject 5 in all the tests, and for Subject 11 in the repetition test; Subject 14 also had difficulties with the length opposition of word-medial consonants in the repetition test). For all subjects, complex errors were somewhat more common in the naming test than in the repetition test. In general, consonant errors were more common than vowel errors (even if Subject 5 had a number of vowel errors in the repetition sample). Subject 11

differed from the other subjects in that he made more metathesis errors. He often substituted /k/ for the word-initial consonants, as well as had neologistic answers in the naming test.

According to the results of the phonetic analysis, Subjects 4 and 6 differed by the greatest number of variables from the other subjects. Furthermore, slight phonetic deviations were made by Subjects 1, 9, 11, 14, and 15. Subjects 14 and 11 formed their own group on the basis of grammatical fluency, as they produced very short sentences.

Subjects 6, 11, and 14 had a primarily temporal lesion, and Subject 12 had a parietal lesion. There was no localization information available for Subject 5. There were CT scans available for Subjects 11 and 12, and EEG results for Subjects 6 and 14. Subjects 11, 12, and 14 had subcortical extensions of the lesions that involved the basal ganglia. Such information was not available for Subjects 5 and 6. It can be tentatively proposed that a syndrome involving voice disorders and problems with alternate motions results from lesions with subcortical involvement.

3. Difficulties in Sequential Motions and in the Repetition of Long Words

The group was first defined on the basis of the subjects' difficulties in the sequential motion test, and lack of difficulties in the alternate motion tests. In this way, Subjects 4, 8, and 9 were included in the group. Furthermore, subjects who failed in the alternate motion tests also had difficulties in the sequential motion test (an exception was Subject 12). Subjects 2 and 10 paused once in the test of sequential motions, but made no real errors. Subject 4 had a series of approximations that resulted in a correct production. Subjects 8 and 11 had metathesis errors. Subject 9 made an anticipation error. Subjects 5 and 14 made complex and severe errors, Subject 6 made one false start and one metathesis error.

When the qualitative characteristics of these deficits were analyzed, the group was first defined negatively with respect to the two groups discussed above. On the basis of phonological errors it would be more natural to include Subject 11 in the present group than to group him with Subjects 5, 6, and 14.

The repetition test proved to be more sensitive than the sequential motion test for mild articulatory difficulties. All the subjects with difficulties in sequential motions shared a difficulty in articulation of long, phonetically complex words. When those subjects with difficulties in the repetition of long words were added to the group under discussion, the entire group consisted of Subjects 1, 2, 4, 8, 9, and 10. All of

these subjects differed from one another. No one causal factor could explain the observed deficits. Subject 1 had an auditory discrimination problem. Subjects 4 and 9 often omitted the word-final syllables of long items in both the repetition and naming tests. Subject 4 had morphological problems accompanying his phonological problems, and Subject 9 had phonological anosognosia. Subject 8's phonological problem surfaced in the picture description test only, not in the tests that contained isolated words. These errors have been discussed in detail in chapter 5.4.

A Comparison with Traditional Clinical Classifications

The patients were first classified on the basis of their performance on the articulation tests. The groups corresponded to those described by Darley et al. (1975), according to whom subjects failing in the alternate motion test were classified as "dysarthric", those failing in the sequential motion test and in the repetition of long words were described as "speech apractic", and those having problems with "meaningful items" were "aphasic".

The subjects were not prediagnosed, and on the basis of the tests included in the present study it was impossible to reliably determine the aphasia types as described by e.g. Goodglass and Kaplan (1983). However, it can be assumed that a majority of the subjects would not present a traditional aphasia syndrome in its purest form. Most subjects were tested more than one year post-onset, and the aphasic symptoms were already mild. There are different opinions about the classification of patients with residual aphasia -- sometimes the patients are classified into traditional categories, whereas sometimes no classification is made. The results of our study indicate that there are clear differences between patients with residual aphasia.

In traditional aphasiology, those subjects exhibiting predominantly production difficulties accompanied with relatively good comprehension abilities, have been diagnosed as Broca's aphasics. The subjects whose production is better than their comprehension are classified as Wernicke's aphasics. Broca's aphasics are nonfluent, whereas Wernicke's aphasics are fluent. In conduction aphasia, spontaneous production and comprehension are relatively good, but difficulties arise in the repetition test.

The classifications presented by Darley et al. (1975) and Goodglass and Kaplan (1983) do not completely overlap because they focus on different features of the syndromes. On the basis of the major symptoms, it is possible to suggest tentative correspondences between the two classifications. Of the present subjects, the group with voice disorders plus difficulties in the alternate motion tests (i.e. dysarthria

according to Darley et al.) could be classified as Broca's aphasics or, more precisely, as having a syndrome that resembles Broca's aphasia. Subjects 11 and 14 were nonfluent, not only on the basis of articulatory criteria, but also on the basis of grammatical criteria. The patients who had "aphasia" according to Darley et al. resemble Wernicke's aphasics even when their comprehension was relatively good (in the present study, these subjects had mild problems in the semantic condition of the word-picture matching test). Such patients are often considered to be recovered Wernicke's aphasics (Caplan, 1987). The third group, "apraxia of speech" according to Darley et al., would correspond best with conduction aphasia. In the present comparison, transcortical aphasias were ignored.

The tests that are commonly used for diagnosing speech apraxia and conduction aphasia have much in common: speech apraxia tests consist of diadochokinesis and the repetition of words with varying phonetic complexity, and subjects having speech apraxia should have difficulties with the repetition of long words. Conduction aphasia is traditionally considered to be a repetition disorder. Here, the patient's spontaneous speech is normal, and he or she has no severe comprehension problems. Kohn (1985) has described conduction aphasia on the basis of the linguistic characteristics of naming responses: patients of this group had "literal paraphasias" in naming, as opposed to the neologisms of Wernicke's aphasics, and to the distortions of Broca's aphasics.

Kertesz and Phipps (1977) distinguished between two conduction aphasia groups: those with a more severe production problem, and those with a more severe perception problem. In the present study, Subject 1 had problems with auditory syllable discrimination. There were three subjects who had phoneme discrimination difficulties according to the word-picture matching test (Subjects 1, 2, 9). These subjects made phonological errors in the repetition test (Subject 1 made most of the mistakes in long, phonetically complex words). Subjects 2 and 9 also made some errors in the naming test. These subjects often tried to correct their phonological errors in the naming test, and they were often successful at these corrections. Subject 9 had the most serious naming problems, and produced long sequences of approximations which were characterized as phonological anosognosia. In the repetition test, there were fewer, and less successful attempts at correction. Subjects 2 and 9 also had features of fluent aphasia. In conclusion, it was difficult to distinguish between features of mixed aphasia and speech perception problems. It is possible that phoneme recognition deficits always lead to speech production problems, but it is also possible that these difficulties are independent of one another. Subject 8 did not have speech

perception problems. Speech production problems do not lead to speech perception problems: subjects with the most severe speech production problems did not have auditory discrimination problems.

It is often assumed that speech apraxia is caused by an anterior lesion. In the present study, Subject 2 was the only patient with an anterior lesion who exhibited this problem, although there were other patients with similar symptoms who did not have an anterior lesion. Posterior lesions often seemed to result in nonfluent aphasia (similar results have been obtained by e.g. Karis and Horenstein, 1976). The lesions of the most nonfluent patients also extended to the subcortical nuclei. In future studies of aphasic speech, more attention must be paid to the size and subcortical extensions of lesions.

The present analysis demonstrated that residual aphasic patients also differ from one another. The observed differences were characterized by the traditional aphasia categories, which can be used as a quick means for roughly identifying the types of deficits. The groups formed in the present study were loose categories -- clusters of several independent deficits. Most patients have large lesions, their deficits are varied, and thus most patients belong to several categories simultaneously. A larger-scale experiment with prediagnosed patient groups should be performed before final conclusions can be made concerning the relationship of traditional aphasia categories to the types of phonological errors described in the present study.

7.2 The Linguistic Implications of the Groups

Auditory Discrimination and the Role of Segments in Speech Perception

An auditory discrimination problem was observed in Subject 1. This subject had neither severe comprehension difficulties, nor severe speech production problems. Most subjects included in the study had some speech production problems. For some subjects having speech perception problems, there may have been a link between auditory discrimination and the speech production problems. However, it is impossible to test this hypothesis on the basis of the present data.

Blumstein et al. (1977) demonstrated that auditory discrimination problems do not explain the speech perception or comprehension problems observed in Wernicke's aphasia. Also, pure word deafness is rare (Saffran, Marin and Yeni-Komshian, 1976).

The speech perception and comprehension problems in aphasics seem to be related to the higher stages (i.e. lexical access) of the process (Jauhiainen and Nuutila, 1977).

Auditory discrimination problems many be far more common than clinical tests reveal. Various types of hearing loss should be checked (e.g., on the basis of error patterns), and their relation to aphasia should be studied in detail. An increase in the sophistication of the tests would undoubtedly increase detection of auditory discrimination problems. Standardized tests (with a normal age matched comparison group) are needed to minimize problems of patient classification. Better syllable lists with systematically varied phonetic contrasts should be prepared and administered in a controlled way (e.g. tapes presented in a sound-proof environment).

Speech Motor Control and the Role of Segments in Speech Production

The analysis of phonetic variation revealed that phonological errors cannot be explained by increased variation alone, nor can all types of variation be explained by only studying segmental errors. Thus, some types of phonetic variation (and voice disorders) and segmental errors in speech production seem to dissociate in aphasia. Most of the present patients with "Broca's aphasia" had problems with both alternate and sequential motions. It seems likely that they had a complex syndrome, and the segmental errors (which are related to the problem with sequential motions) form one component of the syndrome. Phonetic features that evidenced a "lower level" deficit of speech motor control were the centralization and considerable lengthening of vowels. It is usually assumed that increased variation in vowel durations would refer to a motor control problem. This claim was difficult to evaluate on the basis of the present data, as the nature of phonetic features in deviant speech should be studied in more detail.

It remained unclear whether or not there was a difference between segmental errors for patients with and without alternate motion problems. On the contrary, there was a clear difference between patients who predominantly made word-initial errors, as opposed to patients with predominantly word-final errors. The following discussion focuses on patients who made word-initial errors (i.e. on Subjects 5, 6, 11, and 14). Word-initial errors were usually consonant errors. Anticipation and metathesis errors were common. Thus, these kinds of errors were made by patients with the most severe type of speech apraxia.

Patients made anticipation errors that usually simplified the word form such that the sequence of movements became less complex. This kind of a phenomenon is

referred to in natural phonology where mental entities under examination are called phonological processes. According to Donegan (1978), Stampe defines the natural phonological process as follows:

> "... a mental operation that applies in speech to substitute, for a class of sounds or sound sequences presenting a specific common difficulty to the speech capacity of the individual, an alternative class identical <in all other respects> but lacking the difficult property." (p. 3)

Natural phonological processes are considered to be automatic adaptations of the speaker to the articulatory and perceptual difficulties of sounds and sound sequences. They are motivated either phonetically (in terms of articulation) or phonologically (preservation of phonological distinctions) (Donegan, 1978: 127). A phonological system is a collective result of phonological processes. It was unclear whether the sound sequences referred to adjacent sounds only, or to a whole phonological form of a lexical entry. The present data support the latter proposal.

In natural phonology, the motor (phonetic) functions and the central (phonological) functions are considered to operate separately. The natural phonological process is a part of the planning phase, and as such it does not refer directly to the actual production of the sound (c.f. Stampe, 1969; Ohala, 1974). Substitutions caused by natural phonological processes are considered to be systematic.

Natural phonological processes have been observed in first language acquisition and in second language learning. According to Donegan, slips of the tongue cannot be considered phonological processes because they are not systematic. However, Wurtzel (1984: 18) has tried to find evidence for natural phonological processes in the speech of aphasic patients. Errors by aphasic patients are never systematic. The extent to which the substitutions in first language acquisition are actually systematic should be investigated in detail.

When children are unable to produce sounds correctly (they have natural phonological processes that adults have not retained), they often have the right internal representations of the words (i.e. they "hear" the phonologically important distinctions). The adherents of natural phonology think that, in addition to the phonological processes, one needs an "idea" of what to pronounce. According to the present data, aphasic patients often aimed at the correct target, as was indicated by the anticipation errors. In this respect, the situation of the second language learner may be different.

Natural phonological processes seem to have something in common with the theory of co-ordinative structures in physiological phonetics (c.f. Kelso, Tuller, and

Harris, 1983). This theory may also account for the specification of the child's articulation in very much the same way as does natural phonology.

Lexicon

In the previous discussion, the lexicon has been referred to in connection with various variables under investigation (both speech production and perception variables). At the lexical-semantic level the deficits seem to be more modality independent than they are at the "segmental" level. However, with new data more double dissociations may be found among the lexical variables.

A slightly higher number of phonological errors were observed in the naming test than in the repetition test. The naming errors were more complex. In the picture description test, many errors were difficult to classify: the morphological and phonological aspects of the difficulties may have amalgamated. Thus, the analysis is made more difficult by the "linguistic complexity" of the test, and the subjects may also make a higher number of errors in the more demanding tests than in the more simple tests.

Some subjects made more errors word-finally than word-initially. Joanette et al. (1980) have proposed that this is due to the instability of the phonological representation, or due to a difficulty in keeping the representation active long enough to control for the production of the item. There were also subjects who often produced neologisms and/or verbal paraphasias. The data also contained some contaminations. These error types may also refer to the processing of the phonological form. Verbal paraphasias appear to be random selections from the lexicon. Contaminations result from a simultaneous activation of two items. Neologisms are more difficult to explain, as they may, for example, be contaminations of several items, or just random phoneme strings. In the present data, neologisms usually obeyed the phonotactic constraints of Finnish. The only exceptions were a few neologisms made by the nonfluent patients, and these items were also inaccurately articulated. In contrast to the errors discussed under natural phonology, these lexical errors refer to words (phonological forms of the lexical entries) in addition to, or rather than, segments.

The contrast between segmental phonological errors and lexical errors is, however, vague. Segmental errors, for example metathesis errors, may also refer to the word form in the lexicon. In the present data, there were two types of metathesis errors --

some obeyed the phonotactic constraints of Finnish, and some did not. The latter type of metathesis errors was produced by the most nonfluent aphasic patients.

In the listening experiment, named words produced by the controls and by the most fluent aphasics were evaluated as less fluent than repeated words produced by these subjects. This may refer to lexical retrieval as a source of phonetic variation. It is not known which phonetic variables are affected by such "high level processing". Repeated words may be easier to produce because the speech perception process has already activated the lexical item to be produced.

Results from the listening experiment also showed that there was a strong non-word effect. Non-words, and literal paraphasias that resulted in non-words, were rated as less fluent than real words. This fact was easiest to explain by reference to the role of the lexicon in speech perception. Furthermore, the results of the repetition test supported this explanation. In repetition, non-words were more difficult than real words: non-words were often repeated as real words, and real words were repeated as other real words, rather than as non-words. It was difficult to determine the cause for this -- was it speech perception or speech production in question? Certain aphasics with severe segmental problems in their speech production tended to repeat non-words as real words. This supported the hypothesis that speech production factors also play a role in the phonologically motivated word substitutions of the repetition test.

There are two conflicting theories about normal speech perception. According to Bradley and Forster (1987), the word form is recognized first, and then followed by lexical access. Marslen-Wilson (1987) has advocated an interactive view of speech perception. These models give the following predictions about the subject's performance in the word-picture matching test (in which the items were either unrelated, phonologically or semantically related):

(1) If word recognition precedes lexical access, then there should not be patients who fail in the phonological condition of the test and simultaneously exhibit good performance in the other two conditions of the test.

(2) If lexical access precedes or may interfere with word recognition, the patients should then be able to compensate for the difficulties that come to surface in the phonological condition. Thus, difficulties should not arise in the other two conditions of the word-picture matching test.

(3) If word recognition is impossible without any reference to lexical access, there should not be poor performance in the semantic condition of the test and simultaneously excellent performance in the phonological condition of the test, because lexical access difficulties should interfere with all speech perception.

Results:

(1 - 2) The results show that many patients have their poorest performances in the phonological test condition rather than in the other two conditions. A double dissociation was found between the phonological and semantic conditions. Thus, the result supports Marslen-Wilson's interactive model of speech perception because the patients seem to be able to compensate for their speech recognition problems.

(3) The prediction (3) is true for most patients' verbs: those who show great difficulties with semantically-related items also do somewhat poorly in phonologically-related items. However, for nouns this prediction is not true: there were two patients (1 and 9) who showed a double dissociation between the two conditions. The difficulties observed with verbs can be accounted for by the depiction effect. One seems to use lexical access only when word recognition fails.

A more detailed analysis of both speech perception and production in aphasia are needed. Several types of lexical deficits seem to exist. The relation of modality independent and modality specific problems, and the questions of auditory discrimination and speech motor control warrant further investigation.

Phonological anosognosia

Phonological anosognosia refers to the behavior where the subject produces the right item but does not accept it as correct. This leads to a kind of sound play -- attempts at self-correction. In the present study, this behavior was observed only for Subject 9 in the confrontation naming test. This subject also had apparent difficulties word-finally: he often omitted the final syllables of long items.

There were two types of aphasiological theories: some stressed the modality-specificity of the aphasic symptoms, and some considered that a proper linguistic deficit should be modality-independent. In the present study, only the lexicon (i.e. the memory of the conventional aspects of language) was considered to be modality-independent. In connection with speech perception, the lexical aspects were referred to by the term "lexical access", whereas the lexical aspects of processing in speech production were referred to by the term "lexical retrieval". The lexical entry's semantic and phonological representations were also discussed.

The term "lexicon" was used in a very wide sense. All the linguistic information is learned and represented in memory. This is also true of the phonetic aspects of speech production: languages may differ in their "articulation basis" -- in some languages all sounds are produced in a relatively frontal position, whereas others prefer back articulations. It may be assumed that "rules of grammar" provide a structure for the organization of the memorized linguistic information. "Lexicon" in a narrow sense, refers to such linguistic structures for which there are no good rules. It may be further assumed that, when a person has learned the organizing principles for his or her native language, these principles are not disturbed by (local) brain damage. The aphasic symptoms reflect the interplay of the memory and the actual speech production and perception processes. This is indicated by the fact that not only phonological errors but also lexical and semantic errors are unsystematic, i.e., the same item is sometimes produced correctly, sometimes incorrectly. For example, neurochemical changes could, in principle, make lexical information less easily available to the processes (but the information would not have completely disappeared). The nature of aphasic errors may be partly explained by the local nature of brain damage in aphasia and by the distributed organization of linguistic memory (e.g. Allport, 1985).

Epilogue

Several kinds of phonological deficits were observed in this study. Establishing a distinction between phonetic vs. phonological deficits was an early attempt at a classification of the phonological errors. The present classification can also prove to be a simplification: each error type may be heterogeneous. The results obtained support the proposal by Green (1986): errors are a result of a problem in regulating the activity of an intact system. The deficits of different patients occur at different levels or aspects of the speech language production and perception. These errors represent a complex interplay of the lexicon (in a wide sense) with speech production and perception abilities.

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Appendix 1

The Tests

(i) Syllable Discrimination

The following syllable pairs were presented to the subjects who were asked whether or not the two syllables were similar. The subjects were instructed to say "yes" when the syllables were similar, and "no" when the syllables were not similar.

1. na - ka	2. ke - re	3. pe - pe
4. tu - ty	5. ti - ni	6. kä - kä
7. po - pä	8. li - lä	9. nä - nä
10. ly - ry	11. mö - pö	12. my - my
13. ku - nu	14. sy - sy	15. re - re
16. pu - pu	17. mo - mo	18. sö - sö
19. ro - to	20. mu - mu	21. sö - nö
22. sa - si	23. lö - lö	24. ta - ta
25. nä - nä	26. lo - lo	

(ii) Word-Picture Matching

A complete set of materials can be obtained from Hänninen et al. (1987). The test consisted of six picture sheets, with ten pictures on each sheet. The picture sheets were the following:

1. Suomi 'Finland', silmä 'eye', kello 'watch', kala 'fish', laiva 'boat', lehti 'newspaper', poliisi 'policeman', kivi 'stone', kirkko 'church', nainen 'woman'

2. naula 'nail', kaula 'neck', korppi 'raven', kortti 'post card', neula 'needle', heltta 'wattle', korkki 'cork', teltta 'tent', keula 'bows', taltta 'chisel'

3. kaulus 'collar', hiha 'sleeve', tasku 'pocket', solmio 'tie', vyö 'belt', rusetti 'bow', hattu 'hat', sukka 'sock', olkaimet 'suspenders', käsineet 'gloves'

4. tanssii 'dance', nostaa 'lift', syö 'eat', maalaa 'paint', lentää 'fly', pelaa 'play (a game)', soittaa 'play (an instrument)', opettaa 'teach', istuu 'sit', rukoilee 'pray'

5. pakkaa 'pack', haraa 'rake', laulaa 'sing', hakkaa 'chop', harjaa 'brush', lakkaa 'varnish', viilaa 'file', kiilaa 'inappropriately pass a car', halaa 'embrace', keilaa 'bowl'

6. polvistuu 'knee', kumartuu 'stoop (down)', konttaa 'crawl', hiipii 'creep', kävelee 'walk', hyppää 'jump', kiipeää 'climb', kompastuu 'stumble', liukastuu 'slip', juoksee 'run'

When presenting the items to the subjects, the examiner instructed them to point to corresponding pictures. When two or three items were presented at a time, the subjects were asked to point to the pictures in the same order as the items were presented to them. The items used in this test were the following:

sheet 1: 1. silmä
2. laiva

	3. kala
	4. kivi
sheet 2:	5. keula
	6. korkki
	7. teltta
sheet 3:	8. tasku
	9. hiha
	10. sukka
sheet 1:	11. kello - nainen
	12. kirkko - lehti
	13. Suomi - poliisi
sheet 2:	14. heltta - neula
	15. kaula - kortti
	16. korppi - naula
	17. teltta - korkki
sheet 3:	18. kaulus - vyö
	19. solmio - käsineet
	20. hiha - hattu
sheet 1:	21. laiva - kala - silmä
	22. kivi - kello - lehti
	23. nainen - kirkko - Suomi
sheet 2:	24. teltta - kortti - kaula
	25. neula - taltta - korppi
	26. naula - keula - heltta
sheet 3:	27. vyö - hiha - kaulus
	28. solmio - käsineet- tasku
	29. olkaimet - rusetti - sukka
	30. hattu - solmio - käsineet
sheet 4:	31. tanssii
	32. istuu
	33. maalaa
	34. soittaa
sheet 5:	35. kiilaa
	36. lakkaa
	37. harjaa
sheet 6:	38. juoksee
	39. kiipeää
	40. kumartuu
sheet 4:	41. opettaa - lentää
	42. rukoilee - nostaa
	43. syö - pelaa
sheet 5:	44. laulaa - hakkaa
	45. harjaa - keilaa
	46. pakkaa - viilaa
	47. haraa - lakkaa

sheet 6: 48. hiipii - kumartuu
49. kävelee - polvistuu
50. konttaa - juoksee

sheet 4: 51. lentää - soittaa - istuu
52. maalaa - syö - opettaa
53. pelaa - rukoilee - tanssii
sheet 5: 54. kiilaa - laulaa - hakkaa
55. pakkaa - harjaa - viilaa
56. keilaa - lakkaa - haraa
sheet 6: 57. polvistuu - kiipeää - hiipii
58. konttaa - juoksee - polvistuu
59. kävelee - hyppää - kompastuu
60. kumartuu - liukastuu - konttaa

(iii) diadochokinesis

1. papapa
2. tututu
3. takeli takeli takeli

(iv) repetition of words, non-words and syllables

words:
5. rumpu, 6. teettää, 7. pöönä, 8. kallistuminen, 9. köökki, 10. tunne, 11. teema, 12. neekeri, 13. konna, 14. kukko, 15. tuuli, 16. pää, 17. kuusi, 18. puolin, 19. luuta, 20. koti, 21. ystävällisyys, 22. mökki, 23. soolo, 24. kotelo, 25. tööttää, 26. tuttu, 27. limppu, 28. tönö, 29. mäkihyppy, 30. kello, 31. sälpä, 32. soosi, 33. sekularisaatio, 34. toosa, 35. kilpi, 36. on, 37. korpi, 38. kokko, 39. kirkonkellot, 40. kämppä, 41. loota, 42. söötti, 43. pyykki, 44. liina, 45. luulo, 46. kotikolo, 47. kurssi, 48. matala, 49. marssi, 50. suuri, 51. tanssi, 52. tulppa, 53. transkriptio, 54. parta, 55 seassa, 56. kulta, 57. koko, 58. kiittää, 59. silta, 60. suunta, 61. keräsi, 62. lintu, 63. ele, 64. papupata, 65. kyy, 66. töölö, 67. tulee, 68. väite, 69. köli, 70. tonni, 71. pöllö, 72. tie, 73. lempi, 74. luultavasti, 75. seepra, 76. teesi, 77. tölli, 78. ui, 79. olo, 80. seestyy, 81. kesäkeli, 82. söpö, 83. ajaa, 84. liika, 85. kylpy, 86. toivo, 87. lööperi, 88. soi, 89. keppi, 90. sello, 91. hulivili, 92. tossu, 93. paperi, 94. nappi, 95. kasa, 96. karikkoinen, 97. tonttu, 98. akka, 99. koppi, 100. palapeli, 101. kelo, 102. pupu, 103. kellertävä, 104. tulli, 105. peto, 106. pankki, 107. setä, 108. idea, 109. katalysaattori, 110. nootti, 111. sukka, 112. halveksunta, 113. tuli, 114. taakka, 115. kaasu, 116. koi, 117. mummu, 118. rikas, 119. kapakala, 120. kyky, 121. penkki, 122. räjäyttää, 123. tuonnempana, 124. merkki, 125. ahdas, 126. kirkko, 127. punssi, 128. norsu, 129. tylsä, 130. takka, 131. varsi, 132. sääli, 133. lelupaikka, 134. syylä, 135. mamma, 136. nunna, 137. kansi, 138. kattila, 139. känsä, 140. pulssi, 141. kissankello, 142. sirppi, 143. kotitonttu, 144. hylsy, 145. korppu, 146. jälkeenpäin, 147. helppo, 148. lottovoitto, 149. saa, 150. kehystämätön, 151. kakkulapio, 152. soopa, 153. avaa, 154. myy, 155. tölkki, 156. antaa, 157. vääryys, 158. no, 159. käki, 160. kateketiikka, 161. kämppä, 162. kiva, 163. valssi, 164. kaato, 165. kuuma, 166. käpy, 167. tilli, 168. painotella, 169. tippa, 170. linna, 171. varmaan, 172. paalu, 173. kyllä, 174. roiskuu, 175. kaappi, 176. sivullinen, 177. suunta, 178. taivutteleminen, 179. luuttu, 180. puukko, 181. taka, 182. pyhyys, 183. ei, 184. takistoskooppi, 185. tokeni, 186. tapa, 187. kassa, 188. kahlitsematon, 189. käännä, 190. sokerikakku, 191. lääke, 192. kuulee, 193. valheellisuus, 194. pääsi, 195. mukaan, 196. sääski, 197. letaliteetti, 198. sokeri,

199. armahtaa, 200. raaka, 201. pässi, 202. kääpä, 203. maistuu, 204. luu, 205. kortti, 206. talopula, 207. tänään, 208. pika, 209. portti, 210. tervehtii, 211. teltta, 212. pituisyytti, 213. kiltti, 214. ehkä, 215. kurki, 216. pulssi, 217. soma, 218. kelkka, 219. lyö, 220. tyyli, 221. kyyti, 222. kuu, 223. lokero, 224. käsi, 225. suo, 226. nätti, 227. kapula, 228. lohkesi, 229. spektroskooppi, 230. rusetti, 231. kärki, 232. joo, 233. solki, 234. painostava, 235. halko, 236. leksikostatistiikka, 237. sanka, 238. vie, 239. lanka, 240. tina, 241. piika, 242. roposi, 243. ranta, 244. syli, 245. lipesi, 246. proktoskooppi, 247. sentti, 248. vesipeto, 249. käpysi, 250. paasi, 251. kova, 252. kipusi, 253. tyyni, 254. lupasi, 255. piina, 256. keittää, 257. piikki, 258. tiili, 259. pytty, 260. pyssy, 261. kylä, 262. vielä, 263. tornimainen, 264. tyttö, 265. lepäsi, 266. ruma, 267. lanttu, 268. kissa, 269. vapisi, 270. tyyppi

non-words:

1. kysättö, 2. pette, 3. söö, 4. lättö, 5. tekki, 6. unkura, 7. kosu, 8. kaa, 9. pänti, 10. kie, 11. tultta, 12. tinkko, 13. lesirinko, 14. korssa, 15. ömpärö, 16. supa, 17. pelo, 18. lätö, 19. tyke, 20. lee, 21. salkuturo, 22. mintti, 23. lopa, 24. soltta, 25. reli, 26. losakkema, 27. juppa, 28. venttu 29. roppe, 30. puttavaakko, 31. outakouro, 32. timmo, 33. sorni, 34. nelka, 35. tiluki, 36. sepula, 37. kössä, 38. lapuka, 39. liu, 40. nerikutto, 41. tanku, 42. korsa, 43. lunti, 44. tyy, 45. lae, 46. posura, 47. turipekko, 48. minte

syllables:

le, ko, pä, su, si, pi, la, tö, ky, to

(v) naming

The complete set of materials can be obtained from Laine (1985).

1. sänky, 2. kello, 3. kirja, 4. talo, 5. kitara, 6. sakset, 7. kampa, 8. kukka, 9. saha, 10. hammasharja, 11. helikopteri, 12. harja, 13. mustekala, 14. sieni, 15. pyykkipoika, 16. kainalosauvat, 17. kameli, 18. naamari, 19. rinkeli, 20. penkki, 21. maila, 22. etana, 23. tulivuori, 24. katiska, 25. tikka, 26. kanootti, 27. majakka, 28. seppele, 29. majava, 30. huuliharppu, 31. sarvikuono, 32. käpy, 33. kota, 34. puujalat, 35. saranat, 36. kaktus, 37. sukellusvene, 38. harppu, 39. kiuas, 40. länget, 41. pelikaani, 42. stetoskooppi, 43. viulu, 44. kuonokoppa, 45. helmitaulu, 46. kaulin, 47. pyramidi, 48. rusetti, 49. maissi, 50. harppi, 51. merihevonen, 52. mikrofoni, 53. turbaani, 54. pingviini, 55. sfinksi, 56. dominot, 57. amppeli, 58. paletti, 59. sarkofagi, 60. yksisarvinen

(vi) picture description

1. park scene (Hänninen et al., 1987)
2. series of six pictures (Paradis, 1987)

Appendix 2

Finnish Phonology

Finnish has eight vowel phonemes and thirteen consonant phonemes. The vowel phonemes are /i y u e ö o ä a/, and the consonant phonemes are /p t k d s h v j l r m n ŋ/. There is a phonemic length opposition for both vowels and consonants (except for /d v j h/ that are always short). Main stress is on the first syllable.

There are sixteen diphthongs in Finnish: /ei äi ui ai oi öi yi au ou eu iu äy öy ie yö uo/. Other vowel combinations also occur, but they always have a syllable boundary between the vowels. Due to vowel harmony, only either front or back vowels can occur in one word. Vowels /i/ and /e/ are neutral, and they can occur with both front (y ö ä) and back (u o a) vowels.

All single consonants except for /d/ and /ŋ/ can occur word-initially. In native Finnish words, /d/ is the "weak" variant of /t/ under consonant gradation. However, there are loan words where /d/ occurs even word-initially. Some speakers may substitute /t/ for /d/. The distribution of the velar nasal is restricted: the nasal occurs only word-medially before a velar stop. The weak variant of this cluster (under consonant gradation) is a long velar nasal. There are minimal pairs such as /kannas/ - /kaŋŋas/. It is commonplace to say that there are consonant clusters neither word-initially nor word-finally. However, such clusters may occur in loan words, but some speakers may simplify the clusters.

There are approximately 57 clusters of two consonants that occur between the vowels of first and second syllables (c.f. Karlsson, 1982: 118). Also some clusters of three consonants occur between the first and second syllables, all being of the type "resonant + obstruent + obstruent". In loan words, the clusters of three consonants are more varied than in native Finnish words, and even more complex consonant clusters (of four consonants) can occur word-medially.

The syllabic structure of Finnish words is systematic. There is a syllable boundary between each CV-unit (and also between vowel combinations). There are 10 different syllable types: V, CV, VC, CVC, VV, CVV, VVC, CVVC, VCC, CVCC.

A typical Finnish word is bisyllabic. For example, if a CVC-word is borrowed into Finnish, an /i/ is added word-finally, which renders the word bisyllabic. The number of monosyllabic words is small. Trisyllabic and four-syllabic words are common, especially in running text where words are inflected.

This appendix was based on information provided by Karlsson (1982).

Appendix 3

Word-Picture Matching

Analysis of Variance (19 x 3 x 3 x 2)

Variables:
subject (subj, s): there were fourteen aphasic patients and five control subjects; Subject 4's data was not included in the analysis because only a part of the test was presented to him
item (i): number of simultaneously presented items (1, 2, or 3)
relation (rel, r): there were three types of items - unrelated, phonologically and semantically related
part of speech (part, p): the items were nouns and verbs

Because of the high number of variables, all interactions could not be analyzed.

source of variation	degrees of freedom	SSE	f-value	P-value
main effects				
subject	18	6.734	9.06	0.0001
item	2	0.553	6.69	0.0013
relation	2	1.836	22.22	0.0001
part of speech	1	0.668	16.18	0.0001
interactions				
subj x item	36	2.031	1.37	0.0753
subj x rel	36	4.648	3.12	0.0001
subj x part	18	2.197	2.95	0.0001
item x rel	4	0.208	1.26	0.2850
item x part	2	0.095	1.15	0.3155
part x rel	2	0.240	2.91	0.0549
s x i x r	-			
s x i x p	-			
s x r x p	-			
i x r x p	4	0.429	2.60	0.0349
s x i x r x p	-			

Appendix 4

Proportion of Correct Answers in Word-Picture Matching

Comparison of unrelated (unrel), phonologically related (phon rel), and semantically related (sem rel) nouns and verbs

	nouns			verbs		
subject	unrel	phon rel	sem rel	unrel	phon rel	sem rel
1	0.90	0.65	0.90	1.00	0.88	1.00
2	1.00	0.97	1.00	0.90	0.95	0.85
3	1.00	1.00	1.00	0.97	0.95	0.75
4	0.97	0.86	1.00	0.33	0.67	-
5	1.00	0.87	1.00	1.00	0.45	0.75
6	1.00	0.77	0.85	0.92	0.57	0.60
7	1.00	1.00	0.87	1.00	0.92	0.88
8	1.00	1.00	1.00	1.00	1.00	1.00
9	0.90	0.92	0.62	1.00	0.87	0.62
10	1.00	0.72	0.82	0.93	0.68	0.67
11	0.92	0.70	0.90	0.88	0.78	0.37
12	1.00	0.87	0.97	0.97	0.80	0.97
13	1.00	0.97	0.93	0.92	0.92	0.58
14	0.95	0.83	0.87	0.77	0.85	0.85
15	1.00	0.97	0.80	1.00	0.87	0.90
16	1.00	1.00	1.00	1.00	1.00	1.00
17	1.00	0.97	1.00	1.00	1.00	1.00
18	0.95	0.96	1.00	1.00	1.00	1.00
19	1.00	0.92	0.97	0.97	1.00	1.00
20	1.00	1.00	1.00	1.00	1.00	1.00

Comparison of nouns and verbs when the test items were presented one, two, and three items at a time

	nouns			verbs		
subject	1	2	3	1	2	3
1	0.90	0.75	0.80	1.00	0.95	0.93
2	1.00	1.00	0.97	0.90	0.90	0.90
3	1.00	1.00	1.00	0.90	0.90	0.87
4	1.00	0.90	0.89	-	-	0.50
5	1.00	0.90	0.97	0.60	0.80	0.80
6	0.90	0.85	0.87	0.80	0.75	0.53
7	1.00	0.90	0.97	1.00	0.90	0.90
8	1.00	1.00	1.00	1.00	1.00	1.00
9	0.80	0.80	0.83	0.80	0.85	0.84
10	0.90	0.90	0.73	0.80	0.85	0.63
11	1.00	0.75	0.77	0.80	0.70	0.53
12	0.90	1.00	0.93	0.90	1.00	0.83
13	1.00	1.00	0.90	0.90	0.75	0.77
14	1.00	0.85	0.80	0.80	0.90	0.77
15	1.00	1.00	0.77	1.00	1.00	0.77
16	1.00	1.00	1.00	1.00	1.00	1.00
17	1.00	1.00	0.97	1.00	1.00	1.00
18	1.00	0.95	0.96	1.00	1.00	1.00
19	1.00	0.94	0.93	1.00	1.00	0.97
20	1.00	1.00	1.00	1.00	1.00	1.00

Appendix 5

Sub-Samples of Words in the Repetition and Naming Tests

The numbers refer to the words that are listed in appendix (1).

Sub-samples of the words in the repetition test:

10 trisyllabic words (total 10):
12, 24, 48, 61, 93, 138, 198, 223, 227, 230

10 monosyllabic words (total 10):
16, 65, 72, 116, 149, 154, 204, 222, 225, 238

acoustically analyzed words: (total 103)
6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 22, 23, 25, 26, 28, 30, 32, 34, 38, 40, 41, 42, 43, 44, 45, 57, 60, 66, 69, 70, 71, 75, 76, 77, 80, 82, 84, 87, 89, 90, 92, 94, 95, 97, 99, 101, 102, 104, 105, 107, 110, 111, 113, 114, 115, 120, 130, 132, 134, 136, 140, 152, 159, 164, 166, 167, 169, 170, 172, 173, 175, 179, 180, 181, 186, 187, 189, 191, 194, 196, 201, 202, 208, 220, 221, 224, 226, 240, 241, 244, 250, 253, 255, 257, 258, 259, 260, 261, 264, 268, 270

derivations: (total 15)
8, 21, 74, 96, 103, 112, 123, 150, 168, 176, 178, 188, 193, 234, 263

compounds: (total 16)
29, 39, 46, 64, 81, 91, 100, 119, 133, 141, 143, 148, 151, 190, 206, 248

bisyllabic words without consonant clusters: (total 84)
10, 11, 13, 14, 15, 17, 19, 20, 22, 26, 28, 30, 38, 43, 44, 45, 50, 57, 69, 70, 71, 84, 89, 90, 92, 94, 95, 101, 104, 105, 107, 110, 111, 113, 114, 115, 120, 130, 132, 134, 136, 159, 162, 164, 165, 166, 167, 169, 170,172, 173, 175, 179, 180, 181, 186, 187, 189, 191, 200, 201, 202, 208, 217, 220, 221, 224, 226, 240, 241, 244, 250, 251, 253, 255, 257, 258, 259, 260, 261, 264, 266, 268, 270

bisyllabic words with a consonant cluster: (total 51)
5, 27, 31, 35, 37, 40, 47, 49, 51, 52, 54, 56, 59, 60, 62, 73, 85, 97, 99, 106, 121, 124, 126, 127, 128, 129, 131, 137, 139, 140, 142, 144, 145, 147, 155, 163, 196, 205, 209, 211, 213, 215, 218, 231, 233, 235, 237, 239, 243, 247, 267

Sub-samples of the words in the naming test

short: 1, 2, 3, 4, 7, 8, 9, 14, 20, 21, 22, 25, 32, 33, 38, 43, 49, 50

trisyllabic: 5, 17, 19, 24, 26, 27, 28, 29, 35, 48, 57, 58

compound: 10, 11, 13, 15, 16, 23, 30, 31, 34, 37, 44, 45, 51

Appendix 6

Words in the Rating Experiment

The words are listed in the order they were presented to the listeners. For incorrect items, a transcription of the subject's production is provided. In connection with the tests, "(w)" refers to the repetition of existing words, and "(n)" to the repetition of non-words.

subj	target	transcription (for incorrect items)	test
TAPE 1			
5	viulu		naming
17	sieni		naming
17	katiska		naming
14	kukka		naming
17	mäkihyppy		repetition (w)
4	tonttu		repetition (w)
5	matala	patala	repetition (w)
13	kuttu		repetition (n)
9	lunti		repetition (n)
5	saha	saaha	naming
17	känsä		repetition (w)
14	maila	mbaila	naming
4	kampa	kamppu	naming
4	kello		naming
6	hylsy	hyysy	repetition (w)
5	pöllö		repetition (w)
11	papupata	katukaa	repetition (w)
12	outakouro	outakouru	repetition (n)
13	sokeri		repetition (w)
4	peli		naming
16	harppu		naming
12	losakkema	losakkemo	repetition (n)
9	etana	etena	naming
11	kesäkeli	kesikelä	repetition (w)
13	kattila		repetition (w)
6	lintu	tintu	naming
9	amppeli	ampperi	naming
16	majakka		naming
9	pöytä		naming
12	kameli		naming
11	lööperi		repetition (w)
12	kahlitsematon	(hesitantly)	repetition (w)
5	konna		repetition (w)
14	lätö	vätö	repetition (n)
17	kiuas		naming
4	kirja	kansio	naming
9	seppele		naming
6	mintti		repetition (n)
14	kaa		repetition (n)
11	paperi	kaperi	repetition (w)
6	taakka	kaakka	repetition (w)
12	käpy		naming
4	koti	kuti	repetition (w)
5	lee	ee	repetition (n)
4	penkki	penk-ke	naming
11	pyykkipoika	kyykki-koika	naming
11	kapula		repetition (w)

13	pingviini	balkki/valkki	naming
9	kirja	kirjo	naming
11	peto	tepo	repetition (n)
16	timmo		repetition (n)
9	sänky	tuori	naming
6	sakset		naming
9	nerikutto	nirikutta	repetition (n)
11	tiluki		repetition (n)
16	rinkeli		naming
16	silta		repetition (w)
12	puttavaakko		repetition (n)
6	rinkeli	pakkara	naming
17	majava		naming
5	kotelo	ka-otelo	repetition (w)
14	piirturi		naming
4	hammasharja	hampa	naming
16	nappi		repetition (w)
13	luuta	ruuta	repetition (w)
12	tossu	tossi	repetition (w)
16	luuttu		repetition (w)
9	tylsä	kylsä	repetition (w)
17	solki		repetition (w)
13	kylpy		repetition (w)
14	korpi		repetition (w)
13	sepula		repetition (n)
12	turipekko	puritekko	repetition (n)
14	kampa	sampa	naming
16	korsa		repetition (n)
17	mikrofoni		naming
17	nelka		repetition (n)
16	kampa		naming
4	kämppä	kämppe	repetition (w)
6	juppa		repetition (n)
9	talo		naming
14	portti		repetition (w)
13	valssi		repetition (w)
6	länget	lännet	naming
4	kosu	kusu	repetition (n)
6	neekeri		repetition (w)
12	lesirinko		repetition (n)
14	korssa		repetition (n)
13	mustekala		naming
6	puukko		repetition (w)
11	pankki	kamppi	repetition (w)
13	puujalat	koivu	naming
5	etana	banaani	naming
12	kyky	pypy	repetition (w)
16	tultta		repetition (n)
5	kitara	kitala	naming
14	sänky		naming
5	rusetti	susetti	repetition (w)
11	seppele	keneve	naming
17	lokero		repetition (w)

TAPE 2

9	stetoskooppi	lääkäri	naming
14	sänky	käntky	naming
14	kampa		naming

11	sakset		naming
9	parta		repetition (w)
16	kakkulapio		repetition (w)
13	kainalosauvat	sääne	naming
17	unkura	onkura/unkura	repetition (n)
14	viulu	?vivulu	naming
12	kuonokoppa	konope	naming
6	lopa	ootta	repetition (n)
9	tanku		repetition (n)
13	helikopteri	rapula	naming
16	mustekala		naming
13	luulo	luuo	repetition (w)
12	tönö		repetition (w)
11	kämppä		repetition (w)
12	kanootti	kanea	naming
17	vesipeto		repetition (w)
5	tonni	tolli	repetition (w)
11	majakka	vanakka	naming
17	sokeri		repetition (w)
4	seppele		naming
11	kukko	kunkko	repetition (w)
13	etana		naming
5	tinkko		repetition (n)
13	tekki		repetition (n)
4	tikka	tikki	naming
14	majava	paparba	naming
6	palapeli		repetition (w)
14	lee	nee	repetition (n)
4	merkki	mirkka	repetition (w)
6	kapula	apula	repetition (w)
5	kissankello		repetition (w)
16	pässi		repetition (w)
16	lätö		repetition (n)
12	rusetti		repetition (w)
12	tulivuori	puli	naming
12	talo		naming
16	nunna		repetition (w)
6	sepula	vipula/pipula	repetition (n)
9	kattila		repetition (w)
4	harja	vaasi	naming
17	sokerikakku		repetition (w)
9	minte	linte	repetition (n)
11	kanootti		naming
4	papupata	papaput	repetition (w)
5	paperi	kaperi	repetition (w)
12	sekularisaatio	sikulii	repetition (w)
12	paasi		repetition (w)
17	tikka		naming
17	roppe		repetition (n)
4	luuttu		repetition (w)
6	mäkihyppy	mäpihytty	repetition (w)
14	kitara	kirtala	naming
11	lapuka	sapula	repetition (n)
14	pette		repetition (n)
11	kampa	kaska	naming
13	tiluki		repetition (n)
6	saha	pistosaha	naming
16	kotelo		repetition (w)
13	losakkerna		repetition (n)

12	majava		naming
13	helmitaulu	herni	naming
5	tyke	tuke	repetition (n)
6	solki		repetition (w)
5	tervehtii		repetition (w)
17	sarana		naming
14	kello		naming
17	harppi		naming
5	hulivili		repetition (w)
11	merihevonen	kurvi	naming
9	kameli	kameri	naming
6	venttu	enttu	repetition (n)
13	kota	teltta	naming
5	penkki		naming
13	kärki		repetition (w)
16	kaulin		naming
9	harja		naming
16	korppu		repetition (w)
4	kurssi		repetition (w)
11	katiska		naming
5	kaasu		repetition (w)
6	norsu		repetition (w)
16	nerikutto	nerikuttu	repetition (n)
4	soltta	soltto	repetition (n)
4	kapakala		repetition (w)
14	sorni	sonrri	repetition (n)
17	kelkka		repetition (w)
16	neekeri		repetition (w)
4	kukka	kukkare	naming
9	korssa		repetition (n)
17	valheellisuus		repetition (w)
12	ömpärö	ympärö	repetition (n)
5	neekeri	keekeri	repetition (w)
9	kota	.	naming
11	naamari	kaamari	naming
6	etana	siili	naming
14	lanka		repetition (w)
9	pyykkipoika		naming

TAPE 3

11	kotelo		repetition (w)
13	unkura		repetition (n)
11	puujalat	kole	naming
12	valheellisuus		repetition (w)
17	tinkko		repetition (n)
12	etana	etena	naming
16	papupata		repetition (w)
14	silta	kilta	repetition (w)
6	sänky	länky	naming
12	maila	maola	naming
6	kasa	aza	repetition (w)
12	posura		repetition (n)
9	takka	tagga	repetition (w)
13	tapa		repetition (w)
16	kameli		naming
5	seppele		naming
11	lätö	vätö	repetition (n)
16	kissa		repetition (w)

5	kie	jie	repetition (n)
17	rusetti		naming
17	ranta		repetition (w)
13	kelkka	kilkka/kelkka	repetition (w)
13	katiska		naming
16	sokeri		repetition (w)
12	leksikostatistiikka	leksostoo	repetition (w)
4	kainalosauvat	kauneus	naming
11	lunti		repetition (n)
14	majava	irli	naming
14	tonttu		repetition (w)
13	sivullinen		repetition (w)
4	suunta		repetition (w)
5	limppu		repetition (w)
16	kesäkeli		repetition (w)
4	rinkeli	pullaus	naming
14	kukka	sukka	repetition (w)
6	penkki		naming
9	kello		naming
5	sieni		naming
16	mintti		repetition (n)
4	sänky		naming
14	minte		repetition (n)
16	hulivili		repetition (w)
4	sälpä	selvi	repetition (w)
14	kyyti		repetition (w)
5	amppeli	eline	naming
17	länget		naming
14	merkki	pikki	repetition (w)
16	sakset		naming
13	hylsy		repetition (w)
11	talo		naming
17	kampa		naming
6	kääpä	ääpä/pääpä	repetition (w)
11	parta		repetition (w)
6	lokero	okeero	repetition (w)
17	neekeri		repetition (w)
13	saha	sahrat	naming
9	käsi	täsi/käsi	repetition (w)
14	kukko		repetition (w)
4	pelo		repetition (n)
17	kosu		repetition (n)
12	maissi		naming
11	sarana	sanara	naming
13	harppu		naming
6	pyssy		repetition (w)
12	merihevonen	merohi	naming
17	käpy		naming
9	turipekko		repetition (n)
16	kattila		repetition (w)
6	tulivuori	tuhtu/tuste	naming
5	kämppä	kemppä	repetition (w)
6	papupata	makupata	repetition (w)
14	tanssi	tassi	repetition (w)
11	sorni		repetition (n)
12	kainalosauvat	kaima	naming
9	rinkeli		naming
4	rumpu		repetition (w)
11	köli		repetition (w)

9	kirkko		repetition (w)
4	tultta	tuutto	repetition (n)
5	kota	pora	naming
13	peto	veto/peto	repetition (w)
13	pyhyys	hyhyys/pyhyys	repetition (w)
12	kitara		naming
6	salkuturo	kalkutulo	repetition (n)
6	kota	teltta	naming
9	lapuka		repetition (n)
9	tuli		repetition (w)
11	korssa		repetition (n)
4	timmo		repetition (n)
17	mökki		repetition (w)
16	sepula		repetition (n)
14	tunne	kunne	repetition (w)
12	palapeli		repetition (w)
17	paperi		repetition (w)
9	kanootti	etelä	naming
5	majava	hajala	naming
5	harppi	ruiku	naming
9	pänti	känti	repetition (n)
4	voitto	vouttu	repetition (w)
5	majakka	adema	naming

TAPE 4

13	kameli		naming
16	kitara		naming
13	valheellisuus		repetition (w)
12	pöönä	föönö	repetition (w)
16	pelo		repetition (n)
14	mintti		repetition (n)
4	käki		repetition (w)
17	kirja		naming
6	paperi	parperi	repetition (w)
13	länget	huhmari	naming
4	tanku		repetition (n)
11	tinkko	kinkko	repetition (n)
14	sieni	tsieni	naming
13	tippa		repetition (w)
17	saha		naming
6	sokeri		repetition (w)
9	tiili		repetition (w)
11	neekeri	keeteli	repetition (w)
6	lesirinko		repetition (n)
5	hevonen		naming
4	parta	parba	repetition (w)
6	kukka		naming
14	kanootti	katetti	naming
9	penkki	puura	naming
14	käpy		naming
16	harppi		naming
12	papupata	papupatpa	repetition (w)
12	mikki		naming
4	kainalosauvat	kankkius	naming
17	kotikolo		repetition (w)
12	sepula	sipula	repetition (n)
14	pulssi		repetition (w)
16	viulu		naming

11	piikki	kiippi	repetition (w)
16	kissankello		repetition (w)
6	maissi	bamaani	naming
5	kattila		repetition (w)
17	amppeli		naming
12	tapa		repetition (w)
4	kilpi		repetition (w)
9	kesäkeli		repetition (w)
5	etana		naming
4	pullo		naming
5	kurssi	kursti	repetition (w)
4	konna	kuuni	repetition (w)
13	kameli	kirahva	naming
16	kello		naming
14	seppele		naming
11	pänti	känti	repetition (n)
11	kirja	käsi	naming
5	tossu	lussu	repetition (w)
14	limppu	mippu	repetition (w)
14	reli	serli/sirli	repetition (n)
16	sarana		naming
11	kota	koppelo	naming
14	pää		repetition (w)
17	lanttu		repetition (w)
12	nerikutto		repetition (n)
17	maissi		naming
12	syylä		repetition (w)
9	timmo	immo	repetition (n)
5	pensseli	pentteli	naming
9	posura	kosura	repetition (n)
4	harppu	harppoli	naming
13	puttavaakko	uttavaakko	repetition (n)
9	katiska	katitsa	naming
17	lottovoitto		repetition (w)
13	ömpärö	ympärä	repetition (n)
9	kitara	mantori	naming
13	sello		repetition (w)
5	tultta	turtti	repetition (n)
6	kampa	ampa	naming
5	tanssi		repetition (w)
16	sänky		naming
16	turipekko		repetition (n)
5	käpy	äpi	naming
13	majava		naming
4	juppa		repetition (n)
6	talo	jupa	naming
9	sokerikakku	sokerikampku	repetition (w)
17	outakouro	outakouru	repetition (n)
12	kameli	kase	naming
17	kyyti	pyyti	repetition (w)
11	vääryys	kääpy	repetition (w)
17	mustekala		naming
6	rusetti		repetition (w)
5	tekki	tetti	repetition (n)
6	tiluki		repetition (n)
14	tuuli	kuulli	repetition (w)
16	tiili	tilli	repetition (w)
9	talopula		repetition (w)
11	kotitonttu	kotikonkku	repetition (w)

12	katiska	kapi	naming
12	taivutteleminen		repetition (w)
6	kössä	puyssä	repetition (n)
4	talo		naming
9	kaktus	kaksu	naming
13	loota		repetition (w)
11	minte	rinte	repetition (n)
11	tyke		repetition (n)

TAPE 5

11	käpy	säpy	naming
9	kotitonttu		repetition (w)
4	mintti		repetition (n)
6	naamari		naming
12	kallistuminen		repetition (w)
16	köli		repetition (w)
16	kiuas		naming
12	norsu	norsi	repetition (w)
9	sokeri	sokeli	repetition (w)
14	penkki		naming
13	korppu		repetition (w)
6	seppele	eppeles	naming
4	kössä	kyssy	repetition (n)
13	tölkki	kölkki	repetition (w)
4	palapeli	palipelip	repetition (w)
9	mäkihyppy	mäkihyppi	repetition (w)
17	ömpärö		repetition (n)
14	tunne	kunne	repetition (w)
13	dominot	kuuto	naming
12	piikki		repetition (w)
12	amppeli	teline	naming
5	ko		repetition (n)
17	salkuturo		repetition (n)
5	talo	alo	naming
13	helikopteri	rapuli	naming
5	rusetti	suntti	naming
12	unkura		repetition (n)
6	kosu		repetition (n)
9	nappi		repetition (w)
12	kanootti	kanade	naming
12	harppi		naming
11	tonni		repetition (w)
17	tina		repetition (w)
14	tikka	kikka	naming
14	etana		naming
4	saha		naming
12	kyy	pyy	repetition (w)
16	paletti		naming
16	majava	piisami	naming
6	kattila		repetition (w)
16	nuoli		naming
5	pänti		repetition (n)
16	kortti		repetition (w)
4	sorni	sorli	repetition (n)
14	lintu	kintu	repetition (w)
6	kameli	kameeli	naming
16	juppa		repetition (n)
9	merkki	mertti	repetition (w)

5	kampa	sampa	naming
17	kitara		naming
13	tinkko		repetition (n)
13	sanka		repetition (w)
16	paperi		repetition (w)
9	papupata		repetition (w)
17	majakka		naming
11	kanootti	kana	naming
9	hulivili	kuivili	repetition (w)
11	kurssi		repetition (w)
6	kaulin	käälin	naming
6	sälpä	pänpä	repetition (w)
14	tultta	tutta	repetition (n)
6	helikopteri	keppi	naming
13	kuonokoppa	patula	naming
9	sänky	sänty	naming
11	kukka		naming
9	luulo	luuno	repetition (w)
11	kuonokoppa		naming
11	lottovoitto		repetition (w)
5	süpa		repetition (n)
14	pöllö	pömppö	repetition (w)
14	luuta	kuusta	repetition (w)
5	kasa	kada	repetition (w)
5	kesäkeli	kesä-keli	repetition (w)
17	pelo		repetition (n)
4	liina	liima	repetition (w)
17	rinkeli		naming
13	viulu		naming
12	sarana		naming
14	kärki		repetition (w)
4	mökki		repetition (w)
11	kotikolo		repetition (w)
4	sakset	sakolo	naming
6	sieni		naming
11	maila	laima	naming
14	kota	tota	naming
13	venttu	penttu	repetition (n)
13	naamari	lammas	naming
6	tapa		repetition (w)
4	mustekala	lonko	naming
17	halko		repetition (w)
12	kotelo		repetition (w)
16	mikrofoni		naming
17	tuuli		repetition (w)
11	rinkeli	kihveli	naming
5	kirja		naming
16	naamio		naming
17	soltta		repetition (n)
9	kapakala	napakala	repetition (w)
5	söö		repetition (n)
4	neekeri		repetition (w)

Appendix 7

The Answer Sheet Used in the Rating Experiment

KUUNTELUKOE

Kuulet nauhalta sanoja ja epäsanoja. Jokainen niistä toistetaan kaksi kertaa. Tämän jälkeen on 9 sekunnin mittainen tauko, jonka aikana sinun pitäisi kirjoittaa viivalle, mitä kuulit. Käytä suomen ortografiaa. Älä kiinnitä huomiota sanan mahdolliseen merkitykseen, vaan kuuntele tarkkaan ja kirjoita täsmälleen, mitä kuulit. Jos et saa selvää, arvaa! Älä jätä vastaamatta. Merkitse myös arviosi siitä, miten sana oli äännetty, rengastamalla jokin numeroista 1 - 5. 1 tarkoittaa normaalilta kuulostavaa ääntämystä, 5 erittäin oudolta kuulostavaa ääntämystä. Aluksi on muutamia harjoitussanoja. Niiden jälkeen pidämme pienen tauon, jonka aikana sinulla on vielä mahdollisuus tehdä kysymyksiä tehtävästä.

Koehenkilöiden ääntämisen arviointi:
1: normaali ääntämys
2: melko normaali ääntämys
3: vähän poikkeava ääntämys
4: selvästi poikkeava ääntämys
5: erittäin outo ääntämys

THE RATING EXPERIMENT

You are going to hear words and non-words. Each of them will be repeated twice. After each item there will be a 9 second pause during which you should write down what you have heard. Use the Finnish orthography. Don't pay attention to the possible meaning of the item, but write down exactly what you hear. If you are not sure, make a guess! Don't leave blanks! You should also rate how the word was articulated by circling one of the numbers. 1 is used for an articulation that sounds completely normal, 5 for an articulation that sounds extremely strange. At first there will be some practice items. After them we'll make a short pause during which you can still ask if something has remained unclear.

Key:
1: normal articulation
2: relatively normal articulation
3: somewhat abnormal articulation
4: clearly abnormal articulation
5: very awkward articulation

1. ________________	1	2	3	4	5
2. ________________	1	2	3	4	5
3. ________________	1	2	3	4	5
4. ________________	1	2	3	4	5
5. ________________	1	2	3	4	5
6. ________________	1	2	3	4	5
7. ________________	1	2	3	4	5
8. ________________	1	2	3	4	5
9. ________________	1	2	3	4	5
10. ________________	1	2	3	4	5

Appendix 8

Rating Experiment

Analysis of Variance (10 x 3 x 2)

Variables:
subject (subj, s): eight aphasics and two controls
test (t): naming, repetition of words and non-words
correctness (corr, c): correct vs. incorrect responses

1. Relative entropy of the transcriptions

source of variation	degrees of freedom	SSE	f-value	P-value
main effects				
subject	9	4.475	11.02	0.0001
test	2	0.627	6.95	0.0011
correctness	1	0.579	12.84	0.0004
interactions				
subj x test	18	0.738	0.91	0.5675
subj x corr	9	0.355	0.88	0.5475
test x corr	2	0.193	2.14	0.1184
s x t x c	16	0.715	0.99	0.4663

2. Means of the medians

There is no way of doing multivariate analysis for medians. However, for the present purposes, this rule was violated, and the analysis was performed. This means that the results are statistically unreliable.

source of variation	degrees of freedom	SSE	f-value	P-value
main effects				
subject	9	142.866	32.03	0.0
test	2	7.476	7.54	0.0006
correctness	1	4.020	8.11	0.0046
interactions				
subj x test	18	19.029	2.13	0.0045
subj x corr	9	1.672	0.37	0.9469
test x corr	2	1.954	1.97	0.1406
s x t x c	16	9.544	1.20	0.2613

Appendix 9

Means for Formant Frequencies (Hz)

(The analysis was based on completely correct answers.)

subject		1	2	4	6	8	9	10	11	12	14	15	16	18	19	20
a	F1	684	598	699	697	657	585	693	711	702	675	585	675	675	675	733
	F2	1373	1306	1362	1315	1301	1324	1378	1360	1463	1198	1391	1391	1328	1306	1355
	F3	2315	2445	2366	2346	2324	2441	2409	2405	2346	2684	2643	2607	2450	2360	2261
aa	F1	702	639	716	711	634	697	603	720	702	697	598	720	630	607	738
	F2	1275	1261	1215	1274	1202	1193	1157	1265	1337	1153	1198	1256	1270	1171	1319
	F3	2567	2675	2490	2477	2418	2328	2454	2459	2292	2517	2454	2670	2463	2432	2337
e	F1	486	513	489	490	472	436	499	486	468	535	445	486	486	472	454
	F2	1760	1941	1784	1742	1765	1990	1936	1907	1999	2085	1760	2099	1706	1878	2004
	F3	2576	2526	2585	2400	2522	2625	2639	2583	2544	2612	2580	2805	2567	2576	2787
ee	F1	517	504	450	520	468	418	468	445	445	469	450	432	468	477	454
	F2	1896	2126	2036	1932	2157	2121	2099	2153	2157	2086	1954	2333	1904	1945	2090
	F3	2846	2567	2819	2526	2688	2729	2679	2657	2738	2637	2706	2991	2558	2603	2733
i	F1	364	324	346	360	333	297	346	333	337	337	306	333	324	351	324
	F2	2148	2225	2193	2049	2315	2261	2432	2279	2261	2297	2175	2549	2117	2351	2288
	F3	2824	2598	2954	2594	2968	2747	2837	2850	2783	2806	2824	3198	2598	2869	2850
ii	F1	337	283	333	356	324	310	274	337	324	292	301	315	292	337	324
	F2	2229	2450	2332	2097	2301	2243	2513	2382	2315	2416	2288	2594	2270	2319	2373
	F3	2945	2972	3084	2918	2972	2909	2932	2855	3054	2897	2977	3148	2837	2733	2927
o	F1	570	493	520	513	516	486	483	530	493	510	476	520	493	523	472
	F2	1145	1000	1027	1135	1023	1060	1003	948	989	976	996	999	1071	1040	894
	F3	2358	2489	2526	2391	2408	2398	2408	2300	2199	2479	2486	2533	2503	2445	2439
oo	F1	517	477	512	495	540	459	491	508	508	491	463	468	477	508	468
	F2	1044	900	1020	1072	954	945	907	877	923	842	1013	774	1008	918	877
	F3	2364	2661	2604	2445	2459	2423	2394	2337	2319	2518	2495	2513	2508	2472	2387
u	F1	453	435	406	424	405	423	417	405	405	423	396	405	390	393	393
	F2	990	860	762	978	855	945	780	822	789	792	858	732	891	840	759
	F3	2378	2617	2590	2435	2429	2435	2603	2435	2435	2327	2444	2603	2459	2534	2471
uu	F1	375	385	378	440	381	390	364	388	378	364	348	378	385	371	368
	F2	732	709	681	918	763	802	688	736	732	685	754	675	820	816	661
	F3	2432	2668	2611	2486	2557	2636	2685	2516	2510	2661	2408	2553	2472	2513	2483
y	F1	351	358	354	343	332	320	382	359	351	351	328	347	309	355	347
	F2	1660	1725	1719	1826	1868	1752	1837	1602	1945	1616	1907	1988	1683	1528	1896
	F3	2293	2397	2379	2409	2374	2285	2482	2355	2393	2369	2567	2579	2390	2470	2343
yy	F1	337	333	349	391	333	310	346	310	328	324	310	310	306	333	333
	F2	1684	1778	1836	1742	1972	1871	1832	1662	1968	1621	1738	2076	1756	1716	1846
	F3	2369	2414	2394	2319	2333	2277	2405	2346	2351	2443	2328	2603	2391	2531	2337
ä	F1	667	624	612	629	698	640	636	671	652	617	616	663	586	633	675
	F2	1683	1721	1819	1721	1748	1725	1795	1744	1737	1783	1756	1938	1690	1609	1771
	F3	2644	2482	2634	2366	2451	2532	2486	2540	2474	2548	2711	2733	2471	2486	2563
ää	F1	675	607	648	675	648	643	490	688	643	702	535	702	603	594	643
	F2	1630	1747	1736	1707	1729	1616	1778	1720	1765	1648	1756	1941	1679	1634	1756
	F3	2585	2603	2639	2421	2409	2504	2535	2580	2522	2653	2814	2706	2513	2517	2639
ö	F1	499	502	524	495	468	448	454	472	486	459	495	468	468	486	472
	F2	1657	1658	1680	1603	1675	1610	1819	1607	1733	1659	1549	1814	1531	1603	1670
	F3	2369	2388	2362	2274	2355	2437	2517	2369	2292	2394	2490	2684	2481	2459	2387
öö	F1	486	459	432	508	459	425	454	475	454	472	418	463	468	472	448
	F2	1589	1691	1765	1630	1702	1722	1819	1621	1832	1648	1607	1913	1639	1666	1696
	F3	2373	2405	2432	2324	2400	2439	2517	2394	2373	2540	2432	2715	2445	2454	2464

Appendix 10

Vowel Errors in the Acoustically Analyzed Data

The patients'answers were numbered when the model was given more than once. Thus, (1) refers to the answer given after the first model, (2) refers to the answer given after the second model, etc. If the answer was difficult to transcribe the alternative transciptions are indicated by "/". "?" refers to a glottal closure.

subject	target	answer
1.	köökki	kyökki olikos se näin
	paalu	poalu
2.	teema	tiina
	köli	kyli / köli
	teesi	tiisi / teesi
	seestyy	sinisty
	lööperi	hyöperi
	pupu	kepu
4.	pöönä	1) py 2) pyynä
	köökki	kyykki
	konna	kuuni / kunni
	kukko	kok?i
	koti	kuti
	tööttää	tyytti / tyytte
	tuttu	tuu-ti tu-tu
	kello	kil?o
	koko	ku kul kuku
	köli	kölit / kylit
	seepra	tii siipra
	teesi	tiisen (neutral vowel in the 2nd syllable)
	seestyy	siisti
	koppi	1) kup eiku kop 2) kuppi
	pupu	popu
	nätti	1) nättä / nättää 2) nittii
6.	teesi	iesi
	suunta	iynta
	seestyy	iistyy
	tossu	oossu
	koppi	poippi
	käännä	kaännä
	tilli	illi / iini
9.	teettää	tiittä / tiittää
	köökki	kyökki
	teema	tiima
	neekeri	niekeri
	tööttää	työttää
	pyykki	pyökki / pyykki
	seepra	siep-ra
	suunta	sunta / suunta
	kissa	ssa
	tyyppi	kylp-pi
10.	loota	luota
11.	töölö	töölö / työlö
	keppi	teeppi
14.	teettää	hirttää / irttää
	pöönä	pyömä
	köökki	luukki (dark l)
	soolo	too mm suolo
	söötti	tytti / tötti / töötti
	köli	kölli / kolli
	lööperi	looperli
	kyky	kuku / kyky
	käännä	kännä
	piikki	pikki / piikki
	tyyppi	typpi
15.	söötti	syötti
	töölö	työlö
20.	köökki	kyykki

Appendix 11

Means for Vowel Durations (ms)

(The analysis was based on completely correct answers.)

subject	1	2	4	6	8	9	10	11	12	14	15	16	18	19	20
a	152	111	234	202	106	88	102	124	116	186	135	103	109	152	122
aa	283	241	546	283	235	227	250	230	271	320	246	273	303	302	302
e	148	96	280	131	93	86	119	86	115	157	114	103	126	151	130
ee	255	177	497	302	226	279	205	205	276	370	213	253	274	260	236
i	177	111	266	163	102	91	107	124	114	141	98	98	124	142	124
ii	253	231	643	290	250	256	208	268	282	317	236	246	301	273	280
o	155	109	232	169	117	82	100	128	116	132	138	111	128	152	117
oo	270	270	483	304	223	201	218	235	273	380	258	281	320	314	291
u	140	116	301	170	112	84	147	128	118	166	113	108	129	152	125
uu	248	224	548	291	228	169	220	202	269	447	235	250	309	275	257
y	115	120	392	154	104	130	108	103	101	143	95	95	108	138	121
yy	235	245	642	309	219	338	232	217	256	305	234	254	286	304	300
ä	142	134	243	165	116	110	128	126	120	137	135	119	139	161	164
ää	293	278	869	292	242	280	234	222	280	322	263	285	294	317	326
ö	152	115	227	184	113	88	107	120	128	147	124	112	126	164	112
öö	261	222	536	296	242	193	202	212	314	297	240	250	276	250	262

Patterns of Phonological Disturbances in Adult Aphasia addresses the questions of abnormal language behavior caused by brain damage. In aphasia, linguistic problems are often accompanied by motor difficulties (speech apraxia, dysarthria), or speech perception problems.

In this study, phonological errors are discussed in relation to the normal language system, and to speech production and perception abilities. Fifteen aphasic subjects and five age-matched normal controls were administered a variety of tests to analyze their phonological production and perception abilities. Each subject's behavior is described in detail, and several types of phonological errors are distinguished. From a theoretical point of view, the results have implications concerning natural phonology and lexical phonology, but they also form a basis for clinical classification.

The book is addressed to linguists and phoneticians, especially to those involved in cognitive and clinical linguistics. It will also be of interest to speech pathologists, to clinical neuropsychologists, and to others concerned with the organization of language in the brain.

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