SOURCES OF ERROR IN THE READING OF DIFFERENT TYPES OF APHASIC PATIENTS

by

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Abstract

SOURCES OF ERROR IN THE READING OF DIFFERENT TYPES OF APHASIC PATIENTS

by

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Twenty aphasic patients were administered 135 monosyllabic words to read. Multiple regression analyses of their reading performance addressed three questions: 1. Which word characteristics influence aphasic reading? 2. Do different word characteristics account for the performance of different types of aphasics (e.g., nonfluent vs. fluent)? 3. Does the performance of individual aphasics reflect the pattern of performance obtained from group data? The patients were grouped by fluency (Nonfluent, Fluent), agrammatism (Agrammatic, Non-Agrammatic) and Diagnostic Category (Broca's, Fluent-Poor Comprehension, Fluent-Good Comprehension) using the Boston Diagnostic Aphasia Examination and other language measures. Thirteen patients with scans were also grouped by site of lesion (Mixed, Posterior) and lesion size (Large, Small). The dependent measure was word score, on a four-point scale designed to reflect phonological proximity to target. Word variables were frequency and related measures (e.g., written, spoken, Heritage frequency), grammatical category, semantic and associative measures (e.g., imageability, ease of association), phonological measures (e.g., word length) and

orthographic measures (e.g., consistency of pronunciation). Subject variables were severity of aphasia, fluency, agrammatism and diagnostic category. With respect to the first question, subject variables, especially severity of aphasia, accounted for most of the variance in the reading performance of all the patients. Significant word variables were word being an adjective and Heritage frequency. With respect to the second question, different word variables accounted for the reading performance of the Nonfluent and Fluent groups: Nonfluent patients read more accurately words other than verbs, of high Heritage frequency, that were short; Fluent patients read adjectives more accurately. The results were replicated in the subset of words containing the semantic/associative variables. When those variables were added, Ease of Association suppressed all other variables for the Nonfluent group; Imageability was added for the Fluent group. Patients in the Large/Mixed groups read adjectives more accurately, whereas patients in the Small/Posterior groups read high Heritage frequency words that are pronounced consistent with their neighbors more accurately. With respect to the third question, individual patients were affected by a range of variables, primarily as a function of severity and fluency. Results are discussed in terms of two competing theories of lexical organization.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

a. Presentation of the problem:

Persons with aphasia make a variety of errors when reading different words. Consider, for example, the following reading responses, made by three different aphasic patients:

1. beg→***beggar***
2. beg→***argued, bed, bed***
3. beg→***bo, bo, blud, blub, bub...***

At the grammatical level, "beg" is a verb. It occurs infrequently in writing (11 times in a million words),[1] and somewhat more frequently in conversation (7 times in 190,000 words).[2] Despite its low frequency, it is rated as being a very familiar word.[3] "Beg" is not an early-acquired word, being typically introduced for reading in the third grade.[4] Semantically, it is rated as being fairly abstract yet imageable.[5] Phonologically, it is a three-phoneme word that begins and ends in a stop consonant. "Beg" is orthographically simple: made up of three letters, it is similar to 12 other words of the same length that can be generated by changing one letter while preserving other letter positions and is pronounced consistently with all of them. The frequency of its spelling pattern (the

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[1] As per Francis and Kučera's (1982) frequency count.

[2] As per Brown (1984).

[3] As per Toglia and Battig's (1978) ratings.

[4] As per Harris and Jacobson's (1972) "Basic Elementary Reading Vocabularies".

[5] As per Toglia and Battig's (1978) ratings.

averaged frequency of occurrence of be and eg) is, however, low (140 times in a million words).[6]

Now compare the above with the following responses, produced by the same three aphasics in the same order:

1. bed→***sleepy time...bell boy***

2. bed→***bed***

3. bed→***wed, we-bed, bed***

"Bed" is phonologically and orthographically very similar to "beg". Unlike "beg," however, it is a noun and is encountered relatively frequently in writing (127 times in a million words) and in conversation (18 times in 190,000 words). Like "beg", it is rated as being very familiar. However, it is typically introduced for reading earlier, in the first grade. Semantically, it is rated as being both highly concrete and imageable.

What is the contribution of each word characteristic to the production of these two words? Which word characteristics influence the reading of different patients?

These examples raise questions about the source of the reading errors. There are two sources of error: One source stems from word or linguistic characteristics that may account for reading performance. Words differ with respect to a number of variables, such as grammatical category, frequency of occurrence, concreteness, orthographic regularity and length. These variables are hypothesized to reflect organizational principles of the lexicon. Consequently, dissociations arising from these variables in the performance of brain-damaged subjects reveal psychologically relevant components of

[6] Obtained from Solso and Juel (1980).

the normal cognitive system. A second source of the errors stems from patient characteristics. Different variables may account for the performance of different types of patients.

b. Aims of the present investigation:

The present study aims to address the following three questions:

1. Which word characteristics influence aphasic reading?
2. Do different word characteristics account for the performance of different types of aphasics (e.g., nonfluent and fluent aphasics)?
3. Is individual aphasic performance consistent with aphasic group performance (e.g., for groups in terms of fluency)?

The first question focuses on the role of word variables (grammatical category, frequency of occurrence, concreteness, length, etc.) in the reading performance of aphasic patients. The last two questions focus on the relationship of word and subject variables (such as aphasic classification and severity) in the reading performance of different aphasic patients.

1. Which word characteristics influence aphasic reading?

Investigators have emphasized the importance of different variables in aphasic word reading. Some predict that a concreteness effect will always be accompanied by a grammatical class effect as they both relate to the same underlying semantic or associative dimension of words (Friedman, 1996; Jones, 1985). Others predict that grammatical class effects can occur without concreteness effects since grammatical class represents an independent organizational principle of the lexicon (Caramazza & Hillis, 1991).

A number of studies have examined the effect of single variables or combinations of variables on aphasic reading (e.g., Shallice & Warrington, 1975; Caramazza & Hillis, 1990). The majority of studies have employed factorial designs, where the variable of interest (most commonly grammatical category, frequency or concreteness) is manipulated while other variables (usually length, frequency or concreteness) are controlled for. Nevertheless, the interrelations of variables such as grammatical category, concreteness, and other less-investigated variables such as age of acquisition and associative measures make it difficult to draw conclusions from the factorially-oriented aphasia literature. For example, nouns and verbs have distinct semantic structures (Miller & Fellbaum, 1991), with verbs having more meanings than nouns, on average (Gentner, 1982). Children and adults use nouns considerably more often in speech than verbs (Vihman, 1981). Nouns are also acquired earlier than verbs (Bates, Marchman, Thal, Fenson, Dale, Reznick, Reilly & Hartung, 1994). Given the number of interrelationships that exist among the variables, it is difficult if not impossible to vary the levels of a single variable while controlling for the remainder.

The present investigation addresses these concerns by employing multiple regression analyses that permit the simultaneous consideration of a number of theoretically important variables and their contribution to reading performance. Regression techniques also allow for the inclusion of variables that are less frequently investigated but nevertheless related to reading performance. Few aphasia studies have examined the contribution of a range of variables to reading in a systematic and comprehensive way.

2. Do different word characteristics account for the performance of different types of aphasics (e.g., nonfluent and fluent aphasics)?

Different word variables may account for the performance of different types of aphasics. The aphasia literature has focused primarily on the performance of individual patients. Few studies have examined the effect of a number of word variables in groups of aphasics (divided on the basis of fluency, etc.).

3. Is individual aphasic performance consistent with aphasic group performance?

The relationship between individual and group patterns is crucial in aphasia research. Caramazza (1984) claims that the investigation of any aspect of aphasia by grouping patients in terms of syndrome is flawed because such groupings merely reflect arbitrary clusters of symptoms. As a result, significant individual differences may be obscured in the group analysis. It is, therefore, theoretically important to examine whether individual performance patterns are consistent with patterns of performance obtained from group data.

The remainder of the introduction examines variables that have been shown to affect reading performance. The focus is on reading in aphasia; however, selective reviews of findings from the normal and child literature are included where pertinent. The introduction includes predictions made by the theories reviewed, issues not addressed by the aphasia literature and an overview of how the present study will address them.

As an heuristic device, the organization of the introduction broadly follows Paivio and O'Neill's (1970) theoretical analysis of meaning in terms of its representational, referential and associative aspects. According to the investigators, representation refers to the availability of some form of memory representation corresponding to a physical stimulus. This representation is presumed to be a function of the subject's frequency of experience with the stimulus. Reference is defined in terms of the image arousal or concreteness of a word. Finally, association is defined in terms of the availability of other words as associates to the stimulus. Thus, representational meaning is related to the recognition threshold of a word. Referential and associative meaning, on the other hand, refer to higher-order processes aroused by the stimulus after it has been identified. In this investigation, the representational level includes variables such as frequency (and related measures) and grammatical category; the referential level includes semantic variables such as concreteness, imagery and pleasantness; and the associative level includes ease of association of a word with other words and number of attributes or associates.[7]

A. Representational aspects:

1. Written frequency:

Frequency has been examined extensively in word recognition in the literature on normal subjects and is a key variable in models of the organization of the mental lexicon.

a. Word frequency in the lexicon:

Words that occur more often in a language are recognized and read faster than words that occur less frequently. Referred to as the "word frequency effect", this finding

[7] Grammatical category, not addressed by Paivio (1970) is placed under the representational level on account of its postulated role as an organizational principle of the lexicon. However, its relationship to the other two levels is also addressed.

is robust and consistent. Frequency of occurrence is a strong determinant of picture naming response time (Oldfield & Wingfield, 1965), lexical decision time (Glanzer & Ehrenreich, 1979), word naming response time (Berry, 1971; Frederiksen & Kroll, 1976; Forster, 1981; Forster & Chambers, 1973) and susceptibility to phonological error in spontaneous speech (Stemberger & MacWhinney, 1986).

The word frequency effect has led to a number of models of word recognition as well as models of the organization of the mental lexicon. The models can be grouped into three broad categories: serial search models (e.g., Forster, 1976; 1981), parallel access models (e.g., Morton, 1969; McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989) and hybrid models (e.g., Forster, 1989; Paap, Newsome, McDonald & Schvaneveldt, 1982).

i. Serial search models:

Serial search models (e.g., Forster, 1976; 1981) propose a frequency-ordered lexicon in which the entries for high-frequency words are serially searched before entries for low-frequency words. Models differ, however, with respect to whether the search takes place in a single lexicon or in two lexicons. Glanzer and Ehrenreich (1979) proposed the existence of two lexicons: one consisting of high-frequency words only and a second consisting of all the words in the language. High-frequency lists are accessed first in the shorter lexicon, whereas low-frequency lists are accessed in the unabridged lexicon. The investigators showed that the frequency composition of a word list affected lexical decision performance, a finding incompatible with the existence of a single lexicon. Berry's (1971) finding that reading latencies to both high-frequency and low-frequency words were faster in homogeneous than in mixed lists also supports the dual-lexicon hypothesis.

Forster (1981), in turn, challenged the dual lexicon hypothesis. He hypothesized that subjects repeatedly exposed to a high-frequency list and then presented with an intermediate-frequency list should approach the new list with a bias towards the initial short search. Conversely, subjects repeatedly exposed to a low-frequency list and then presented with an intermediate-frequency list should show a tendency to omit the initial short search. As a result, subjects in the low-frequency condition should show superior performance over time, assuming that few of the intermediate-frequency words are found in the shorter lexicon. Using word naming rather than lexical decision (to minimize the decision aspect of the task), Forster found no shift in strategy as a result of experience in a pure list, consistent with a frequency-ordered search within a single lexicon. In this lexicon, orthographically similar words are grouped together into subsets, listed in order of frequency.

ii. Parallel access models:

Parallel access models (Morton, 1969; McClelland & Rumelhart, 1981) and their connectionist descendants (e.g., Seidenberg & McClelland, 1989) explain the word frequency effect in terms of a process of simultaneous comparison of a word with all entries. The effect results from the fact that the criterion for a satisfactory match between a word and lexical entries is not constant for all entries but varies according to frequency of usage.

Morton's (1969) logogen model is the oldest of the parallel access models. According to this model, when a logogen (a word identification or detection device) has accumulated information above a threshold value, a candidate response is made available. The criterion for a satisfactory match is not constant for all entries: high-frequency words have lower thresholds, so that fewer features need to be extracted for identification and they thereby reach threshold quicker than low-frequency words. Morton (1982) revised his logogen model by postulating separate, modality-specific input and output systems for word recognition. In this model, however, frequency effects do not arise at the logogen level but rather in the cognitive system, itself. Furthermore, word frequency does not have direct representation in the cognitive system but reflects correlated properties such as association strength.

McClelland and Rumelhart's (1981) interactive-activation model also employs a parallel access mechanism. Frequency effects arise because of higher resting activation levels for high-frequency words. Lateral inhibition between activated words eliminates competitors, thus serving to select the best match. This competition distinguishes the interactive-activation and the logogen models: whereas the logogen model assumes that the first logogen to reach a threshold of activation will be the best match, the interactive-activation model assumes that the best match will be the one that survives the competition process. This distinction is crucial with respect to predictions of the frequency effect in reading (see below, p. 22).

Connectionist or parallel distributed processing (PDP) models (e.g., Seidenberg & McClelland, 1989) assume fundamentally different architectures from the above models. Whereas in the parallel access models one node corresponds to each word in a connectionist architecture, PDP models represent words as patterns of activity across interconnected micro-elements. These elements encode orthographic, semantic and phonological information. Pattern learning occurs through repeated coactivation of elements and a strengthening of the connections between them by modification of weights of the links among the units. This learning is frequency-dependent. Note that PDP models include no formal concept of the lexicon, as there are no abstract units corresponding to words. Word identification is simply a pattern of activation across a set of elements. The unique contribution of PDP models is that they provide a mechanism for learning to recognize new words, since the frequency effect is a measure of degree of learning. PDP models make different predictions about the frequency effect from the interactive activation model (see below, p. 22).

iii. Hybrid models:

Hybrid models (e.g., Forster, 1989; Paap et al. 1982) employ a combination of parallel access and serial search mechanisms. Identification occurs in two discrete stages: the first stage is derived from word detector models and involves a fast, parallel activation of words. Unlike word detector models, however, the result is not unique identification but a small set of candidates that are serially examined in order of their frequency.

b. Word frequency in models of reading:

There are two broad types of models of reading: dual-route models and single-route models. The models make different predictions of the frequency effect.

Dual-route and modified dual-route models of reading (e.g., Herdman, LeFevre & Greenham, 1994; McCann & Besner, 1987; Monsell, Doyle & Haggard, 1989; Coltheart, Davelaar, Jonasson & Besner, 1977) explain the frequency effect within the framework of two reading strategies. According to the dual-route theory of reading

(Coltheart et al. 1977; Coltheart, 1980a) in English (and other languages with deep orthographies), an addressed or lexical route retrieves a pronunciation directly from the whole orthographic pattern of a word. This route is presumably used to pronounce highly irregular words like *yacht* and is assumed to be the fluent reader's preferred strategy for reading high-frequency words. The assembly or sublexical route assembles a pronunciation from fragments of orthographic patterns on the basis of grapheme-phoneme correspondences. This route is considered indispensable for reading unfamiliar or nonsense words. In the classical dual-route theory of reading (Coltheart et al. 1977; Coltheart, 1980a), the lexical and sublexical routes are assumed to operate independently. More recent versions, however (e.g., Monsell et al. 1989), propose that both processes are activated in parallel during reading and that their outcome is pooled.

The frequency effect in dual-route models crucially depends on engaging the addressed (lexical) route which is suppressed under the assembly (sublexical) route (Frederiksen & Kroll, 1976; Monsell et al. 1989). One source of evidence for this is the regularity-by-frequency interaction reported in studies of reading latency (Seidenberg, Waters, Sanders & Langer, 1984; Taraban & McClelland, 1987; Waters & Seidenberg, 1985). Irregular words are susceptible to frequency effects because the subject presumably relies exclusively on an addressed route involving a lexical lookup. Regular words, on the other hand, are immune to frequency effects because they can be read via an assembly route.

Cross-linguistic studies of the frequency effect compare languages with "deep," phonologically opaque orthographies with languages with "shallow," phonologically transparent orthographies (Baluch & Besner, 1991; Frost, 1994; Frost, Katz & Bentin, 1987). These studies show that the greater the orthographic depth, the more the lexical mechanism is engaged and the greater the frequency effect.

Dual-route models have been criticized from the single route perspective. Single-route models can be broadly classified into analogy models (e.g., Glushko, 1979; Jared , McRae & Seidenberg, 1990) and PDP models (e.g., Seidenberg, 1985; Seidenberg & McClelland, 1989). The two types of models overlap in some of their assumptions.

Analogy models of reading are based on a single mechanism for reading words. These models attack the premise that reading occurs either through the use of spelling-to-sound rules or via lexical mechanisms. According to such models, the pronunciation of a word is synthesized from the phonological codes of all the activated lexical representations that share phonology with the stimulus word (neighbors). This is related to the sum of a word's "friends" (orthographically related words with a similar pronunciation) and its "enemies" (orthographically related words with a different pronunciation).[8] Thus, regular and exception words are not fundamentally different from each other because they are both pronounced using the same kind of knowledge. Indeed, a number of studies (Andrews, 1989; 1992; Sears, Hino & Lupker, 1995) have found a facilitatory effect of neighborhood size in lexical decision and reading time when bigram frequency (a measure of commonality of orthographic patterns) and word frequency were controlled.[9]

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[8] For example, *mint, tint, lint* share phonology with each other but not with *pint.*

[9] But see Grainger (1990) and Forster and Shen (1996) for different findings and interpretations.

Different types of models of lexical organization make different predictions regarding the role of neighborhood effects in reading. A facilitatory effect of neighborhood size is consistent with PDP models since they predict that similar words strengthen connections between similar representational units. An inhibitory effect of neighborhood size is consistent with both the interactive activation and serial search models. The interactive activation model predicts an inhibitory effect because of lateral inhibition between activated lexical items. Serial search models predict that because neighbors falsely trigger a serial search (Andrews, 1989; 1992), the larger the orthographic neighborhood, the longer the lexical access time.

The critical assumption of neighborhood effects is that they arise at a lexical level of analysis where lexical similarity is processed and not at a sublexical level where orthographic frequency or commonality of spelling patterns are processed. Although neighborhood size and orthographic similarity are correlated (Landauer & Streeter, 1973), it is theoretically important to separate the contribution of the two. Lexical and sublexical factors have different implications for theories of reading: sublexical analysis predicts no effect of neighborhood size in reading. If such effects arise, it is only an epiphenomenon owing to commonality of spelling patterns.

The frequency effect can also be accounted for by single-route, PDP models (e.g., Seidenberg & McClelland, 1989; Van Orden, Pennington & Stone, 1990). Similar to analogy models, these models propose that an interaction between frequency and regularity is due to a processing conflict within a single mechanism. Unlike analogy models, however, they locate the conflict at the prelexical level of analysis. High-frequency words have stronger orthography-phonology connections than low-frequency words. Low-frequency, inconsistent words result in a delay because they activate an inconsistent set of phonological features.[10] Thus, despite the assumption in the reading literature of a lexical locus of neighborhood effects, a prelexical locus cannot be entirely excluded.

Bernstein and Carr (1996) are among the few investigators to examine individual differences in cognition with respect to single- versus dual-route architectures. Modified dual-route models account for the frequency X regularity interaction by postulating a mismatch between the outputs of the two routes. This mismatch occurs only for low-frequency irregular words; for high-frequency irregular words the lexical route is faster than the phonological route so no mismatch is detected. The investigators used an attention-demanding, interference task designed to debilitate assembled phonology more than addressed phonology. Dual-route theory predicts that such interference would result in an improvement in the reading of low-frequency irregular words because the system would be released from the competition (the RFC effect) of two different and incompatible pronunciations. Single-route theory predicts no such advantage. Bernstein and Carr found an RFC effect but only among a subset of normal subjects, suggesting a dual-route architecture for those subjects. The investigators raised this finding with respect to inconsistencies in the literature on normal reading processes as well as in the

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[10] The issue of dual- versus single-coding strategies in reading is an area of intense debate and beyond the scope of this introduction. Monsell and colleagues (1989) note, however, that revisions of dual-coding (Coltheart et al. 1993) and single-coding (Seidenberg & McClelland, 1989) models have recently converged and thus it has become difficult to distinguish between the two in terms of their predictions. The revised model of Coltheart and colleagues (1993) no longer employs two independent routes but a pooling mechanism of the outcomes of the two routes, which operate in parallel. Seidenberg and McClelland's (1989) PDP model incorporates a dual-route architecture because it also postulates a semantically-mediated route to phonology, operating more slowly than the direct route.

child literature. Indeed, if individual differences in reading system architectures can be demonstrated in normal readers, what can be concluded about different reading patterns in aphasics? Unlike differences due to site of lesion or type of impairment, the effect of such preexisting factors cannot be measured.

c. Written frequency in aphasia:

Aphasia studies have examined frequency effects in a limited manner, despite their theoretical importance. More commonly, frequency of occurrence is a factor that studies control in the context of investigations of semantic or grammatical effects (e.g., McCarthy & Warrington, 1985; Miceli, Silveri, Nocentini & Caramazza, 1988; Miozzo, Soardi & Cappa, 1994). Early studies tended to employ groups of patients rather than individual patients. Generally they have shown that frequency affects picture naming in aphasics as well as in patients with focal lesions (Newcombe, Oldfield & Wingfield, 1965; Rochford & Williams, 1965). More recent studies have focused on the performance of individual aphasic subjects, attempting to pinpoint the locus of the frequency effect and to explicate the role of frequency in the production of different types of error (Ellis, Miller & Sin, 1983; Howard & Orchard-Lisle, 1984; Kay & Ellis, 1987; Miceli, Giustolisi & Caramazza, 1991; Nickels & Howard, 1994; Zingeser & Berndt, 1988).

Some studies (Ellis et al. 1983; Kay & Ellis, 1987; Miceli et al. 1991) have proposed a phonological output locus (rather than a central, semantic locus) of the frequency effect. These studies demonstrated a frequency effect in one modality (e.g. naming) but not in another (e.g., reading), consistent with the existence of modality-specific output lexicons. The co-occurrence of the inability to activate lexical representations in naming but not in reading is also consistent with the dual-route model of reading, because reading can also take place via the sublexical route. A frequency effect has also been shown in an aphasic patient with a phonological deficit affecting oral production in all contexts (Friedman & Kohn, 1990). This deficit was attributed to impaired access to the phonological lexicon rather than to a postlexical access deficit.

Other studies (e.g., Howard & Orchard-Lisle,1984; Nickels & Howard, 1994) have not found a frequency effect when a cognitive deficit is hypothesized to impair semantic processing. These studies have focused specifically on factors that predict semantic errors. Howard and Orchard-Lisle (1984) showed weak or nonexistent frequency effects in the semantic errors of a global aphasic, who made errors in both comprehension and production tasks in a pattern consistent with a semantic deficit. Nickels and Howard (1994) investigated the effect of different word properties on the production of semantic errors in a group of aphasics. Using multiple regression analyses, they found that word length, presence of consonant clusters and familiarity did not affect the production of semantic errors, but imageability did.[11] The investigators proposed that if a semantic deficit leads to the activation of a range of semantically related alternatives, the occurrence of a frequency effect will depend on whether one or many items are activated. If no unique entry reaches criterion, the item with the highest activation level becomes the output, with a resulting frequency effect. If a single semantically related entry reaches criterion, this entry addresses the output lexicon uniquely with no

[11] Nickels and Howard (1994) used familiarity in place of written frequency measures. The two were seen as measuring similar constructs.

frequency effect. Thus, no frequency effects are predicted in semantic errors resulting from central, semantic deficits.

Dual-route models predict frequency effects in patients presumed to rely on the addressed route but not on the assembly route. Indeed, a number of researchers (e.g., Funnell, 1983; Marshall & Newcombe, 1973; Shallice & Warrington, 1980) have proposed that either of the two routes can be selectively impaired in brain damage, as reflected in the syndromes of surface dyslexia, where patients rely on the assembly route, and phonological or deep dyslexia, where patients rely on the addressed route. In the few studies of frequency effects in patients with surface dyslexia, no frequency effects have been found (e.g., Deloche, Andreewsky & Desi, 1982). In patients with phonological or deep dyslexia, frequency effects have been often found together with grammatical and concreteness effects in reading (Shallice & Warrington, 1975; Caramazza & Hillis, 1990).[12]

Most studies examining word reading in aphasia subscribe to some form of dual-route model. An exception is Friedman and Kohn (1990), who explained the reading performance of a patient with a deficit in accessing the phonological lexicon within the framework of single-route, analogy models. Recall that since analogy models do not include a nonlexical reading route, all words (including nonwords) are hypothesized to be read by using the phonological entries of the lexicon and by activating orthographically similar entries (neighbors). Thus, according to analogy models, a deficit in accessing the phonological lexicon would result in a nonword reading deficit,

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[12] A frequency effect was even found in a patient with a reverse concreteness effect, who read abstract words better than concrete words (Warrington, 1981).

a frequency effect and possible concreteness and grammatical category effects. The reading pattern that would emerge would be consistent with phonological dyslexia. According to dual-route models, a deficit in accessing the phonological lexicon would result in reliance on grapheme-to-phoneme rules, a spelling regularity effect but no frequency effect since grapheme-to-phoneme rules apply to regular words of any frequency. The reading pattern that would emerge would be consistent with surface dyslexia. The patient of Friedman and Kohn (1990) showed a severe deficit in reading nonwords and a frequency effect, consistent with phonological dyslexia and thus better accounted for by analogy models.

2. Subjective frequency (familiarity):

Lexical frequency is traditionally defined as the frequency with which a word occurs in print. Despite its consistent role as a predictor of speed and accuracy in word recognition and reading, its adequacy as a measure of frequency in the mental lexicon has been questioned. Frequency may be a multidimensional construct, with different measures of frequency reflecting different aspects of word production. Furthermore, effects attributed to frequency may be due to variables with which frequency correlates. Two measures have recently received attention: subjective/experiential frequency (familiarity) and spoken frequency.

a. Normal processes:

Familiarity is typically measured by asking subjects to rate how familiar they are with a particular word (Carroll, 1971; Connine, Mullennix, Shernoff & Yelen, 1990; Gernsbacher, 1984; Gilhooly & Logie, 1980). Thus it is at least partly a measure of how often a subject has encountered the target word. Familiarity has been shown to be a reliable measure, even with a relatively small number of untrained subjects (Carroll, 1971). Although familiarity correlates highly with printed frequency (Carroll, 1971; Gernsbacher, 1984; Gilhooly & Hay, 1977; Gilhooly & Logie, 1981; Gordon, 1985), the correlation breaks down in the low-frequency range: two words of similar printed frequency can differ greatly in familiarity (Carroll, 1971; Gernsbacher, 1984; Gordon, 1985).

Some evidence exists that familiarity may interact with other variables. Galbraith and Underwood (1973) showed that abstract and concrete words of equal objective frequency differed in subjective frequency (familiarity). When word pairs were matched for frequency and length, the abstract word was consistently perceived as being of higher frequency than the concrete word. In fact, even when the concrete word in the pair had the higher frequency, the abstract word was selected as the most frequent. Galbraith and Underwood postulated that this discrepancy was due to abstract words occurring in more linguistic contexts than concrete words. When subjects rated words by number of contexts in which they appear, abstract words obtained higher ratings than concrete words. The finding of differences in familiarity between abstract and concrete words of the same frequency poses interesting questions concerning the interactions of these variables.

Familiarity has been shown to be a stronger predictor of lexical decision and reading latency than written frequency (Connine et al. 1990; Gernsbacher, 1984; Gordon, 1985). Connine and colleagues (1990) found that familiarity affected delayed reading (delayed by 600 or 1,200 ms), thus concluding that familiarity, but not frequency, plays a critical role in translating a visual into an articulatory representation.

b. Subjective frequency in aphasia:

Familiarity has not been investigated in the reading of aphasics. A small number of studies have examined the role of familiarity in aphasic naming, however. The study of Funnell and Sheridan (1992) is one of a few aphasia studies that have specifically focused on familiarity. The investigators showed that when frequency was controlled, familiarity but not semantic category predicted success in picture-naming in an aphasic patient with a comprehension deficit. According to Funnell and Sheridan, most patients with so-called category-specific deficits show an impairment for animate relative to inanimate things, a finding they attribute to the lower overall familiarity of living things. Two categories that show anomalies in some studies (e.g., those of Breedin, Saffran & Coslett, 1994; Miceli et al. 1991; Warrington & Shallice, 1984) are musical instruments and body parts. Snodgrass and Vanderwart (1980) also found that these two categories broke the high-familiarity-nonliving, low-familiarity-living rule. The investigators concluded that unless familiarity is controlled for in studies where category and familiarity may be confounded, the theory that semantic memory is organized into categories such as living and nonliving things cannot be supported.

3. Age of acquisition (AOA):

a. Normal processes:

A number of investigators (Brown & Watson, 1987; Carroll & White, 1973 a & b; Gilhooly & Logie, 1981) have proposed that word frequency effects may mask other crucial variables. Age of acquisition (AOA) is hypothesized to be one such variable.

AOA is the age at which a lexical item is acquired, as measured typically by asking adults to estimate the age at which they learned a given word. AOA ratings correlate highly with estimates of AOA taken from the frequency of word use in children's reading, writing (Carroll & White, 1973a) and speaking (Jorm, 1991), as well as with children's performance on a variety of other tasks (Walley & Metsala, 1992). Thus, rated AOA is a valid measure of the age at which lexical items are acquired.

Like familiarity, AOA correlates highly with variables that affect word recognition and production: written frequency (Carroll & White, 1973a; Whaley, 1978), length (Morrison, Ellis & Quinlan, 1992; Whaley, 1978) and concreteness (Brown & Watson, 1987; Whaley, 1978). Accordingly the role of AOA has been investigated using regression analyses.

In studies of picture naming in aphasia (Carroll & White, 1973 a & b; Morrison et al. 1992), pictures of words rated as learned early in life were named faster than pictures of words rated as learned later, even when frequency was statistically controlled. In fact, frequency had no effect independent of AOA.

Studies on the role of AOA in lexical decision (Gilhooly & Logie, 1982; Morrison & Ellis, 1995; Whaley, 1978) have produced less clear-cut results. Whaley (1978) found that frequency and AOA each correlated with lexical decision latency when the other variable was statistically controlled. Using a factorial design, Morrison and Ellis (1995) found that both AOA and frequency had an effect on lexical decision speed, consistent with Whaley (1978). Gilhooly and Logie (1982), on the other hand, found that AOA had no effect on lexical decision speed independent of word length, frequency and familiarity. Gilhooly and Logie replicated their results in a second experiment with a different set of words, concluding that AOA is not a significant factor in lexical decision performance and that apparent AOA effects are redundant with those of length, frequency and familiarity. Since Whaley (1978) did not include the critical variable of familiarity, they reasoned, the true contribution of AOA cannot be evaluated.

Studies investigating the role of AOA in reading have produced more consistent results (Brown & Watson, 1987; Gilhooly & Logie, 1981; Morrison & Ellis, 1995; Rubin, 1980). Using multiple regression analyses, investigators have shown AOA either to be the sole predictor of reading latency or at least to be a stronger predictor than written frequency, familiarity or word length (Brown & Watson, 1987; Gilhooly & Logie, 1981). Using a factorial design, Morrison and Ellis (1995) found that AOA had a strong effect on word reading speed when frequency was controlled; frequency, however, had no effect on reading speed when AOA was controlled.[13] Furthermore, AOA was the major predictor of familiarity ratings in multiple regression analyses which included spoken frequency, written frequency and word length (Brown & Watson, 1987). Brown and Watson thus proposed that familiarity is not a measure of experiential frequency (as suggested by Gernsbacher, 1984) but that it mostly reflects AOA.

Reading studies indicate that AOA is an important predictor of tasks that involve overt production, yet most studies on the effects of frequency on reading latency have not controlled for it. Moreover, as Morrison and Ellis (1995) pointed out, an AOA effect is contrary to predictions made by distributed models: such models would predict a reverse AOA effect, since later learning overrides earlier learning.

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[13] Morrison and Ellis also showed that neither frequency nor AOA had any effect on delayed reading (using delays of 100 and 500 ms), consistent with most studies of frequency (e.g., Connine et al. 1990; Monsell et al. 1989) but not of familiarity (e.g., Connine et al. 1990).

b. AOA in aphasia:

AOA has received surprisingly little attention in the aphasia reading literature. Studies of AOA effects in aphasia have largely employed picture naming tasks (Feyereisen, Van der Borght & Seron, 1988; Hirsh & Ellis, 1994; Hirsh & Funnell, 1995; Nickels & Howard, 1994; Rochford & Williams, 1962), although one study has also examined AOA effects in reading (Hirsh & Ellis, 1994).

Rochford and Williams (1962) were the first to address the question of AOA in picture naming. They found that the age at which a name was produced by 80 percent of the children in their study correlated with the number of aphasic subjects able to produce that name correctly in picture naming. Moreover, the order of difficulty shown by the aphasics paralleled that shown by the children. Feyereisen and colleagues (1988) showed that both AOA and familiarity predicted picture naming by aphasic subjects. Frequency was not suppressed by the inclusion of AOA and familiarity, suggesting relatively independent contributions. Hirsh and Funnell (1995) found that the picture naming performance of one progressive aphasic with severe anomia was influenced by AOA whereas that of another progressive aphasic with a semantic memory disorder was influenced by familiarity (both aphasics were tested longitudinally). Hirsh and Funnell also concluded that familiarity and AOA have independent effects on naming.

Hirsh and Ellis (1994) examined the effects of frequency, imageability and AOA on picture naming and reading performance in an aphasic patient, employing the same stimuli for both tasks. Multiple regressions showed that only AOA independently predicted naming performance. No variable independently predicted reading performance, which consisted entirely of phonological approximations. In a further assessment of the patient's reading the authors used an expanded set of stimuli in a factorial design where AOA and imageability were manipulated while frequency and length were controlled. Both AOA and imageability were significantly related to reading performance. Not much can be concluded from this study, however, since it was based on a single patient and two different administrations and designs produced conflicting results.[14]

Age of Acquisition is naturally related to children's performance. V. Coltheart, Laxon and Keating (1988) are possibly the only researchers who investigated children's reading of words that differ in AOA. Using a factorial design in which they varied AOA or imageability while controlling for length and frequency, they found, unsurprisingly, that nine-year-old children read early-acquired words more accurately than late-acquired words. Imageability affected the reading accuracy of the poor readers only. Word reading latencies of the same stimuli showed an AOA but not an imageability effect in adults. V. Coltheart and colleagues proposed that these imageability effects indicate that young poor readers use a semantically-based route. AOA effects for both children and adults, on the other hand, reflect some measure of ease of generation of pronunciation.

Some investigators (Brown & Watson, 1987; Morrison & Ellis, 1995) have proposed that words learned early are pronounced as whole units whereas words learned late are pronounced in a more analytical fashion. Brown and Watson cited Vihman's (1981) evidence for this hypothesis. Vihman showed that young children store words as

[14] Multiple regression analyses can be very sensitive to even small differences in the correlations between the dependent variable and predictor variables or among the predictor variables. Thus, genuine predictors may be suppressed by variables with which they correlate (Morris, 1981; Morrison & Ellis, 1995).

whole units, owing to phonological storage limitations rather than to articulatory incompetence. Storage limitations are reflected in children's use of homonymy, the tendency to use a single word to stand for several adult words. Homonymy is based on the phonological similarity of words, which is the organizing principle of young children's lexicons; organization in terms of higher-order semantic factors occurs gradually and after the age of six or after the child starts school. During the elementary school years the child begins to internalize the orthographic representations of words and to replace the sound-based image of the word with the image of the written word.

4. Grammatical category:

a. General characteristics of different grammatical categories (nouns, verbs, adjectives):

Nouns, verbs and adjectives differ on numerous accounts. Perhaps their most noticed difference is in semantic structure: although nouns and verbs are organized into levels, nouns have hierarchical structures from specific to generic (Miller & Fellbaum, 1991; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976) whereas verbs have a more shallow structure and more than one top node within a semantic field (Miller & Fellbaum, 1991). Adjectives, on the other hand, are organized in terms of opposition or antonymy, as are certain verbs (stative verbs and verbs of change) (Miller & Fellbaum, 1991).

Words of different grammatical categories take different types of words as associates. Fillenbaum and Jones (1965) showed that for nouns, 79 percent of associations were also nouns; for verbs, 43 percent of associations were also verbs; and for adjectives, 65 percent of associations were also adjectives. Thus, "paradigmatic" associations of the same grammatical category are more prevalent in nouns than in verbs or adjectives. Fillenbaum and Jones commented that although paradigmatic associations were the most common associates to all grammatical classes (except articles), it is very rare in discourse for adjacent words to be from the same grammatical class.

Verbs tend to have more meanings than nouns (Gentner, 1982; Miller & Fellbaum, 1991). Nouns in the Collins English Dictionary have, on average, 1.74 senses whereas verbs have 2.11 senses (Miller & Fellbaum, 1991). According to Gentner (1982) the greater polysemy of verbs accounts for the fact that verb concepts are more difficult than noun concepts. Verbs are broader in meaning and have fewer features that are consistently accessed.

Finally, nouns and verbs differ by sheer number. There are approximately three times more nouns than verbs in the Collins English Dictionary (Miller & Fellbaum, 1991). Differences in number are also reflected in language production: a corpus of children's speech consisted of 80 percent nouns, 9 percent verbs and 6 percent adjectives; a corpus of adult speech consisted of 75 percent nouns, 9 percent verbs and 14 percent adjectives (Vihman, 1981). These differences suggest that verbs are retrieved from a smaller store than nouns.

b. The production of words from different grammatical categories in children:

Nouns and verbs are understood and produced at different ages (Bates, Marchman, Thal, Fenson, Dale, Reznick, Reilly & Hartung, 1994; Beckwith & Thompson, 1976; Goldin-Meadow, Seligman & Gelman, 1976). Bates and colleagues (1994) observed three developmental stages in the acquisition of vocabulary in 1,803 children: an initial increase in the proportion of common nouns at a stage of 0 to 100 words, followed by an increase in the proportion of verbs and adjectives between 50 and 200 words and, finally, by a sharp increase in closed class vocabulary at a stage of 400 to 680 words. This finding has implications for the relationship between grammatical category and AOA.

Nouns and verbs differ in semantic organization in children, just as they do in adults (Behrend, 1990; Huttenlocher & Lui, 1979; Sommers, Kozarevich & Michaels, 1994). Nouns are more closely related whereas verbs are relatively more uncorrelated in meaning, with elements of meaning cutting across semantic field (Huttenlocher & Lui, 1979).

Some evidence exists for interactions between phonological and grammatical factors in child speech production. Camarata and Schwartz (1985) showed that both normal and language-impaired children correctly produce a significantly greater percentage of consonants in object words than in action words in both spontaneous and elicited utterances. To control for factors such as onset time or frequency of exposure, the children were presented with unfamiliar object and action words while the investigators demonstrated their meaning. Again, the children accurately produced significantly more object than action words. The investigators proposed that grammatical category affects children's phonological behavior because of their limited processing capacity and the greater syntactic-semantic demands of action words.

c. Grammatical category in aphasia:

Noun and verb production has been investigated extensively in aphasic naming, reading and other tasks. Naming studies have revealed a dissociation between noun and verb production, with nonfluent/anterior aphasics showing greater difficulty with verbs and fluent/posterior aphasics showing greater difficulty with nouns (e.g., Bates, Chen, Tzeng, Li & Opie, 1991; Damasio & Tranel, 1993; Daniele, Silveri, Giustolisi & Gainotti, 1993; Miceli, Silveri, Villa & Caramazza, 1984; Miceli, Silveri, Nocentini & Caramazza, 1988; Williams & Canter, 1987; Zingeser & Berndt, 1990).[15] Nevertheless, a dissociation similar to that observed in naming is not found in synonym and sentence generation (Kohn, Lorch & Pearson (1989) or reading (Gardner and Zurif, 1975). When nonfluent and fluent aphasics differ in performance on these tasks, verb production is impaired regardless of aphasic classification.

Marshall and Newcombe (1966) found that a severely aphasic patient with a widespread left-hemisphere lesion read nouns better than adjectives and both better than verbs. The patient made more semantic errors in the reading of nouns and more visual errors in the reading of verbs and adjectives. Verbs were often read as nouns (e.g., beg→*beggar*). Gardner and Zurif (1975) examined the reading of fluent and nonfluent aphasics and of alexic patients without significant aphasia. Patients from four aphasic groups (Broca's, Wernicke's, Alexics with Agraphia, Global) all showed the same rank order of difficulty: short picturable nouns were the easiest and long "non-nouns" (an assortment of functors and verbs) the hardest.

Later studies of grammatical category effects in reading have attempted to control for factors such as length and phonological structure. Caramazza and Hillis (1991) found a modality-specific verb deficit in two fluent aphasic patients, one in reading and the other one in spelling. A similar pattern was found in the oral and written processing

[15] The double dissociation is not equally clear in all studies. Williams and Canter (1987), for example, found that both nonfluent and fluent aphasics performed better on object-naming than action-naming. Zingeser and Berndt (1990) found that nonfluent (agrammatic) patients performed worse on action-

of homonyms (e.g., *crack* as a noun and as a verb). This indicates that the observed deficit did not concern lexical forms but grammatical categories. Both patients showed normal comprehension of the same words and most of their errors in reading and writing were semantically related responses or omissions. Furthermore, both patients' reading and spelling were affected by frequency but not by spelling-to-sound regularity or by concreteness. The role of concreteness remains ambiguous, however, since it was evaluated as part of a separate stimulus administration. The investigators concluded that grammatical class distinctions are redundantly represented in the phonological and the orthographic output lexicons.

Alternatively, the fact that both patients showed a verb deficit could be attributed either to verbs being more difficult to process than nouns or to verbs being more closely linked to grammatical processing (Caramazza & Hillis, 1995). To counter these explanations, the investigators reported the performance of an anomic aphasic and severely dyslexic patient with a deficit complementary to the two deficits reported by Caramazza and Hillis (1991). The patient made more errors on nouns than on verbs in spoken output tasks (e.g., picture naming, naming to definitions) and more errors on verbs than on nouns in written input tasks (e.g., word/picture verification). Oral reading, a task which involves both written input and spoken output, showed the combined effects of the two deficits, resulting in a smaller verb advantage in this patient who showed functional sublexical (orthography to phonology conversion) mechanisms. The double dissociation within a single patient presented strong evidence in favor of the

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naming but that fluent (anomic) patients did not differ from normals on the production of nouns and verbs.

hypothesis that knowledge of orthographic and phonological forms of words is organized by grammatical category and is processed by independent neural mechanisms.

A selective verb advantage in reading is rarely reported in the literature, however. To my knowledge, only one other study showed better verb than noun reading (Rapp, Benzing & Caramazza, 1995). A patient with considerable expressive difficulties read the verb of homonym pairs better (e.g. *to fish*) but spelled to dictation the noun of the pairs better (e.g., *a fish*). This modality-specific dissociation also extended to naming and picture description (orally and in writing). Note, however, that the extent of the investigation was limited: only 10 noun/verb pairs were used and results were reported in percentages.

Caramazza (1997) elaborated on the proposition that lexical-semantic and syntactic information is independent. According to the Independent Network model of the lexicon, lexical knowledge is organized in sets of independent networks, connected to each other by a modality-specific lexical node. The lexical-semantic network represents word meanings in terms of semantic properties, features or predicates. The lexical-syntactic network represents a word's syntactic features such as grammatical category and tense. The modality-specific lexical representations consist of the phonological and orthographic word forms (P-lexemes and O-lexemes), which are semantically and syntactically specified. In single word reading, a lexical-semantic representation activates simultaneously and independently the lexical-syntactic and P-lexeme networks. Activation of P-lexemes results in activation of the word's phonological properties. However, access of a word's phonological features does not presuppose access of its syntactic features.

Evidence of the independence of lexical-semantic and syntactic information, according to Caramazza (1997), comes from patients who show selective grammatical class deficits restricted to either oral or written production. The existence of modality-specific deficits implies that the lexical-semantic system is intact and that the relation of a lexical-semantic representation to orthographic word forms is independent of the relation of a lexical-semantic representation to phonological word forms.

Grammatical class effects are often reported in deep/phonological dyslexia (e.g., Marshall & Newcombe, 1973; Shallice & Warrington, 1975). Aphasics who are deep/phonological dyslexics typically read nouns better than adjectives and adjectives better than verbs. Indeed, the key characteristics of deep dyslexia are a grammatical category effect, a concreteness effect, inability to read nonwords and the production of semantic errors (Coltheart, 1980a). The key characteristic of phonological dyslexia is impaired nonword (pseudoword) reading (Coltheart, 1996).

A number of investigators have proposed that deep and phonological dyslexia represent a continuum rather than two distinct disorders. As patients improve, the resolution of their symptoms follows a predictable sequence: semantic errors disappear first and nonword reading is the last to be restored (Friedman, 1996; Glosser & Friedman, 1990; Klein, Behrmann & Doctor, 1994). In her review of the published reports of 11 cases of phonological dyslexia, Friedman (1996) showed that the order of recovery was the reverse of the continuum of severity in phonological dyslexia.

Friedman (1996) proposed that deep dyslexia is the result of two deficits: an inability to derive phonology from orthography and an impairment in semantically mediated reading. A disturbance in the phonological pathway results in a nonword reading impairment but real words can still be read via the semantic pathway. An additional impairment in the semantic pathway results in semantic errors, a concreteness effect and a grammatical category effect. When the phonological route is operational there are neither grammatical category nor concreteness effects.

Rare reports exist of grammatical class effects for words read via the phonological route (e.g., Marshall & Newcombe, 1973). Surface dyslexia, the opposite of phonological dyslexia (Coltheart, 1980a; Deloche, Andreewsky & Desi, 1982) is postulated to arise due to a selective impairment in the lexical route (Shallice & Warrington, 1975). If reading in surface dyslexia occurs via the phonological route, it should not be associated with grammatical category effects. One mechanism that can account for grammatical category effects in surface dyslexia, however, has been proposed by Marcel (1980). According to Marcel, access to lexical phonology can take place via a unique visual address as well as via segments of the visual address. This mechanism accounts for the two seemingly opposite syndromes of phonological and surface dyslexia through a single lexical mechanism in a way that is consistent with single-route, analogy models.

A possible explanation for the lack of a double dissociation in reading impairment between nouns and verbs is that reading aloud occurs automatically, without necessarily accessing the meaning of a word, whereas naming must engage the semantic system. Miceli, Giustolisi and Caramazza (1991) proposed that in order for a reading deficit to accompany a naming deficit, the sublexical route must be nonfunctional. One possibility is that aphasics who have difficulty with the sublexical route are primarily nonfluent and by extension have anterior lesions. Consistent with the hypothesis that verbs are represented in anterior brain regions and nouns in posterior brain regions (Damasio & Tranel, 1993; Luria, 1980), verb deficits are observed in nonfluent aphasics with an impaired sublexical route. Fluent aphasics tend to retain sublexical reading and as a result do not show a noun deficit in reading, though they may show such a deficit in naming. Although some studies report a verb deficit in fluent as well as nonfluent aphasics (e.g., Caramazza & Hillis, 1991; Glosser & Friedman, 1990), the aphasics studied have had widespread lesions.

Interestingly, dissociations in the reading of different types of words have been demonstrated as a function of number of errors in subjects without brain damage. Beeman, Friedman, Grafman and Kwabenah (1993) reported a part-of-speech effect (nouns>functors) in normal persons subjected to brief presentations limiting them to 50 percent accuracy. This finding has important implications for the relationship of type of aphasia (and by extension site of lesion) to grammatical category deficits. Degree of impairment is a variable not usually included or controlled for in studies examining grammatical category dissociations.

B. Referential aspects:

This section is not intended to be an exhaustive review of all semantic variables that might affect reading. It focuses on three: concreteness, imageability and pleasantness.

1. Concreteness:

a. Normal processes:

Concreteness is traditionally defined as the extent to which a word can be experienced through the senses (Brown & Ure, 1969) or the extent to which it refers to objects, materials or persons (Paivio, Yuille & Madigan, 1968). A number of studies have shown an advantage for concrete over abstract words on paired associate learning, free recall, naming latency and other tasks (Christian, Bickley, Tarka & Clayton, 1978; James, 1975; Paivio, 1968; 1991; Paivio, Clark, Digdons & Bons, 1989).

Dual-coding theory proposes that abstract and concrete words have distinct representations in the lexicon. Concrete words are represented verbally and also in imagery, whereas abstract words are represented only verbally (Bleasdale, 1987; Paivio, 1968). Paivio (1986) further proposed that the verbal system is located in the left hemisphere and the imaginal system in the right hemisphere.

A number of investigators (Bleasdale, 1987; Chiarello, Senehi & Nuding, 1987; Day, 1977; Kounios & Holcomb, 1994) have argued in favor of dual-coding theory using priming in reading and lexical decision tasks. Some (Day, 1977; Kounios & Holcomb, 1994) have proposed that the two types of words are organized differently in the brain. Day (1977) demonstrated that the effect of concreteness on lexical decision time depended on field of presentation: abstract nouns showed a right visual field (left hemisphere) superiority but concrete nouns showed no difference between right and left visual fields. Kounios and Holcomb (1994) found that concrete and abstract words yielded significantly different ERPs over the right hemisphere but not over the left.

Other investigators either provided evidence against dual coding theory (De Groot, 1989; Theios & Amrhein, 1989) or obtained inconclusive results (Kroll & Merves, 1986). These investigators argued that differences between concrete and abstract words in task performance do not necessarily imply that the two types of words reflect separate lexical systems. Kroll and Merves (1986) compared single and dual coding theories using lexical decision tasks. Dual code models postulate a common memory system for both concrete and abstract words and a special-purpose memory system for concrete words. They predict that concreteness effects will be greater when access to the common memory system is impaired. Further, the word frequency effect should be different for the two types of words: if lexical retrieval for concrete words uses a smaller or abridged memory store, the frequency effect should be smaller for concrete than for abstract words. Kroll and Merves found only a slight advantage in reaction time for concrete as compared to abstract words but they also found a significant frequency effect and a frequency-concreteness interaction. In an additional experiment, subjects were presented with blocks of abstract or concrete words and were subsequently switched to the other word class. According to dual-coding theory, if concrete words are presented first they will bias reliance on the special-purpose memory store. Transfer to an abstract list should, consequently, cause disruption. Consistent with this prediction, there was greater disruption when lexical decisions about concrete nouns preceded lexical decisions about abstract nouns than the other way around. The investigators, however, concluded that the results were equivocal for both single and dual coding models since there was no interaction between word type and frequency on this task.

b. Developmental processes:

A few studies have specifically investigated concreteness or imageability effects in children's reading (V. Coltheart, Laxon, Keating & Pool, 1986; V. Coltheart, Laxon & Keating, 1988; Jorm, 1977). These studies have reported a concreteness effect for poor readers, only. Jorm (1977) hypothesized that good and poor readers use different strategies: good readers rely on grapheme-phoneme analysis and therefore are not affected by concreteness, whereas poor readers use a whole word approach, and as a result, are influenced by the concreteness of the word. A concreteness effect for poor readers has been shown even when length, frequency and AOA are controlled (V. Coltheart et al.1986; 1988).

c. Concreteness in aphasia:

Concreteness and imageability are strikingly associated with the reading performance of aphasics who are deep dyslexic (Coltheart, 1980a; Funnell, 1987) or phonological dyslexic (Funnell, 1987; Patterson, 1978). Such patients, postulated to use a lexical route because they are unable to use phonological coding, also make frequent semantic errors (Coltheart, 1980a&b; Morton & Patterson, 1980; Patterson, 1978; Saffran, Bogyo, Schwartz & Marin, 1980).

The role of the lexical route in the production of semantic errors is further supported by evidence that such errors occur rarely in languages with "shallow orthography" such as Spanish (Ardila, 1991). Indeed, most semantic errors in reading have been reported in English- and French-speaking aphasics. Ardila (1991) commented that Luria never reported any semantic errors in his extensive investigations of Russian-speaking aphasics (Russian also has a shallow orthography).

Semantic errors are frequently reported in investigations of aphasic reading in English. Caramazza and Hillis (1990) showed that two deep dyslexics made predominantly semantic errors in reading. For one patient, the probability of making a semantic error was affected by grammatical class (more semantic errors on nouns). Both patients showed a concreteness effect (more semantic errors on concrete words) (effects reported in percentages).

Tyler, Moss and Jennings (1995) demonstrated an abstract word impairment in two nonfluent aphasics. However, neither patient showed difference in priming between abstract and concrete words on lexical decision tasks, and their definitions suggested the ability to access the meaning of both types of words. Buxbaum and Coslett (1996) found that a patient with features of both deep dyslexia and letter-by-letter reading (pure alexia) had greater difficulty reading abstract than concrete words. Word length interacted with concreteness; however, no frequency or regularity effects were found. The investigators proposed that the patient read via a rapid, whole word strategy relying on the right hemisphere for concrete words and a default, letter-by-letter strategy for nonwords, abstract words and functors. Failing to receive lexical-semantic support for abstract words, he read them sublexically. Saffran and colleagues (1980) proposed that the right hemisphere reflects exactly the skills of deep dyslexics: poor phonological capacities and the ability to read concrete words, only. Along the same lines, Jones and Martin (1985) predicted increases in the likelihood of semantic errors in reading with increases in left hemisphere lesion size.

Eviatar, Menn and Zaidel (1990) compared two hypotheses of the concreteness effect. According to one hypothesis, proposed by Bleasdale (1987), the concreteness effect obtains because abstract nouns are processed by the left hemisphere but concrete nouns are processed by either hemisphere. According to an alternative hypothesis, the concreteness effect arises because concrete words arouse multiple sensory representations of the objects they denote. Although concreteness and multisensory representation are highly correlated in nouns, they are less so in verbs: For example, verbs often have low concreteness ratings but may nevertheless arouse kinesthetic associations. Eviatar and colleagues examined the visual field advantage of concrete versus abstract nouns and "action verbs" (e.g., *kick*) versus "quiet verbs" (e.g., *sell*) in a lexical decision task tachistoscopically. (For convenience, the predicted dissociation between "action" and "quiet" verbs was also called the "concreteness effect".) They administered the tasks to both normal subjects and complete commissurotomy patients who had undergone resection of the corpus callosum in the treatment of intractable epilepsy. Normal subjects responded more accurately to nouns than to verbs and showed a concreteness effect for the nouns in both visual fields but not for the verbs. Similarly, each disconnected hemisphere of the commissurotomized patients responded with better than chance performance to concrete nouns (three out of four patients for the left hemisphere; two out of four for the right). A concreteness effect in both hemispheres belies the predictions of the right hemisphere extension of dual coding theory (Bleasdale, 1987). Like normal subjects, none of the commissurotomized patients showed a concreteness effect for the verbs in either hemisphere and both types of verbs resulted in a significant right visual field (left hemisphere) advantage. Eviatar and colleagues concluded that the concreteness effect exists in both hemispheres, but only for nouns. Because the effect did not extend to verbs, the multisensory interpretation of concreteness was not supported.

Strictly speaking, dual coding theory does not predict a greater concrete than abstract word deficit because loss of the verbal code would favor concrete words but loss of the imaginal code would not clearly favor one type of word over the other. Nevertheless, its right hemisphere extension might account for such a deficit: a separate representation and organization of abstract and concrete words implies that both abstract and concrete word deficits may be expected.

A reverse concreteness effect (greater concrete than abstract word deficit) has never been reported in the literature on normal processes. However, there have been a small number of such reports in the brain injury literature (Breedin, Saffran & Coslett, 1994; Warrington, 1981; Warrington & Shallice, 1984). Warrington (1981) is the only study located to report such an effect in reading. Consistent with deep dyslexic performance, Warrington's patient was unable to read nonsense syllables and had difficulty with phonological transformations; however, his responses tended to be more abstract than the stimuli. The patient also showed a frequency effect across both abstract and concrete words but no grammatical category effect. Warrington placed the locus of the deficit at the semantic system rather than at an output level, since the patient also had difficulty comprehending the words he was unable to read. Warrington concluded that the occurrence of both abstract and concrete word deficits is evidence of categorical organization in the semantic representation of written words.

A few investigators (Breedin, Saffran & Coslett, 1994; Plaut & Shallice, 1993) have proposed alternative explanations of the reverse concreteness effect. Plaut and

Shallice (1993) simulated the effect of superior abstract versus concrete word reading on a network model by lesioning different parts of the model. On the basis of the simulation they argued that it is possible to account for abstract word deficits within a single system. Breedin and colleagues (1994) proposed that abstract and concrete words differ in their perceptual properties. They demonstrated a reverse concreteness effect on word definition, word-picture matching and a synonymy task in a patient with progressive semantic loss and surface dyslexia. The investigators proposed that the patient's concrete word impairment was due to a greater loss of perceptual versus non-perceptual aspects of word meaning.

Some investigators (e.g., Friedman, 1996) predict that a concreteness effect will always be accompanied by a grammatical class effect because they both reflect deficits in the semantic pathway. Similarly, Jones (1985) predicts that both concreteness and grammatical category effects can be attributed to "ease of predication". According to Jones, words that easily generate predicates have widely distributed features in semantic memory and are also highly imageable. Both concreteness and grammatical category effects can be obliterated by controlling for this variable. Other investigators (e.g., Caramazza & Hillis, 1991) predict that grammatical category effects may occur in the absence of concreteness effects, since grammatical category represents an organizational principle of the lexicon independent of concreteness. Concreteness effects in the absence of grammatical category or other effects are consistent with concreteness reflecting distinct organizations of the two types of words (e.g., Bleasdale, 1987; Saffran et al. 1980; Warrington, 1981). If, however, concreteness effects can be attributed to number or distribution of semantic features (e.g., Jones, 1985; Plaut &

Shallice, 1993; Tyler et al. 1995), then a single organization for the two types of words is the most likely explanation. The latter view is compatible with the view of Caramazza and Hillis (1990), who proposed that word frequency and grammatical class have a computational role in the phonological output lexicon but that semantic category simply reflects properties of the arrangement among lexical components.

2. Imageability:

Related to concreteness is the concept of imageability, defined as the extent to which a word elicits a visual image (Paivio et al. 1968). Not surprisingly, concreteness and imageability (or imagery) are shown to correlate strongly (Paivio, 1968; Rubin, 1980; Toglia & Battig, 1978) and to form a single factor (Paivio, 1968; Rubin, 1980). Paivio (1968) viewed concreteness and imageability as alternative measures of the image-arousing quality of verbal material. The close relationship between the two may be why most investigators appear to use them interchangeably.

Nevertheless, the concreteness and imageability distributions in the Paivio et al. (1968) scaling study did not completely overlap. Words with higher imageability than concreteness scores tended to have strong emotional connotations (e.g., *fun, mood, sadness*).[16] This finding is interesting in view of indications that imageability is a stronger predictor of verbal learning and recall than concreteness (Paivio, 1968; Rubin, 1980; but see Richardson, 1975, for an opposite view).

Some evidence that imageability is a stronger variable than concreteness comes from the reading literature. Baddeley, Ellis, Miles and Lewis (1982) found that in

[16] The implications of this point are discussed more fully in the section on Pleasantness.

developmentally dyslexic boys and their age-matched controls, high imageability words were more likely to be read correctly than low imageability words of the same frequency. The investigators used high- and low-imageability words, balanced for length, frequency, and interestingly, concreteness. The two lists that resulted were both fairly abstract (e.g., *profit, revolt* vs. *patent, reason*). The finding of an imageability effect in these words underscores the importance of imageability as a variable in its own right. Possible differences between concreteness and imageability have not been systematically investigated in the reading literature.

3. Pleasantness:

Of the variables pertaining to emotional factors, pleasantness has been included in most of the scaling studies (Brown & Ure, 1969; Toglia & Battig, 1978). Toglia and Battig (1978) defined pleasantness simply in terms of whether a word evokes a pleasant feeling or an unpleasant one. They hypothesized that the relative independence of pleasantness from the other variables in their study was due to pleasant and unpleasant words representing "emotional" as opposed to "neutral" words.

Brown and Ure (1969) measured the variables of emotionality and goodness in addition to pleasantness and found that emotionality and pleasantness correlated highly with each other. Moreover, good, pleasant, concrete and frequent words were rated as easy to associate to. Rubin (1980) found that goodness and pleasantness formed a single factor and emotionality a separate one. As expected, goodness and pleasantness were nonlinear. In fact, pleasant and unpleasant words fell into two separate factors in the Toglia and Battig (1978) scaling study.

The preservation of emotional language in aphasia, even in severely impaired patients, has been noted by Hughlings Jackson (Taylor, 1932). Emotional factors have been neglected in the aphasia literature, however. Some evidence for the role of such factors in reading comes from a developmental dyslexia study. Van Strien, Stolk & Zuiker (1995) showed that dyslexic children classified as using either a predominantly left-hemisphere or right-hemisphere reading strategy (on the basis of their reading errors) made different types of errors when reading anxiety-laden or neutral words presented to the right or left visual field. Despite questions that the study raises concerning the validity of the dyslexic classification and the postulated contribution of different neuroanatomical areas to reading, the finding of a reading facilitation in the left-hemisphere strategy group of dyslexic children using emotional words is of theoretical interest.

C. Associative aspects:

1. Meaningfulness and Number of Attributes (NOA):

Toglia and Battig (1978) defined meaningfulness as the capacity of a word to arouse other words as associates. High meaningfulness words, e.g., *sad*, were words rated as easily associated with other words; low meaningfulness words, e.g., *coal*, were words rated as associated only with difficulty or not at all. Paivio, Yuille and Madigan (1968) measured meaningfulness more directly by giving subjects 30 sec. to associate to each word.

Toglia and Battig (1978) also obtained ratings on number of attributes or features (NOA). Words with high NOA ratings, e.g., *fate*, were words judged as having many attributes, whereas words with low NOA ratings, e.g., *mat*, were words judged as having few attributes. Brown and Ure (1969) defined associative difficulty (AD) in terms of how quickly and easily a word evokes a large number of words and ideas or whether few associated ideas are available and they come to mind slowly. Note that this definition has elements common to both the meaningfulness and the NOA definitions of Toglia and Battig (1978).

Meaningfulness and NOA are shown to correlate highly with each other (Toglia & Battig, 1978). Moreover, meaningfulness correlated more with imageability than with concreteness in the Paivio et al. (1968) scaling study.[17] Paivio and colleagues observed that many items low in concreteness and imageability were high in meaningfulness (e.g., *greed*), but never the other way around. According to the investigators, the asymmetrical relationship between concreteness/imageability and meaningfulness is because abstract words derive their meaning through verbal associates whereas concrete words are associated with both sensory and verbal associate experience.

NOA also relates to Jones' (1985) concept of ease of predication, the number of features associated with a given word. Jones (1985) asked subjects to rate the words common to the studies of Paivio, Yuille and Madigan (1968) and Brown and Ure (1969), defining ease of predication as the ease of putting words into simple factual statements. Ease of predication scores are closely related to the imageability of the words (neither study had NOA measures but Brown and Ure had AD measures). The scores also varied according to grammatical category: nouns had higher scores than

[17] The investigators attributed this difference to the existence of evaluative emotional items with higher imageability than concreteness ratings. The discrepancy between imageability and concreteness has been discussed in the section on imageability.

adjectives, adjectives than verbs, and verbs than functors. Allport (1985) showed that concrete words are organized as associative networks with interconnected features as a function of their frequency of co-occurrence. Abstract words, on the other hand, are more context-dependent, similar to verbs.

The importance of associative measures in aphasic reading has been addressed to some extent by network models and simulations (e.g., Plaut & Shallice, 1993). Associative measures have been neglected in studies of actual aphasic performance. Only one study employed associative measures in addition to a range of other variables (Barry & Richardson, 1988). The investigators examined the effects of a number of word attributes (frequency, concreteness, syntactic class, length, emotionality, pleasantness, goodness, associative difficulty) on the reading of a nonfluent, deep dyslexic patient. An analysis of covariance on correct responses employing the single factor of syntactic class and using the other seven variables as covariates showed that syntactic class had no effect at all on reading performance when the other variables were statistically controlled.[18] A stepwise multiple regression showed that associative difficulty, concreteness and frequency each had significant predictive capacity (but length and the emotion-related variables did not).

Network models of lexical organization (including PDP models) are compatible with the co-occurrence of frequency and associative effects, as frequency is intimately linked to number and strength of connections between units. Serial search models

[18] Syntactic class had seven levels: noun, noun/verb, verb, verb/noun, adjective, adjective/other and other.

provide no explicit mechanism for linking frequency to learning, though for such models frequency represents an organizational principle of the lexicon.

D. Lesion localization issues:

Luria (1980) proposed that neural systems in the left temporal lobe play a critical role in the production of nouns whereas neural systems in the left frontal lobe are crucial for the production of verbs.

Nevertheless, linking grammatical category impairments to site of lesion is difficult for two reasons. First, many studies do not provide neuroanatomical information. Second, those that do are difficult to interpret because patients typically have widespread lesions (e.g., Caramazza & Hillis, 1991; Glosser & Friedman, 1990; Goodglass, Christiansen & Gallagher, 1993; Zingeser & Berndt, 1988; 1990).

A small number of naming studies, however, specifically examined patients with focal lesions. They have shown that patients with superior action naming (naming of pictures depicting actions) to object naming (naming of pictures depicting objects) have lesions in the temporal lobe (Damasio & Tranel, 1993; Daniele et al. 1993; Miozzo et al. 1994). Conversely, patients with superior object to action naming have left frontal damage (Ardila & Rosselli, 1994; Damasio & Tranel, 1993; Daniele et al. 1993). These naming deficits can be found even in the absence of other language deficits (Damasio & Tranel, 1993). The above studies are consistent with the hypothesis that separate neuroanatomical systems mediate the processing of nouns and verbs. The occurrence of such deficits can be independent of aphasia or agrammatism.

Some evidence that the brain processes nouns and verbs through different neural populations also exists in studies on normal subjects. Using silent reading of nouns and verbs, Koenig and Lehmann (1996) found that event related potential (ERP) maps of the nouns and verbs differed significantly. Nevertheless, it is difficult to assign anatomical structures to these neural populations through ERP maps.

Linking concreteness effects to site of lesion is difficult for reasons similar to those for grammatical category: patients tend to have very extensive lesions (e.g., Klein et al. 1994; Laine, Niemi, Niemi & Koivuselka-Sallinen, 1990). Two of the three patients with reverse concreteness effects reported in the literature (Breedin et al. 1994; Warrington & Shallice, 1984) showed bilateral lesions in the temporal lobes, one due to herpes simplex encephalitis and the other associated with mild dementia. The third patient (Warrington, 1981) showed a left-hemisphere temporal-parietal-occipital lesion due to a glioma.

c. Recapitulation:

1. Which word characteristics influence aphasic reading?

As shown in the Introduction, an effect of a given variable, such as grammatical category or frequency, may be attributed to concomitant variations in other variables. Controlling for only those variables considered "critical," those which most studies control for (e.g., frequency and concreteness), overlooks other variables shown to be important in the literature on reading of normal subjects. Moreover, it is possible that a combination of variables rather than a single variable account for aphasic reading performance. A multiple regression approach permits the simultaneous consideration of the contributions of a number of theoretically important variables. Such an approach has been used to a very limited extent in the aphasia reading literature.

2. Do different word characteristics account for the performance of different types of aphasics (e.g., nonfluent versus fluent aphasics)?

This question is of theoretical importance for conceptualizing ways in which nonfluent and fluent aphasics differ. Different variables may account for the reading performance of nonfluent and fluent aphasic patients, or groups of patients using neuroanatomical criteria (such as site and extent of lesion). The contribution of different variables to the reading performance of theoretically or empirically derived groups of patients has not been systematically investigated.

3. Does the performance of individual aphasics reflect the pattern of performance obtained from group data?

Analyses performed at the group level might result in loss of important information at the individual patient level. Such analyses reflect patterns that describe the majority of subjects, thereby resulting in loss of individual variability in performance. Separate analyses of individual patients, on the other hand, provide no systematic way of relating individual to group performance characteristics. The aphasia literature has favored individual analyses at the expense of being able to make predictions about patients sharing similar characteristics. Both the individual and the group level have to be addressed at the same time using the same materials in order to examine possible similarities and differences in a systematic way.

II. METHODS

A. Subjects:

1. General description:

Twenty chronic aphasic patients manifesting a variety of types of aphasia participated in this study. Aphasia was secondary to left-hemisphere cerebrovascular accident. Appendix A1 lists patients tested (partly or fully) but excluded from the study, together with the reason(s) for their exclusion and their classification, if known. No patient was excluded due to unintelligibility.

The patients were classified clinically into Nonfluent and Fluent groups. A language battery formed the basis for the clinical classification, discussed in detail in the Assessment section. Briefly, nine patients with effortful and limited spontaneous language output were placed in the Nonfluent group. Eleven patients with relatively effortless spontaneous language output were placed in the Fluent group. The patients were also rated in terms of severity of aphasia using the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1983) ordinal scale of 0 to 5 (with 0=most impaired to 5=minimally impaired).

Table 1 (a & b) provides the following information about the patients (Table 1a: Nonfluent, Table 1b: Fluent): aphasic classification, severity of aphasia, age/gender, education, occupation and time post-onset as of the date of assessment (TPO). Selected aphasia battery scores are also provided: subtests of the Boston Diagnostic Aphasia Examination (BDAE), the Boston Naming Test (BNT) and the Token Test (TT). The scores of the complete language battery are provided in Appendix A2.

Table 1a: Nonfluent patient information

	NFAG	NFHM	NFRB	NFGG	NFMA	NFBS	NFBM	NFJE	NFIT
Classification	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's
Severity	3	1	2	3	1	1	1	1	1
Age/Gender	50 F	63 M	63 M	50 F	64 M	34 F	58 M	75 F	84 M
Education	part Ph.D. (7)	part Ph.D. (7)	2 yrs Coll. (5)	1 yr Coll. (5)	CPA, LLB (7)	B.A. (6)	B.A. (6)	M.A. (7)	H.S. (4)
Occupation	Editor (freelance) (2)	Teacher Trainer (2)	Sales Rep. (steel) (3)	Medical Transcr. (4)	Tax Attorney (1)	Systems Analyst (3)	V.P./ Gen. Mgr (2)	Teacher (2)	Merch. Marine (6)
T.P.O.	9 yrs	24 yrs	10 yrs	3 yrs	5 yrs	3 yrs	3 yrs	5 yrs	9 mo.
BDAE: Cookie Theft:									
Syll/min. (rate)	75	17	18	66	23	22	29	51	18
Content units/min	14	4	4	12	2	3	6	10	1
IGS	2.76	**1.40**	**1.25**	3.15	**1.50**	**1.00**	**1.60**	**1.33**	**1.00**
Verbal Agil. (/14)	10	5	7	7	9	1	7	4	4
Word Read. (/30)	27	24	27	30	15	0	18	24	15
Sent. Read. (/10)	8	1	3	10	0	0	1	6	1
Autom. Seq. (/8)	8	4	5	8	5	3	5	6	6
B.N.T. (/60)	38	10	36	39	24	5	17	25	17
T.T. (/36)-adjust.	18.5	discont.'d	19.5	31.5	6.5	7.5	15	14	16.5

Table 1b: Fluent patient information

	FLHT	FLWZ	FLCG	FLMC	FLHR	FLRT	FLWL	
Classification	Tra-Sens.	Anomic	Anomic	Conduction	Alexia w/o Agr.	Wernicke's	Tra-Sens.	
Severity	3	2.5	3	2	5	1	3.5	
Age/Gender	69 M	74 M	73 F	69 M	63 M	61 M	70 M	
Education	alm. B.A. (5)	9 grade (2)	H.S. (4)	10 grade (3)	1.5 yr Coll. (5)	B.S. (6)	B.S. (6)	
Occupation	Retailing/ fabric des. (3)	Watch Repairs (5)	Bank Teller (4)	Salesman (3)	Co. President (large) (1)	Auditorium Mgr. (2)	Engineer/ Co. Pres. (small) (1)	
T.P.O.	2 yrs	3 yrs	2 yrs	1 yr	1 yr	3 yrs	1 yr	
<u>BDAE</u> <u>Cookie Theft</u>:								
Syll/min. (r..te)	75	95	99	68	142	123	64	
Content units/min.	10	15	14	9	27	3	5	
IGS	2.92	3.17	2.54	2.55	3.25	2.65* (paraphasias)	3.33	**incorrect words are also counted*
Verbal Agil. (/14)	14	12	8	8	14		13	*to avoid*
Word Read. (/30)	30	30	30	17	29	11	30	*classifying patient*
Sent. Read. (/10)	10	8	8	2	10	0	9	*as agrammatic*
Autom. Seq. (/8)	8	7	7	8	8	1	8	
<u>B.N.T.</u> (/60)	51	33	37	37	44	0	43	
<u>T.T.</u> (/36)-adjusted	19.5	24.5	24	28.5	36	0	23	

Table 1b: Fluent patient information (cont'd)

	FLNG	FLJM	FLHW	FLCD
Classification	Tra-S/Anomic	Tra-Sens	Wernicke's	Anomic*
Severity	3.5	3	3	3
Age/Gender	62 M	49 M	83 M	70 F
Education	M.D. (7)	B.S., J.D. (7)	11 grade (3)	H.S. (4)
Occupation	Physician-Division Head (1)	Attorney/ Judge (1)	Mgr. Cargo Shipping (2)	Admin. Assistant (4)
T.P.O.	6 yrs	4 mo.	5 yrs	7 mo.
BDAE Cookie Theft:				
Syll/min. (rate)	88	98	189	118
Content units/min.	7	9	19	9
IGS	3.00	4.40	2.91	3.18
Verbal Agil. (/14)	14	14	10	14
Word Read. (/30)	25	27	30	27
Sent. Read. (/10)	7	7	9	10
Autom. Seq. (/8)	8	8	8	8
B.N.T. (/60)	20	31	32	7
T.T. (/36)-adjusted	17.5	14.5	16	29.5

**initially Wernicke's*

As Table 1 shows, the Nonfluent group consists of five male and four female patients and the Fluent group of nine male and two female patients. The mean age of the Nonfluent group is 60 (range: 34-87) and of the fluent group, 69 (range: 49-83). Note that the Nonfluent group includes one unusually young subject, which contributed to the mean age difference between the two groups to a small degree. Nevertheless, even fluent patients excluded for failing to meet selection criteria tended to be older than nonfluent patients.[19]

Highest educational attainment and occupation were also obtained from the patients. Educational attainment was coded as follows:

1=under 7 years of schooling

2=Junior High School (7-9 grades)

3=partial High School (10-11 grades)

4=High School graduate

5=some College; Community College

6=completed 4-year College (Bachelor's degree)

7=completed graduate professional training (Master's and above)

No subject has an educational level below the 9th grade. The mean educational score of the nonfluent subjects is 6.00 (range: 4-7) and of the fluent subjects 4.5 (range: 2-7).

Occupation was coded using the Hollingshead Occupational Scale. This scale is rated from 1 to 8, where 1 corresponds to higher executive or proprietor of large concern or

[19] This observation is consistent with the finding of Obler, Albert, Goodglass and Benson (1978) of a significant age difference between Broca's and Wernicke's aphasics. Although factors such as selection bias have been raised as possible reasons for the age difference (Coppens, 1991), the fact remains that an age difference between Broca's and Wernicke's (and other fluent) aphasics is consistently reported in the literature.

major professional (e.g., engineer), 7 to an unskilled employee (e.g., cafeteria worker) and 8 to never having worked in paid employment (e.g., housewife). The mean occupational score of the nonfluent subjects is 2.8 (range: 1-6) and of the fluent subjects is 2.7 (range: 1-5). Thus, although the mean educational level of the nonfluent group is higher than that of the fluent group, the two groups have the same mean occupational attainment. The education and occupation codes for the patients are provided in Table 1 (in parentheses), below the education and occupation descriptions.

The 13 patients for whom CT and/or MRI scans were available were also classified neuroanatomically in two groups on the basis of the scans: a Mixed group and a Posterior group. This classification is independent of their clinical classification and is discussed in detail in the Lesion Analysis section. Briefly, nine patients with lesions involving brain structures on either side of the central (Rolandic) sulcus were placed in the Mixed group. Four patients with lesions involving brain structures posterior to the central sulcus were placed in the Posterior group. No patient had a lesion strictly anterior to the central sulcus. The patients were also rated for overall size of lesion after Damasio and Damasio (1989) on a scale of 1 to 3 (1= lesion occupying 25 percent or less of the affected lobe(s), 2= lesion between 25 and 75 percent and 3= lesion over 75 percent).

Following Kirk and Kertesz (1994), patients were rated as having had no hemiparesis ever as per medical records (0); as having completely recovered from hemiparesis, that is, no hemiparesis being present at the time of assessment (1); or as having mild-moderate (2) or severe (3) hemiparesis.[20]

[20] Kirk and Kertesz (1994) actually used a five-point scale, classifying severity into mild (2), moderate (3) or severe (4). This level of detail is not necessary for the present investigation.

Table 2a provides the following information about the patients, grouped by site of lesion (Mixed, Posterior): lesion size, hemiparesis status (HP), number of tactile errors (hand, face) based on the Reitan-Klove Sensory Perceptual Examination and etiology of CVA (I=infarct (ischemic/embolic), H=hemorrhage). For purposes of comparison with the clinical information shown in Table 1, diagnostic classification and severity of aphasia are also included. Table 2b provides the same information for patients without scans available. Lesion information for individual patients with scans available is provided in Appendix A3. Brief medical histories for each patient are provided in Appendix A4.

As Table 2a shows, the four nonfluent patients for whom there is lesion information fall in the Mixed (Anterior/Posterior) group. The Posterior group consists entirely of fluent patients; however, fluent patients fall both in the Mixed and the Posterior group. No aphasic patients were located with lesions restricted to the frontal lobe.

Table 2a: Patients by Site of Lesion

MIXED

	FLWZ	NFAG	NFBM	NFGG	NFHM	FLCG	FLRT	FLJM	FLNG
Classif.	Anomic	Broca's	Broca's	Broca's	Broca's	Anomic	Wernicke's	Tra-Sens.	Tra-S./An.
Sever.	2.5	3	1	3	1	3	1	3	3.5
Size	1 (prim. ant. subcort.)	3 (F-T-P)	2 (F-T)	1 (F-T)	2 (F-T-P)	2 (F-T)	2 (F-T-P)	1 (F-T-subcort.)	2 (subcort. ant., post.)
HP	2	3	3	3	1	1	1	3	3
Tactile errors (hand, face) /48	0	16 R	16 R	0	2 R	3 R 1 L	2 R	0	16 R
Etiology	I	I	I	I	I	I	I	I	H

POSTERIOR

	FLHR	FLMC	FLCD	FLHW
Classif.	Alexia w/o Agr.	Conduction	Anomic	Wernicke's
Sever.	5	2	3	3
Size	1	1	1	1 *
HP	0	0	1	0
Tactile errors (hand, face) /48	1 L	4 R	0	0
Etiology	I	I	H	H

Table 2b: Patients without scans

	NFRB	NFMA	NFBS	NFJE	NFIT	FLHT	FLWL
Classif.	Broca's	Broca's	Broca's	Broca's	Broca's	Tra-Sens.	Tra-Sens.
Sever.	2	1	1	1	1	3	3.5
Size	N/A	N/A (F-T-P)	N/A	N/A	N/A	N/A (T-O)	N/A (P)
HP	3	1	3	2	2	0	0
Tactile errors (hand, face) /48	20 R	0	6 R	0	5 R	0	1 R
Etiology	N/A	I	I	N/A	I	I	H

2. Inclusion criteria:

Patients were recruited from a variety of sites, including hospitals, rehabilitation centers and private practices. All available patients satisfying the inclusion criteria were considered for the study. The following criteria are discussed in detail in the Assessment section.

1. All patients had suffered a single, unilateral, CVA causing a measurable neurologic deficit.

2. Patients were a minimum of four months post stroke-onset at the time of testing.

3. All patients were native speakers of American English, without significant exposure to another language prior to the age of 13 (as through a non-English home environment). Otherwise, extensive knowledge of another language was not cause for exclusion.

4. All patients were right-handed premorbidly, right-handedness being defined as obtaining a score of at least 17/20 on the Edinburgh Handedness Inventory.

5. No patient showed evidence of dementia.

6. No patient had suffered serious head trauma/neurological damage other than the CVA.

7. No patient had significant uncorrected visual and/or hearing impairments that interfered with the assessment.

B. Stimuli and equipment:

1. Stimuli:

Stimuli consisted of 135 single monosyllabic words, ranging from three to five letters in length. Of these words, 134 began and/or ended in a stop consonant (e.g., bath, mat, beg). The stop consonants were balanced for voicing. Thirty of the words contained consonant clusters in word-initial or word-final position (e.g., *greet*, *ghost*).

Of the 135 words 52 were nouns, 30 were verbs, 19 were adjectives, one was a functor and 33 were words that can be used as both nouns and verbs ("noun/verbs"). Grammatical category was determined using the Francis and Kučera (1982) norms, which provide frequency information for each grammatical category a word belongs to. The words, listed by grammatical category, are given in Appendix B1.

The same words also received ratings for the following measures: frequency and frequency-related measures; semantic and associative measures; phonological measures; and orthographic measures. The measures are described in detail below:

a. Frequency and frequency-related measures:

1. Written Frequency was determined using Francis and Kučera's (1982) count, which is based on a corpus of approximately one million words of running text from 500 publications of a wide variety. The count provides both the total frequency of the lemma and frequencies of inflected forms of the lemma (including the base form). Frequencies of words belonging to more than one grammatical category are provided separately for each category (e.g., *cure* as a noun and as a verb). Using this count, the frequency of the particular form of the stimulus word (which in most

cases is the base form) was calculated. A second written frequency measure corresponding to the total frequency of the lemma was also calculated.[21]

2. Written frequency for school-age children is determined from The American Heritage Word Frequency Book (Carroll, Davies & Richman, 1971). This count is based on a corpus of approximately five million words of running text from over 1,000 different publications for school-age children (for grades 3-9). The corpus is considered to represent the printed language of the American elementary educational system of that era. The Heritage count also lists the frequency of each inflected form of a lemma separately. Unlike Francis and Kučera's (1982) count, however, it does not provide frequencies for words as members of different grammatical categories. As in the previous count, both the frequency of the particular form of the word and the total frequency of the lemma were obtained.
3. Spoken Frequency was determined using Brown's (1984) publication of the London-Lund corpus, which is based on approximately 190,000 words of surreptitiously recorded conversations of educated native speakers of British English. The spoken frequency of the particular form of the stimulus word was obtained using this count.[22]

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[21] Lemma refers to the morphological family of a word as opposed to the particular form of a word (lexeme). Obtaining a total lemma frequency aims to address findings that inflected forms of words contribute to the perceived frequency of a word (Lukatela, Gligorijevic, Kostic & Turvey, 1980) and affect the speed and accuracy of recognition of stems (Nagy, Anderson, Schommer, Scott & Stallman, 1989).

[22] On inspection, the stimulus words of the present investigation were typical of both British and American English. The only exception might be the word "lad", which appears to be more typical of British English. Nevertheless, both its British spoken frequency and its American written frequency are similarly low.

4. Age of Acquisition (AOA) was taken from Harris and Jacobson's (1972) Basic Elementary Reading Vocabularies, a reading vocabulary corpus based on 127 elementary school textbooks for the first six grades (including pre-primer and primer). The corpus lists each word under the grade in which it first appears in the textbooks. Based on the reading vocabularies, each stimulus word was assigned a grade (K-6).
5. Familiarity was taken from Toglia and Battig's (1978) Semantic Word Norms. It is a rating of how common or familiar a word is, on a scale of 1 (low) to 7 (high).

b. Semantic and associative measures were derived from Toglia and Battig's (1978) norms, scaled from 1 to 7.

1. Concreteness, a measure of the extent to which a word refers to concrete objects that can be experienced by our senses.
2. Imagery, a measure of the extent to which a word can arouse a mental image.
3. Meaningfulness, a measure of the ease with which a word can be associated with other words.
4. Number of Associates, a measure of the whether a word has many or few attributes or features.
5. Pleasantness, a measure of whether a word evokes a pleasant or unpleasant feeling.

c. Phonological Measures:

1. Length: Number of letters (3-5).
2. Presence of consonant cluster: Whether a word begins or ends in a consonant cluster.

d. Orthographic Measures:

1. Bigram Frequency, a measure of how frequently a letter pair appears in a specific position within a word of a certain length, indicating how orthographically common the spelling pattern of a word is. The measure was obtained from Solso and Juel's (1980) count of bigram frequencies of two-through-nine-letter words from the Kučera and Francis (1967) frequency count of about one million words. Bigram frequency is derived by adding all the bigram frequencies of a particular word and by dividing the sum total by the number of bigrams of the word. For example, the total bigram frequency of "bead" is: be(3213) + ea(3613) + ad(1198) =8024. The average bigram frequency of the word is 8024/3= 2675.
2. Neighborhood size, a measure of the number of words that are orthographically similar to the stimulus word. Using the N-metric (Coltheart et al. 1977), a word's neighborhood consisted of all the words resulting from a one letter change of that word (keeping letter position constant). This was achieved via computer program (part of the MRC Psycholinguistic Database, compiled by Coltheart and available on the internet via anonymous ftp). For example, the neighbors of "dull" are: *bull, cull, full, gull, hull, lull, mull, null, pull, dell, dill, doll, dual, duel, duly* (N= 15).
3. Consistency, a measure of the extent to which a word is pronounced in a manner consistent with its neighbors. It was calculated as the ratio of number of enemies over number of rhyme neighbors of a word. For this measure, a subset of the total number of neighbors was used: those words which shared the rhyme with the stimulus word but differed in onset. In the above example, the subset of the total

neighborhood of "dull" consists of: *bull, cull, full, gull, hull, lull, mull, null, pull* (N= 9). The underlined words are enemies because their pronunciation is inconsistent with that of the stimulus word. The consistency ratio is thus 3/9.

Appendix B2 provides the orthographic values of the stimulus words, listed by word length.

2. Equipment:

The sessions were recorded onto high-quality cassette tape using a Sony WM-D6C Professional Walkman and a Sony 6 EMC 909 microphone.

When results of recent hearing tests were not available, hearing screenings were conducted using a Groson-Stadler 17 (GSI 17) portable audiometer.

C. Procedure:

1. Assessment:

The following battery of tests provided information on aphasic type and severity of impairment:

a. Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1983):

Picture description:	Cookie Theft
Fluency:	Verbal Agility
Automatic speech:	Automatized Sequences
Repetition:	Repetition of Words
	Repetition of Phrases (High & Low Probability)
Auditory comprehension:	Word Discrimination
	Body-Part Identification

	Commands
	Complex Ideational Material
<u>Naming</u>:	Responsive Naming
<u>Oral Reading</u>:	Word Reading
	Oral Sentence Reading

b. <u>Boston Naming Test</u> (60 item version, Kaplan, Goodglass, & Weintraub, 1983).

c. <u>Token Test</u> (short form: DeRenzi & Faglioni, 1978).

Following BDAE criteria, patients classified as Broca's aphasics had lower fluency and severity of aphasia scores than auditory comprehension and naming scores. Patients classified as Wernicke's aphasics had lower auditory comprehension, severity and naming scores than fluency scores. Patients classified as Anomic aphasics had poor word finding ability but high fluency, auditory comprehension and severity scores. Patients classified as Conduction aphasics had low repetition scores, especially at the sentence level, with superior auditory comprehension. Patients classified as Transcortical Sensory aphasics had relatively preserved repetition in the context of features like those of Wernicke's aphasia. There were nine patients classified as Broca's aphasics, two as Wernicke's aphasics, three as Anomic aphasics, one as Conduction aphasic, four as Transcortical Sensory aphasics and one as having Alexia without Agraphia. Note that three of the nine Broca's aphasics (NFBS, NFHM, NFJE) had average Comprehension scores below the 50^{th} percentile. According to the BDAE, the 50^{th} percentile represents an arbitrary cutoff below which Broca's aphasics can be classified as Mixed Nonfluent. Moreover, the four Transcortical Sensory aphasics had features of a mild Wernicke's aphasia, rather than a severe Wernicke's aphasia that the BDAE predicts for such patients.

Consistent with BDAE criteria, Broca's aphasics were classified as Nonfluent, and Wernicke's, Anomic, Conduction, and Transcortical Sensory aphasics as Fluent. To measure fluency, the BDAE also uses the criterion of phrase length, defined as the longest number of words occurring in approximately every 10 starts (the scale ranges from one to seven). Phrase length was measured for each patient using the Cookie Theft description task (which was recorded). Nonfluent patients had smaller phrase lengths than Fluent patients, on average. A few exceptions were observed, however. The two Broca's aphasics who were less impaired and non-agrammatic (NFAG, NFGG) had phrase lengths of seven words or more (see Index of Grammatical Support section that follows for determining agrammatism). According to the BDAE, Broca's aphasics who are less impaired (e.g., with a severity score of 3) lose many of the distinctive characteristics of Broca's aphasia and their articulation and fluency approach normal levels. In addition, one agrammatic Broca's aphasic with a severity score of 2 (NFRB) was able to produce phrases of up to seven words; however, he did so during informal conversation on a topic of interest to him and not during Cookie Theft description. All Fluent patients consistently produced phrases of at least seven words, with the exception of FLMC, a Conduction aphasic; he produced a maximum of five words, interrupting his phrases often during his phonological approximations of the words. Note that the BDAE does not contain a cut-off criterion for classifying patients in terms of fluency.

Degree of severity of aphasia was assessed using the BDAE scale of 0 to 5 (with 0 corresponding to "No usable speech or auditory comprehension" and 5 to "Minimal discernible speech handicaps...").

Three indices were derived from the Cookie Theft description task: Syllables per Minute, Content Units per Minute and Index of Grammatical Support (IGS). The values of the three indices are provided in Table 1 under Cookie Theft. They were calculated as follows:

Syllables per Minute was estimated following the procedure of Yorkston and Beukelman (1980). The total number of syllables produced by the patients was multiplied times 60 and was divided by the total time (in sec) it took the patient to describe the picture. This is an index of the rate of speech of the patient.

Content Units per Minute was also estimated following the procedure of Yorkston and Beukelman (1980). The number of content units was multiplied times 60 and was divided by the total time (in sec) it took the patient to describe the picture. The content units counted in the present study are the ones listed by the investigators. Following their procedure, each content unit was counted once. This is an index of the information rate provided by the patient.

Index of Grammatical Support (IGS) was estimated following the procedure of Menn, Ramsberger and Helm-Estabrooks (1994). The total number of correct words found in content units was counted and added to the total number of correct endings attached to these words. The sum was divided by the number of content units. No index was computed if there were no content units. Note that a content unit can consist of a single word (e.g., "washing") or of a group of words (e.g., "falling over"). For purposes of consistency with the other measures, Yorkston and Beukelman's (1980) list of content units was also employed. The Index of Grammatical Support was used as a measure of the presence of agrammatism. Menn and colleagues (1994) showed that the IGS is generally lower for Broca's aphasics than for fluent aphasics. Table 1 lists the IGS of all the patients, shown in bold for those who are agrammatic. Patients who were agrammatic obtained IGS scores of 1.60 and lower (1.00 being the lowest score possible); non-agrammatic patients (fluent and non-fluent) obtained IGS scores of 2.54 and higher. Two nonfluent aphasics were non-agrammatic. Thus, the two groups were clearly separate on this measure.

Appendix A5 provides two scoring examples for all three ratios, one from a nonfluent, agrammatic patient and another one from a fluent, non-agrammatic patient.

In addition to the language battery, a set of tests aiming to screen for specific deficits were administered. The tests were:

a. Mini Mental State Examination (MMSE)-(Folstein, Folstein & McHugh, 1975)

b. Modified NIH Stroke Scale: visuospatial neglect items

c. Reitan-Klove Sensory Perceptual Examination (SPE): tactile, auditory and visual sections

d. Edinburgh Handedness Inventory (Oldfield, 1971)

The MMSE provides a screening measure for dementia. This scale was often administered with modifications, as the presence of aphasia interfered with successful performance. It is, therefore, interpreted qualitatively.

Visuospatial neglect items from the modified NIH Stroke Scale were employed to screen for the presence of unilateral visual inattention, which would interfere with the reading tasks. The section consisted of a line bisection task, letter and line cancellation tasks, figure copying tasks and compound word reading tasks. Consistent with Schenkenberg, Bradford and Ajax (1980), two scores were obtained for the line bisection task: one for the number of unmarked lines and a second one for deviation from center, computed in terms of cm away from center. As expected for left-hemisphere-damage patients, no patient showed the presence of neglect in these tasks.

The SPE (tactile, auditory and visual sections) allows for the detection of gross hemisensory or visual field defects (such as homonymous field cuts). Such defects can provide important information concerning site of lesion, especially when CT or MR scans are absent.

Handedness ratings were obtained from the Edinburgh Handedness Inventory. This inventory requires the patients to demonstrate certain movements with their preferred hand such as writing, eating with a spoon, etc. For those patients with hemiparesis, information was obtained from interview, stressing that the questions applied to premorbid hand use. Patients showing right-hand preference in 17 out of the 20 items were considered right-handed.

Hearing status was obtained from the patients' medical records if a hearing test had been administered within two years of testing. Otherwise, a hearing screening was conducted by the experimenter using a portable audiometer. Subjects were tested for threshold in the following frequencies: 500 Hz, 1 kHz, 2 kHz, 3 kHz, and 4 kHz following standard audiometric procedures (Woodford, 1993). No subject scored below 40 dB in the 500 Hz to 2 kHz range, the range considered the most important for speech perception (Moore, 1988). Visual acuity (with the use of glasses) was assessed informally during the modified NIH Stroke Scale reading tasks. Subjects requiring glasses to read wore them during testing.

Testing typically took place over two sessions. During the first session the test battery was administered following a fixed order of test presentation. In the second session the experimental stimuli were administered for reading (and repetition). A third session was sometimes necessary for subjects who tired or did not have a period of time long enough to complete the test battery or reading tasks in a single session.

2. Stimulus administration:

The patients were recorded in a variety of settings. These included offices within hospitals, rehabilitation centers or their patients' own homes. Location selection was determined by the patient's willingness or ability to travel. This and other similar constraints resulted in many patients being recorded in their own homes.

The following stimuli were also presented to the subjects at the same time as the monosyllabic stimulus words: 32 sentences (22 of which included 11 of the noun/verb words) and 32 single disyllabic words. These stimuli are not relevant for the present study and will not be elaborated on further. They are mentioned here solely for purposes of clarifying stimulus randomization and presentation.

The stimulus words were printed in lower case form on 5 x 8 cards using non-proportional font (Courier), size 14. All word and sentence stimuli were divided into six equal parts. They were presented to the subjects blocked by stimulus type (single words, sentences). Within each block, stimuli were randomized. They were distributed into three sections, as shown below:

SECTION A	words - sentences - words - sentences
SECTION B	sentences - words - sentences - words
SECTION C	words - sentences - words - sentences

All stimuli were presented for reading and repetition in the following order:

1. SECTION A reading	4. SECTION A repetition
2. SECTION B repetition	5. SECTION B reading
3. SECTION C reading	6. SECTION C repetition

This way, all types of stimuli were presented at the beginning and the end of a given section and all stimuli were read and repeated. (Only single-word reading productions were analyzed in the present investigation).

No time limit was imposed for the reading condition. Patients were encouraged to attempt to read all words. Nevertheless, if they had made several unsuccessful attempts to read a given word, were completely unable to read it, or were very frustrated by it, they were reassured that it was all right and were allowed to proceed to the next word.

3. Lesion analysis:

Information on lesion location and extent were obtained from CT scans and/or MRIs. Scans were available for 13 of the subjects. The location and extent of lesion for each subject were assessed using the procedure described in Lesion Analysis in Neuropsychology (Damasio & Damasio, 1989). The templates provided by the authors allow the measurement of brain lesion areas from CT scans and MRIs obtained at different angles. Each set of templates corresponds to a certain angle of incidence and contains 10-13 cuts obtained at different levels at that angle. A mesial and lateral view of a left hemisphere drawing, onto which lines corresponding to the level and angle of incidence are marked, accompanies each template. The first template set corresponds to cuts obtained at the most horizontal incidence (parallel to the inferior orbitomeatal line) and the last set corresponds to cuts obtained at a 90 degree angle to the same line. The remaining four template sets correspond to intermediate incidences. The first five sets (the transverse cuts) were the primary sets used for the measurements, as most scans are taken at horizontal angles. When available, cuts at 90 degree angle (coronal cuts) were used as additional sources of localization information. Such cuts are especially useful for locating lobar boundaries and for plotting occipital lesions, as the calcarine fissure cannot be recognized from transverse cuts (Damasio & Damasio, 1989).

The lesion analysis procedure is summarized below:

a. Template selection:

To select the appropriate template, the angle of incidence of each scan was compared with each of the six sets of templates. Specifically, the left-hemisphere drawings showing angles of incidence of the templates were compared with the angle of incidence of the scan. The template matching the angle of the scan most closely was selected. Comparison of neuroanatomical landmarks between scan and template (such as ventricular shape) provided additional information for making the selection. The stage of template selection is the most crucial part of plotting because selection of the wrong angle might result in plotting a lesion on a different part of the brain than the one shown on the scan.

b. Plotting the lesion:

Once the best-fitting template set was chosen that set was enlarged, if necessary, to fit the scan cuts. Because of brain variability in size and especially width, length of cut was used as an approximate guide to determining the size of enlargement.

The lesion was charted on the template at every level at which it occurred for which there was a corresponding template cut. The correspondence between number of scan cuts and template cuts was not always exact. This is due to variations in both the thickness of the cuts in the scans and individual brain size (Damasio & Damasio, 1989). In such an event (usually with scan cuts being slightly more than template cuts), the scan cut showing the greatest extent of lesion that corresponded to the template cut was selected for plotting.

The lesion was drawn by directly superimposing the template on the scan and tracing the lesioned area (when the size and outline of the template cut matched that of the scan). Otherwise, the X/Y plotting approach, described in Damasio and Damasio (1989) was employed.

c. Making measurements:

Damasio and Damasio (1989) also provide template sets with cells of anatomical areas. These templates match exactly the templates used for charting the lesion but contain anatomical cells representing neural areas of interest. The cells are delineated by a boundary and are identified by a letter and number code. An appendix provides the neuroanatomical location that corresponds to the code. These templates were made into transparencies and were superimposed on the templates on which the lesion was plotted. The cells showing a lesion were recorded on a separate sheet.

Two types of measurements were made: overall area of lesion and extent of involvement of each neuroanatomical area. Only overall area of lesion was used in the present study. Consistent with Damasio and Damasio (1989), overall area of lesion was estimated as follows: a lesion occupying less than 25 percent of the total area of the affected lobe was assigned a score of 1; between 25 and 75 percent, a score of 2; and more than 75 percent, a score of 3. (If more than one lobe was affected, the lobe with the greatest area of lesion was measured). The score provided a gross measure of extent of lesion. Extent of involvement of each neuroanatomical area was measured the same way, except that a score of 1 to 3 was assigned to each cell rather than to the total area of lesion. The score in this case provided a gross measure of the extent of damage to each anatomical structure. To facilitate measurements, area percentages were calculated by inserting a transparent square grid, counting the number of squares occupied by the lesion at each level, and calculating the percentage in relation to the total number of squares in each area of interest.

Subcortical lesions were integrated into the present classification as follows: lesions in anterior regions of the basal ganglia and internal capsule (caudate head, anterior putamen, globus pallidus, anterior limb of the internal capsule) were classified as anterior. Lesions in posterior regions of the basal ganglia and internal capsule (posterior putamen, tail of caudate, posterior limb of the internal capsule) were classified as posterior. Subcortical areas were derived from the atlas Human Brain Anatomy in Computerized Images (Damasio, 1995), as they are not delineated in the Damasio and Damasio (1989) templates.

Five scans were randomly selected for reliability measurements. A physician familiar with the reading of scans was given an overview of the scoring method employed and was asked to select the appropriate template for each scan and to assess the extent of lesion using the same scale (for each lobe affected and overall). There was 100 percent agreement in both template selection and in estimation of lesion size. Appendix A3 provides two examples of plotted and scored scans in addition to lesion information.

D. Data coding and statistical analysis:

1. Error coding:

The reading productions of the aphasic patients comprised the corpus of the study. They were scored in terms of phonological similarity to target, as follows:

All patient productions were transcribed from audiotape by the investigator and were coded according to a four-point scale. Broad phonetic transcriptions of the productions were employed to make this judgment. A word was divided into an initial consonant (or consonant cluster), a middle vowel and a final consonant (or consonant cluster). A production received a score of "1" if all three parts were produced correctly; a score of "2" if two of the three parts were produced correctly; a score of "3" if one of the three parts was produced correctly; and a score of "4" if no part was produced correctly. A part was considered correct if it corresponded to its target, perceptually. Incorrect productions receiving a score of "2" or "3" consisted of consonant substitutions, deletions or insertions, vowel errors, morphological errors that preserved part of the word and syllable insertions that preserved part of the word. Successive approximations (*conduit d' approche*) that included the target word received a score of

"2" in order to differentiate between words produced correctly immediately and words produced correctly after one or more attempts. As a convention, however, correct productions that included additional words such as articles or comments were given a score of "1". Incorrect productions receiving a score of "4" included no verbal response, indications that the patient was unable to respond, and words with no phonological relationship to target such as semantically unrelated words, synonyms, neologisms, comments or descriptions of the words.

Table 3 below provides examples at each level of error:

Table 3: Scoring examples

1	Production same as target, perceptually Productions including the target word: robe→*a robe* post→*post them* god→*good god*
2	bean→***mean*** beg→***bed*** deck→***duck*** lick→***stick*** sad→***tsad*** frock→***rock*** guest→***guetst*** coast→***ko*** weep→***weeping*** greed→***greedy*** best→***bendix***
3	frog→***prock*** god→...***dead*** base→***bank*** rope→***broke*** stop→***tak*** lid→***in*** lid→***later*** beep→***weeping***
4	No verbal response goal→***belar*** vote→***special name, every day, many many years*** deaf→***hearing .. what?*** Wed→***married*** stop→***taxi***

If more than one response was provided, the production closest to the target was scored. Examples were: got→*[kʌtk], [kæ], [<u>kat</u>] .. [kat]* (score of "2"); gull→*[haki] .. no, no, no, fly .. OK [<u>gɔlts</u>]* (score of "3"). As already mentioned, in the event the series contained the target word, however, the production was still assigned a score of "2" (e.g., lack→*<u>lack</u>, [lak], lack, lapid).*

Eleven percent of the productions of each patient (the same words from each patient) were selected for reliability purposes. The stimulus words were semi-randomly selected, ensuring that three-letter, four-letter and five-letter words (which contained consonant clusters) were included and that an equal number of words was included from each of the three reading sets. The productions were recorded onto a tape and were transcribed by a speech scientist (KH). The transcriptions were, in turn, coded using the four-point scale by a different speech scientist (VT). Coding agreement between the investigator and VT was calculated using Cohen's kappa (Cohen, 1960), a measure of agreement for nominal and ordinal measures which corrects for chance agreement between raters.[23] The kappa value was .72, which is consistent with conventional measures of reliability.

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[23] Kappa reflects proportion of agreement after chance agreement is removed from consideration. The upper limit of kappa is +1.0 and the lower limit is between zero and -1.0, depending on the distribution of judgments by the two judges. The use of chi-square for the evaluation of agreement between judges is inappropriate because chi-square tests the null hypothesis with regard to association, not agreement. Consequently, chi-square is inflated by any departure from chance association, either disagreement or agreement. A significant chi-square, thus, implies that the judgments are associated but not necessarily in the direction of agreement (Cohen, 1960).

2. Data analysis:

a. Measures:

The word production scores (1-4) formed the outcome (dependent) measure. The predictor variables, described in the Stimuli section, are summarized below:

Predictor variable:	Unit of Measurement:
Frequency and frequency-related measures:	
1. Written Frequency (WFREQ)	no. of entries (in 1 million)
2. School-age written frequency (HERIT)	no. of entries (in 5 million)
3. Spoken Frequency (SFREQ)	no. of entries (in 190,000)
4. Age of Acquisition (AOA)	grade level (K=1 to 6=7)
5. Familiarity (FAM)	1 (low) to 7 (high)
Grammatical category	
nouns, verbs, adjectives, noun/verbs	dummy coded
Semantic and associative measures:	All: 1 (low) to 7 (high)
1. Concreteness (CON)	
2. Imagery (IMG)	
3. Ease of Association (Meaningfulness) (EOA)	
4. Number of Associates (NOA)	
5. Pleasantness (PLS)	
Phonological measures:	
1. Length (LENGTH)	3-5 letters
2. Presence/absence of consonant cluster (CLUSTER)	

Orthographic measures:

1. Bigram Frequency (BIFREQ)	total bigram freq./no. bigrams
2. Neighborhood size (NEIGH)	no. of words
3. Consistency (CONSIST)	no. enemies / no. words sharing rhyme with target

Written frequency, Heritage frequency and spoken frequency measures were computed using the lexeme of the word. With the exceptions or four words (*got, dealt, lit, could*), this corresponded to the base form of the word (e.g., *stop, weep*).

Total lemma frequency measures were also computed for written frequency and Heritage frequency. Total lemma frequency included the base form of a word and its inflections and derivations. Any lexemes differing from the lemma, however (e.g., seek: *sought*) were excluded from the count. A conservative approach of excluding compound words (e.g., bedroom) was adopted; however, this criterion does not affect the total lemma frequency much.[24] Of interest is that computing the total frequency of a word tended to affect the frequency of verbs more than of nouns (as verbs have more inflections than nouns).

For purposes of direct comparison of the frequency values, Heritage frequency was divided by 5 (as it is derived from a corpus of 5 million words) and spoken frequency was multiplied times 5.3 (as it is derived from a corpus of 190,000 words). Heritage frequencies less than 5 were not divided by 5, however, as this would result in a

[24] Nagy and colleagues (1989) showed that the critical factor affecting word recognition speed was frequency of inflectional families. Adding frequencies of derivational families resulted in a very small gain in speed.

number less than one. Out of the 135 stimulus words, 2 were not listed in the Heritage count and 71 were not listed in the Brown (spoken frequency) count. For those words a value of 1 was assigned. There were 16 words with no AOA values. The six Toglia and Battig ratings (FAM, CON, IMG, EOA, NOA, PLS) were available for 75 out of the 135 words.

A logarithmic transformation was applied to Written Frequency, Heritage Frequency and Spoken Frequency to normalize the distributions and linearize their relationships with the dependent measure. A square-root transformation was applied to Bigram Frequency.

b. Statistical analysis:

The word production scores formed the outcome measure, with the 16 predictor variables as the independent measures at the word level. Stepwise multiple regression analyses examined the independent effect of each predictor while controlling for the effects predicted in common with the other predictor variables (due to intercorrelations).

Analyses also incorporated two types of subject variables: clinical variables and neuroanatomical variables. Clinical variables were Severity, Fluency, Agrammatism and Diagnostic Category. Because of the small number of patients in each of the Fluent diagnostic groups, only two fluent subgroups were formed: one of patients with relatively poor comprehension (Transcortical-Sensory, Wernicke's) and another of patients with relatively good comprehension (Anomic, Alexic without Agraphia, Conduction).[25] Note that the variable Severity of Aphasia overlapped almost entirely

[25] An exception was made for patient FLWL, a high-functioning Transcortical-Sensory aphasic who was classified with the Good Comprehension group on the basis of his BDAE and Token Test performance.

with Agrammatism: patients with severity scores of 1 (most severe) were, with the exception of a Wernicke's aphasic, agrammatic. Neuroanatomical variables were Site of Lesion and Lesion Size. Multiple regression analyses were also performed for each individual patient to determine the independent contributions of each of the predictor variables to each patient's reading performance. The results were then compared to the group findings.

To address the question of whether total lemma frequency is a better predictor of reading performance than lexeme frequency, regression analyses were also performed using total Written and Heritage frequencies. The results were compared with those of analyses conducted using the lexeme frequencies of the two measures.

Analyses were performed three times. First, the complete set of words was employed with the 10 predictor variables that all words receive ratings on (Written, Spoken and Heritage Frequency, Age of Acquisition, Grammatical Category, Length, Consonant Cluster, Neighborhood, Consistency and Bigram Frequency). Second, the subset of 75 words containing the Toglia and Battig ratings was employed with the same 10 predictor variables, to replicate the findings in the subset of words. Third, the six Toglia and Battig variables (Familiarity, Imagery, Concreteness, Ease of Association, Number of Associates and Pleasantness) were included in the above subset to examine which remain significant predictors of performance.

III. RESULTS

A. Descriptive analyses:

1. Grammatical category characteristics of the stimulus words:

The grammatical category membership of the complete set of 135 words, as well as of the subset of 75 words, is shown in Table 4.

Table 4: Stimulus words by grammatical category

	All words		75-word subset	
	N	%	N	%
Nouns	52	38.52	34	45.33
Verbs	30	22.22	8	10.67
Adjectives	19	14.07	14	18.67
Noun/verbs	33	24.44	19	25.33
Functors	1	0.74	0	0.0

The subset of 75 words (those with Toglia & Battig ratings) has a smaller proportion of verbs than the complete set. The difference is consistent with the fact that most semantic word norms are based on words that can be used as nouns.

2. Word reading score by clinical group:

The word reading scores were examined in terms of three clinical groupings: Fluency, Agrammatism and Diagnostic Category. Fluency involves two categories (Nonfluent, Fluent), as does Agrammatism (Agrammatic, non-Agrammatic). Diagnostic

Category involves three categories (Broca's, Fluent-Poor Comprehension, Fluent-Good Comprehension).

a. Word reading score by Fluency:

The distribution of reading scores was examined separately for the Nonfluent and Fluent patients. There were 1119 productions from the nine Nonfluent patients and 1453 productions from the 11 Fluent patients, resulting in a total of 2572 productions.[26]

Figure 1: Distribution of word scores for the Nonfluent and Fluent groups

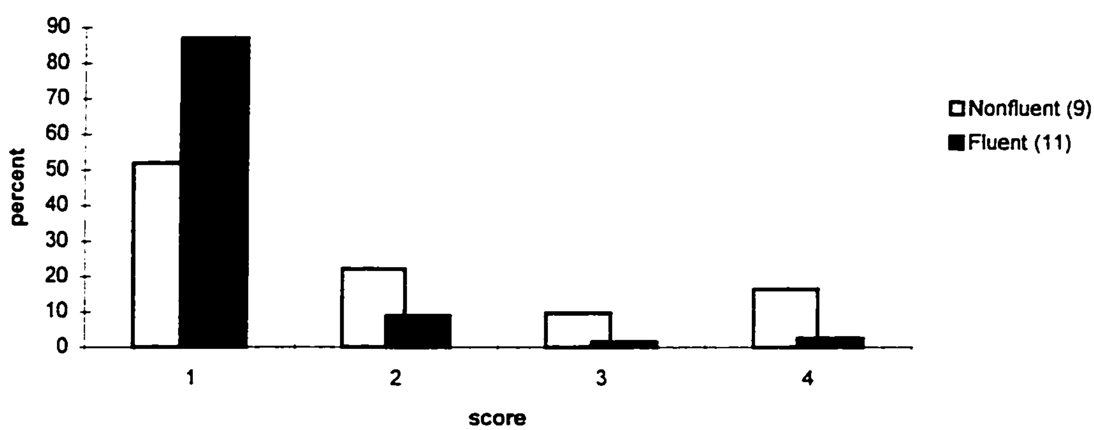


Figure 1 shows that the Nonfluent patients are more impaired in reading than the Fluent patients, as evidenced by their smaller proportion of scores of 1 (correct productions) and the greater proportions of scores of 2, 3 and 4. Within each group, however, the majority of the productions are correct (score of 1) and most errors involve a change in one out of the three parts of the word (score of 2).

[26] The reason the total number of words read is 2572 rather than 2700 (135x20) is that three Nonfluent and one Fluent patients were administered a subset of 103 words rather than the complete set of 135 words. The four patients who were administered the 103 word list were the first to be evaluated. The list was subsequently expanded to 135 words to include more verbs and adjectives.

b. Word reading score by Agrammatism:

The distribution of word reading scores was examined with respect to the presence or absence of agrammatism. The reading scores of the seven Nonfluent patients who are also Agrammatic are compared with the reading scores of the 13 patients (11 Fluent, 2 Nonfluent) who are non-Agrammatic. There were 849 productions for the Agrammatic group and 1723 productions for the non-Agrammatic group.

Figure 2: Distribution of word scores for the Agrammatic and non-Agrammatic groups

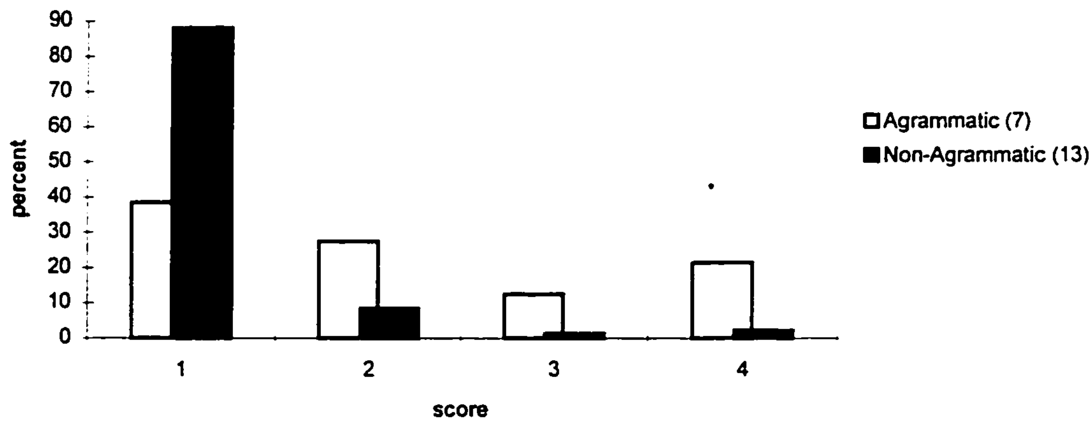
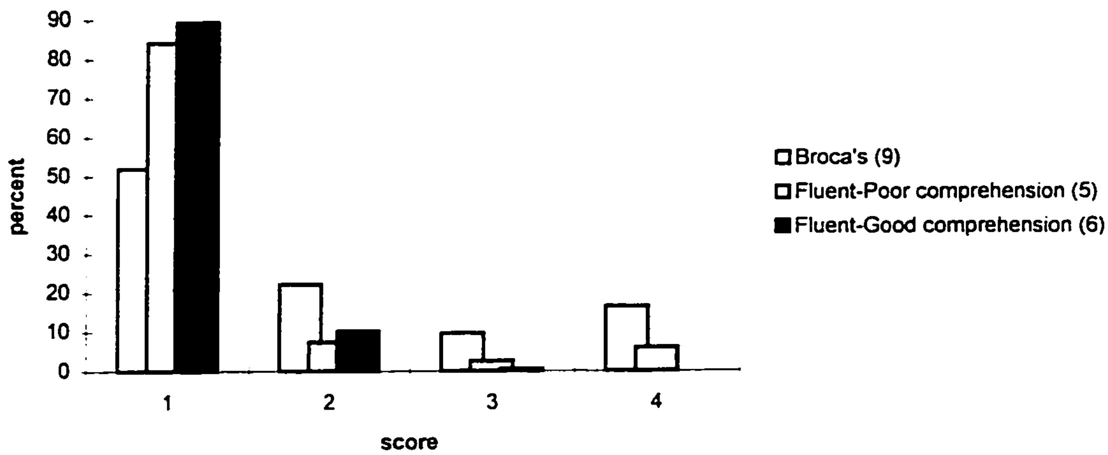


Figure 2 shows that Agrammatic patients are overall more impaired in reading than non-Agrammatic patients. A comparison of Figure 2 with Figure 1 also reveals that those patients from the Nonfluent group who are Agrammatic are more impaired than Nonfluent patients overall. Note, however, that the seven Agrammatic patients also have the most severe aphasia scores: six have Severity of Aphasia scores of 1 and one has a score of 2. Non-Agrammatic patients are (with the exception of one patient) much less impaired. Percentages of scores under each scoring category for the patients classified by Fluency and Agrammatism are provided in Appendix C1.

c. Word reading score by Diagnostic Category:

The distribution of word reading scores was examined with respect to Diagnostic Category. There were 1119 productions in the Broca's group, which consisted of the nine Nonfluent patients, 643 productions in the Poor Comprehension group, which consisted of five Fluent patients, and 810 productions in the Good Comprehension group, which consisted of six Fluent patients.

Figure 3: Distribution of word scores by Diagnostic Category



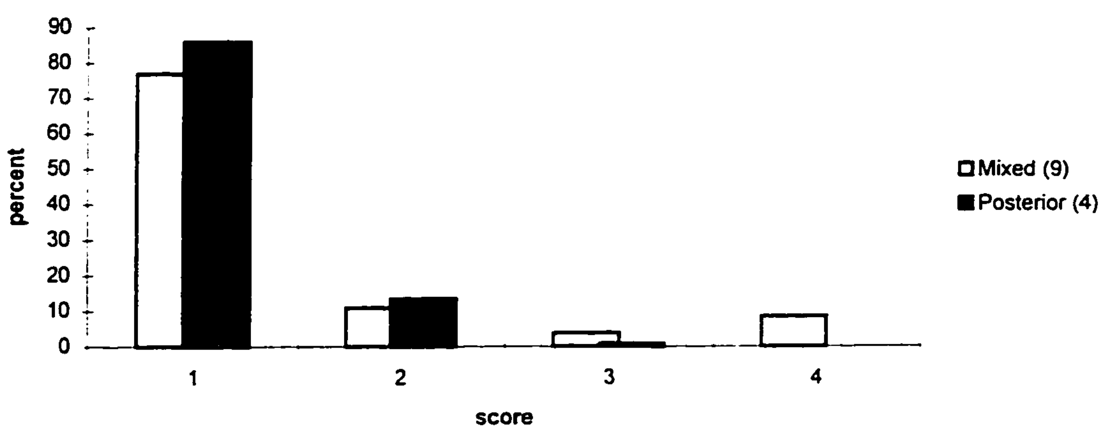
Consistent with the two previous Figures, the nine Broca's aphasics show the most impairment in reading of the three Diagnostic Categories. The Poor Comprehension group has a somewhat greater percentage of accurate productions than the Good Comprehension group. Appendix D1 provides a distribution of reading scores for each patient.

3. Word reading score by neuroanatomical group:

a. Word reading score by Site of Lesion:

Word reading performance was examined with respect to Site of Lesion for those 13 patients for whom scans were available. There were 1151 productions in the Mixed group, which consisted of nine patients, and 540 productions in the Posterior group, which consisted of four patients.

Figure 4: Distribution of word scores for the Mixed and Posterior groups

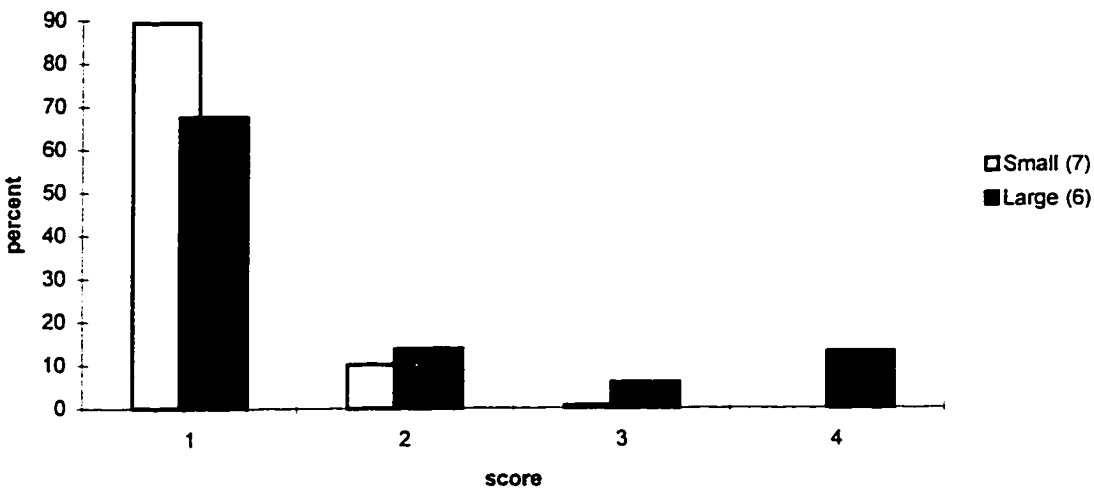


As Figure 4 shows, patients in the Posterior group are less impaired in reading than patients in the Mixed group, as evidenced by their greater proportion of scores of 1 and the smaller proportions of scores of 3 and 4. Note that all four Posterior patients are Fluent and have relatively small lesion sizes (size of 1). Mixed patients are both Nonfluent and Fluent and have larger lesions, on the whole.

b. Word reading score by Lesion Size:

Word reading performance was also examined with respect to Lesion Size. Of the 13 patients with scans available, seven had Small lesions (size of 1) and six had Large lesions (size of 2 & 3). Since only one patient received a score of 3. a binary classification was used.

Figure 5: Distribution of word scores by Lesion Size



As Figure 5 shows, patients with small lesions are less impaired in reading than patients with large lesions. This relationship is at a gross level of lesion size, however: patients with a lesion size of 2 varied widely in reading impairment and the patient with a lesion size of 3 showed reasonably intact reading performance. Appendix A3 provides Site of Lesion and Lesion Size information for each patient.

4. Summary of descriptive analyses:

Patients in the Nonfluent/Agrammatic group were more impaired in reading than patients in the Fluent/non-Agrammatic group. Patients in the Mixed/Large lesion group were more impaired in reading than patients in the Posterior/Small lesion group. Within each group, however, the majority of productions were correct and most errors involved a change in one part of the word, only.

B. Group regression analyses:

1. Regression analyses by word and subject variables:

The 14 continuous predictor variables (Written Frequency, Heritage Frequency, Spoken Frequency, AOA, Bigram Frequency, Consistency, Neighborhood, Length, Familiarity, Concreteness, Imageability, Ease of Association, Number of Associates and Pleasantness) were centered on zero. Centering was achieved by subtracting the mean of each variable from every value of that variable. Note that centering only affects the intercept of the regression equation, which becomes the predicted word reading score for a predictor variable of average value.[27] The slopes of the regression equation indicate the expected change in the word reading score associated with a unit increase in the predictor variable. The greater the value of the slope the bigger the expected change in the reading score. Steeper slopes generally have more predictive power than flat slopes.

There were two categorical variables, Grammatical Category and Cluster. Grammatical category was coded using four dummy variables (Noun, Verb, Adjective, Noun/Verb). Cluster was coded as a binary variable (presence/absence of consonant cluster in the word).

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[27] Centering is a procedure that is statistically recommended in regression analyses (Bryk & Raudenbush, 1992). The purpose of centering is to make the intercept more meaningful in the interpretation of the regression equation. Without centering, the intercept would stand for the predicted word reading score for a predictor variable of zero value.

As a preliminary investigation of the variables that predict aphasic reading performance, both word and subject variables were entered into stepwise multiple regressions. The word reading scores of all 20 patients (a total of 2572 scores) formed the dependent variable. Word variables entered into the regression analyses were: Written Frequency (WFREQ), Heritage Frequency (HERIT), Spoken Frequency (SFREQ), AOA, Grammatical Category, Bigram Frequency (BIFREQ), Consistency (CONSIST), Neighborhood (NEIGH), Length and Cluster. Subject variables entered into the regression analyses were: Fluency (Fluen), Agrammatism (Agr), Diagnostic Category and Severity (Sev).

Results of this and of subsequent analyses are reported in the form of regression equations where the reading score (Y) is predicted by the intercept plus the slopes of the variables that attain significance. The value of the intercept is given first, followed by the values of the slopes of the variables that attain significance. The slopes are provided in parentheses next to the variable names. In all the regression equations that follow, the weights of the slopes are listed in order of significance (provided in parentheses under the slopes) rather than in order of absolute size of the slopes; this is because the t value takes into account the standard error, which is not reflected in the regression weights. Predictor variables attaining significance at .05 and below are reported.

As we will see in the next two tables (5 & 6), subject variables, especially severity of aphasia, were much more important than word variables in accounting for the reading performance of all the patients. Adjective and Heritage Frequency were the most important of the word variables.

Table 5: Multiple regression analyses of word and subject variables

Y = 1.741 + Sev (-.354)	+ Agr (-.465)	+ ADJECT (-.149)	+ Fluen (.152)	+ HERIT (-066)
(.0000)	(.0000)	(.0046)	(.0058)	(.0098)

Table 5 shows the regression equation that predicts reading score when both word and subject variables are included for all 20 patients. Word variables are shown in upper case and subject variables in lower case. Three subject variables and two word variables achieved significance. Severity of aphasia was the strongest predictor of reading performance, accounting for 31.8 percent of the variance. The addition of Agrammatism increased the variance accounted for to 33 percent. Whether a word is an Adjective, Fluency and Heritage Frequency followed (the addition of each increasing the variance to 33.5, 33.7 and 33.9 percent). The regression equation indicates that a low Severity score (that is, a greater level of impairment), the presence of Agrammatism, the non-Adjective status of the word, Fluency and low Heritage Frequency are predictors of reading impairment (a high reading score since 4=most incorrect).[28] The presence of consonant cluster just failed to reach significance (p=.0589). What is most striking is the amount of the variance accounted for by subject as opposed to linguistic variables, especially by Severity and Agrammatism. Appendix C2 provides the following information about the regression analyses in addition to the slopes: the standard errors

[28] The slope of Fluency is positive, indicating that Fluent status is associated with greater reading impairment after the effects of the other subject variables (Severity, Agrammatism) are partialled out. Although this may seem counterintuitive, it accounts for the production of those Fluent patients who are impaired readers. When Fluency is entered on its own it has a negative slope, which indicates that Nonfluent status is associated with greater reading impairment. The change from negative to positive is due to the introduction of Agrammatism, which accounts for most of the variance of Fluency.

of the slopes, the t values and the levels of significance. The findings thus indicate that patient classifications on the basis of Agrammatism and Fluency are meaningful and informative. Analyses based of these two classifications are therefore carried out to investigate specific predictors of reading performance for each group.

Note, however, that in the above analyses Agrammatism is entered as a categorical variable. To test its generality as a predictor of reading performance, analyses were conducted a second time using the Index of Grammatical Support (IGS), a continuous variable, instead. Results reaffirmed the importance of Agrammatism as a predictor of reading performance: the predictor variables achieving significance (in order of t size), were: Severity, Index of Grammatical Support, Adjective, Heritage and Fluency. Appendix C3 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

The role of subject variables in predicting reading performance was further explored by including additional subject variables in multiple regression analyses.

Table 6: Multiple regression analyses of word and additional subject variables

Y = 1.525 + Sev (-.214) + Igs (-.234) + Content (-.031) + Rate (.003)

(.0000) (.0000) (.0000) (.0000)

+ADJECT (-.141) + HERIT (-.066)

(.00421) (.0092)

Table 6 shows the regression equation that predicts reading score when both word and subject variables are included for all 20 patients. Subject variables entering this analysis are Severity, Fluency, IGS, content words per minute (Content) and syllables per minute (Rate). IGS, Content and Rate, derived from the Cookie Theft description task, have been described in the Methods section. Word variables are shown in upper case and subject variables in lower case. Four subject variables and two word variables achieved significance. Severity of aphasia was again the strongest predictor of reading performance, accounting for 31.8 percent of the variance. The addition of IGS similarly increased the variance accounted for to 33.3 percent. Content and rate increased the variance to 33.8 and 34.5, respectively. Similar to Table 5, the variables Adjective and Heritage Frequency followed. Adjective increased the variance accounted for to 35 and Heritage Frequency to 35.2. Thus, linguistic variables accounted for less than a percentage point over and above the variance accounted for by subject variables. The results again underscore the importance of subject variables in predicting reading performance for all the aphasic patients together.

A series of regression analyses were performed for each of the three clinical groupings (Fluency, Agrammatism, Diagnostic Category). All analyses were performed twice: once entering the complete set of 2572 words and a second time using the subset of 1448 words, those words for which there are Toglia and Battig ratings. The 10 word variables used in the previous analysis of word and subject variables were employed in the regression analyses that follow. Analyzing the 1448 words extends the findings of the complete set of words to a subset of the words. Adding the six Toglia and Battig variables (FAM, IMG, CON, EOA, NOA, PLS) in the second analysis serves to examine which variables remain significant and which are suppressed when the semantic and associative variables are added.

2. Regression analyses by clinical criteria:

a. Analyses by Fluency and Agrammatism:

To explore which of the variables are of potential importance as predictors of reading performance, a series of correlation analyses were performed separately for the Nonfluent and Fluent groups. The following variables showed a significant correlation with reading score for the Nonfluent group: Written Frequency, Heritage Frequency, Spoken Frequency, AOA, Grammatical Category (Adjective, Verb), Cluster and Length. When the subset of words with the Toglia and Battig ratings was examined, Familiarity, Imageability, Ease of Association and Number of Associates were added (but Written Frequency was no longer significant). Only Grammatical Category (adjective) showed a significant correlation with reading score for the Fluent group. When the subset of words with the Toglia and Battig ratings was examined, only Imageability was added. The results of the correlation analyses are provided in Appendices C4 to C6.

Stepwise multiple regressions for each group examined the role of each independent variable in predicting word reading performance, controlling for the effects predicted by the other independent variables.

Table 7: Multiple regression analyses of word variables by Fluency (all words)

NONFLUENT

Y = 1.859 + VERB (.204) + HERIT (-.125) + LENGTH (.118)			
	(.0269)	(.0292)	(.0358)

FLUENT

$Y = 1.215 + ADJECT\ (-.127)$
(.0083)

Table 7 shows that the variables that predict reading performance are different for the Nonfluent and Fluent groups. For the Nonfluent group, verbs, words of low Heritage Frequency and relatively long words resulted in less accurate productions (higher average reading scores). For the Fluent group, words that are other than adjectives resulted in less accurate productions. The three variables that predicted Nonfluent reading performance accounted for only 2 percent of the variance. Similarly, the single predictor of Fluent reading performance accounted for only .06 percent of the variance. These percentages are consistent with results of analyses incorporating all the patients and underscore the importance of subject variables as predictors of reading performance. The greater intercept of the Nonfluent versus the Fluent group reflects the Nonfluent group's greater average reading impairment.[29] Note that of the four frequency-related variables correlating significantly with reading score in the Nonfluent group (Written Frequency, Spoken Frequency, AOA, Heritage Frequency), only Heritage Frequency remains significant in multiple regression analyses. Appendix C7 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

[29] As the reading scores range from 1 (correct) to 4 (most erroneous), an intercept of 1.859 indicates greater impairment than an intercept of 1.215.

Figures 6, 7 and 8 illustrate the relationships of the three predictor variables, Grammatical Category, Heritage Frequency and Word Length, to mean word score for patients grouped by Fluency.

Figure 6: Mean word score by grammatical category

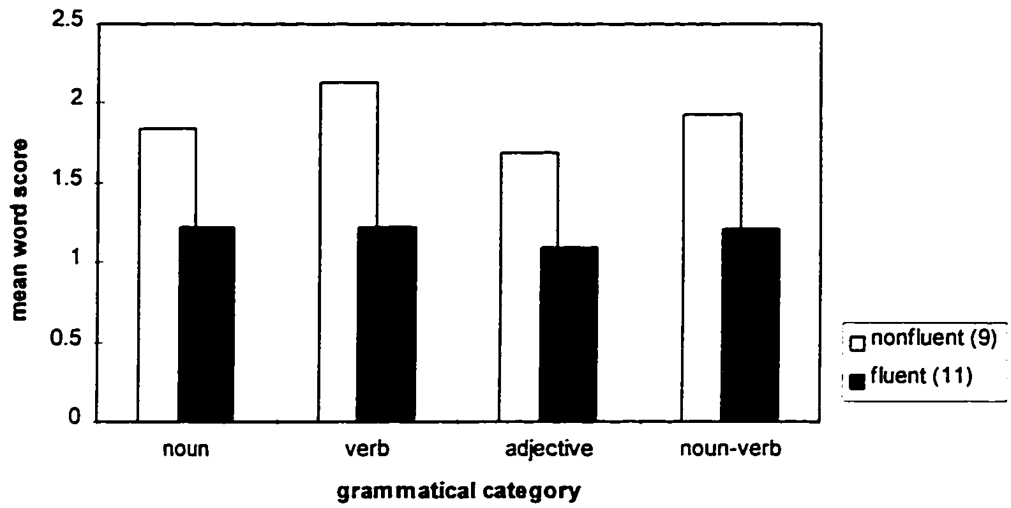

Figure 6 shows that Nonfluent patients read verbs worse than adjectives and nouns (F=5.14, p=.0016, using Bonferroni post hoc comparisons), as reflected in the higher mean word score (that is, more erroneous reading performance) for the verbs. Fluent patients read adjectives better than verbs (F=2.79, p=.0396, using Bonferroni post hoc comparisons) but showed no difference between nouns and verbs as a group. Their overall lower mean word score reflects their better reading performance.

Figure 7: Mean word score as a function of Heritage Frequency

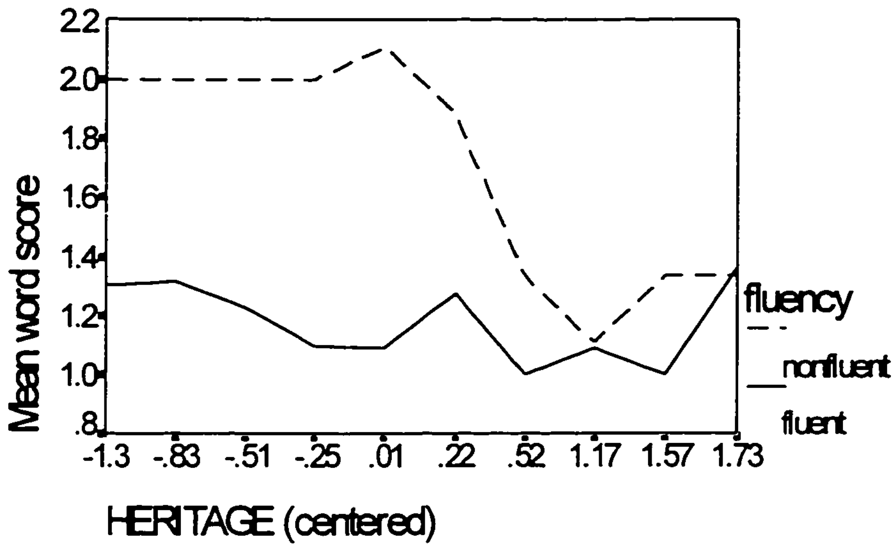

Figure 7 shows that the relationship of Heritage Frequency to mean word score is negative for Nonfluent patients, indicating that the lower the Heritage Frequency the higher the mean word score (that is, the greater the reading impairment). No such relationship is seen for the Fluent group, as a whole.

Figure 8: Mean word score as a function of Word Length

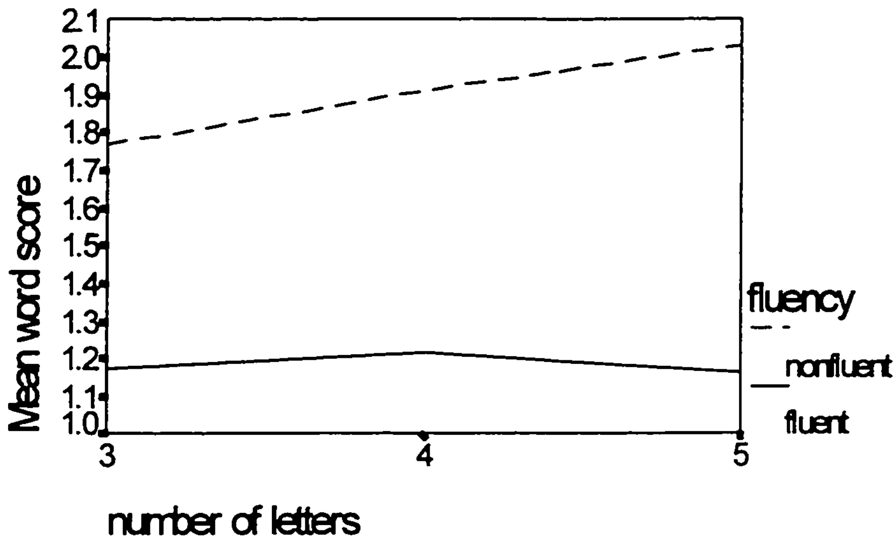

Figure 8 shows that the relationship of word length to mean word score is positive for Nonfluent patients, indicating that the shorter the word the lower the mean score (that is, the greater the reading accuracy). No relationship of word length to word score is seen for the Fluent group, as expected.

A side-question arises of whether total lemma frequencies are better predictors of reading performance than lexeme frequencies. The question was examined by conducting simple regressions using total Heritage Frequency (T-HERIT) and total Written Frequency (T-WFREQ), as well as Heritage (HERIT) and Written Frequency (WFREQ). Only Nonfluent productions were entered into the analyses, since only the Nonfluent group showed a Heritage Frequency effect.

Table 8: Simple regressions of lemma and lexeme Written and Heritage Frequencies

NONFLUENT

Variable	Beta	SE Beta	t	P	Intercept	P
WFREQ	-.162	.048	-3.40	.0007	1.904	.0000
T-WFREQ	-.164	.059	-2.77	.0057	1.904	.0000
HERIT	-.187	.050	-3.77	.0002	1.904	.0000
T-HERIT	-.179	.053	-3.39	.0007	1.904	.0000

As Table 8 shows, the lexeme frequencies of the above variables were somewhat better predictors than their total frequencies. That the lemma frequencies were also good predictors of performance argues for the psychological validity of the lemma frequency. Nevertheless, the use of the lemma frequencies does not appear to add predictive power over and above that of the lexeme frequencies.

The predictor variables were also entered into stepwise multiple regressions using the subset of words containing the Toglia and Battig ratings. To replicate the previous findings, analyses were conducted first without the Toglia and Battig ratings.

Table 9: Multiple regression analyses of word variables by Fluency (75-word list)

NONFLUENT

Y = 1.742 +	VERB (.396) +	AOA (.082) +	CLUSTER (.213)
	(.0057)	(.0075)	(.0501)

FLUENT

Y = 1.221 + ADJECT (-.150) (.0058)

The regression equations of Table 9 are similar to those of Table 8. For the Nonfluent group, verbs resulted in more impaired reading performance in both the complete set of words and the 75-word subset. The second and third variables that predicted performance differed slightly in the two sets: for the 75-word set, Age of Acquisition and Consonant Cluster achieved significance instead of Heritage Frequency and Length. Nevertheless, the two sets of variables are very similar. AOA is closely related to Heritage Frequency; in fact, it is one of the three predictors of Heritage Frequency in multiple regression analyses where Heritage Frequency is entered as the dependent variable. Cluster is related to Length, as words with consonant clusters are also longer. For the Fluent group, words that are Adjectives resulted in better reading performance in both sets of words. The results, thus, essentially replicate the findings using the complete set of words. Appendix C8 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

The Toglia and Battig variables were added to the regression analyses of the subset of words containing the Toglia and Battig ratings.

Table 10: Multiple regression analyses of word variables by Fluency

(75-word list, Toglia & Battig variables)

NONFLUENT

Y = 1.827 + EOA (-.297)
(.0001)

FLUENT

Y = 1.227 + ADJECT (-.181) + IMG (-.070)
(.0012) (.0055)

Table 10 shows that when the Toglia and Battig variables were added, only ease of association attained significance for the Nonfluent group. Words of low Ease of Association resulted in greater reading impairment (higher reading score) than words of high ease of association. Note that Ease of Association suppressed the variables that were significant in the regression equation without the Toglia and Battig variables (verb, AOA, Cluster). Thus, only Ease of Association contributed independent variance to reading performance when the effects of all the other variables were taken into account. For the Fluent group, adjective and Imageability contributed independent variance to reading performance (the only two variables that correlated significantly with reading score). Thus, words other than adjectives with low imageability ratings resulted in greater reading impairment. Again, the greater intercept of the Nonfluent group reflects the Nonfluent group's greater reading impairment. Appendix C9 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

Stepwise multiple regression analyses of the complete set of words for patient groups divided by Agrammatism replicated those for patient groups divided by Fluency (see Appendix C10): for the Agrammatic group, words that are verbs, of low Heritage Frequency and relatively long resulted in greater reading impairment. For the non-Agrammatic group, words other than adjectives resulted in greater reading impairment. The larger intercept of the Agrammatic than Nonfluent group (2.101 vs. 1.859) reflects the Agrammatic group's greater average reading impairment.

Regression analyses were also conducted using the subset of words containing the Toglia and Battig ratings (using the same predictor variables as in the previous analyses). As in the groups by Fluency, the regression equations using the subset of 75 words were similar to those using the complete set of words. For the Agrammatic group, words that are verbs, of late AOA and relatively long resulted in greater reading impairment. For the non-Agrammatic group, words other than adjectives resulted in greater reading impairment.

When the Toglia and Battig variables were added to the above regression analyses, the results by Agrammatism replicated those by Fluency. For the Agrammatic patients, words of low Ease of Association resulted in greater reading impairment. For the non-Agrammatic patients, words other than adjectives and of low Imageability resulted in greater reading impairment.

b. Analyses by Diagnostic Category:

Analyses were also conducted by Diagnostic Category: the Fluent group was divided into patients with relatively poor comprehension and patients with relatively good comprehension. Results for the Broca's aphasics are not provided in any of the analyses by Diagnostic Category because the Broca's group is identical to the Nonfluent group.

Table 11: Multiple regression analyses of word variables by Diagnostic Category (all words)

FLUENT-POOR COMPREHENSION

$$Y = 1.332 + \underset{(.0308)}{\text{ADJECT}\ (-.205)}$$

FLUENT-GOOD COMPREHENSION

$$Y = 1.112 + \underset{(.0040)}{\text{HERIT}\ (-.053)}$$

Table 11 shows that the variables that account for the reading performance of patients with relatively poor comprehension are different from the variables that account for the reading performance of patients with relatively good comprehension. For the Poor Comprehension group, adjective predicted reading performance, consistent with analyses for the Fluent group as a whole. For the Good Comprehension group, Heritage Frequency predicted reading performance, with Consistency just missing significance. Thus, for the Good Comprehension group, words that are of low Heritage Frequency resulted in greater reading impairment. The role of orthographic variables in the reading performance of different groups of aphasics is examined in more detail in a section that follows. The larger intercept of the Poor relative to the Good Comprehension group reflects the former group's greater reading impairment. Appendix C11 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

Regression analyses conducted using the subset of 75 words showed results similar to those of the complete set. Adjective remained significant for the Poor Comprehension group. Consistency and adjective reach significance for the Good Comprehension group in this subset of words. The results of the regression analyses are provided in Appendix C12.

Regression analyses were also conducted with the Toglia and Battig variables.

Table 12: Multiple regression analyses of word variables by Diagnostic Category

(75-word list, Toglia & Battig variables)

FLUENT-POOR COMPREHENSION

Y = 1.361 + ADJECT (-.276) + IMG (-.106)		
	(.0144)	(.0361)

FLUENT-GOOD COMPREHENSION

Y = 1.087 + IMG (-.049) + NOUN (.067)		
	(.0108)	(.0491)

In this subset of words, the variables that predicted the reading performance of Fluent patients with Poor Comprehension were the same as the variables that predicted the reading performance of Fluent patients, in general (see Table 10). The reading performance of the Fluent patients with Good Comprehension, however, was predicted by different variables (similar to the analyses using all the words). Recall that Heritage Frequency was the only significant variable in the previous analysis without the Toglia and Battig variables. In this analysis, Imageability was more important than Heritage Frequency but did not entirely subsume it, as Heritage Frequency just failed to reach significance (p=.0544).

Findings of an orthographic effect in certain analyses merit a closer look at the role of these variables while controlling for word length in a more systematic way. In the analyses so far, words of all three lengths (three, four and five letters) have been included in multiple regression analyses, controlling for the effect of number of letters by adding the predictor variable Length. In the analyses that follow, only words of the same length (four-letter words) are considered. The choice of four-letter words is made for a number of reasons: First, consistency of pronunciation has a range of values for four- and five-letter words (few three-letter words have any enemies). Second, there are more four- than five-letter words (79 vs. 26 words per patient). Third, the inclusion of only four-letter words provides a more phonologically homogeneous environment (only 13 of the 79 four-letter words have consonant clusters). Appendix B2 shows the number of enemies and number of neighbors sharing the same rhyme for each four-letter word.

A total of 1524 words entered the analyses (669 for the Nonfluent group, 855 for the Fluent group.) In addition to the three orthographic variables (Neighborhood, Consistency & Bigram Frequency), two frequency variables (Heritage & Written Frequency) were included to control for possible frequency effects.

Table 13: Multiple regression analyses of orthographic variables by Fluency

(all 4-letter words)

NONFLUENT

Y = 1.917 + HERIT (-.190)
(.0044)

FLUENT n.s.

Table 13 shows that orthographic variables do not predict reading performance of four-letter words when frequency is controlled for any group. No variable reached significance for the Fluent group as a whole.

Analyses were also conducted for the groups by Diagnostic Category, which is the classification showing the most promise for the examination of orthographic effects in the previous analyses.

Table 14: Multiple regression analyses of orthographic variables by Diagnostic Category

(all 4-letter words)

FLUENT-POOR COMPREHENSION n.s.

FLUENT-GOOD COMPREHENSION

Y = 1.121 + HERIT (-.062)
(.0122)

Similar to analyses using words of all lengths (Table 11), Heritage Frequency accounted for the reading accuracy of patients in the Good Comprehension group. Consistency of pronunciation just failed to reach significance in this analysis (p=.0536). No variable reached significance in the Poor Comprehension group.

c. Summary of regression analyses by clinical criteria:

i. Representational aspects:

Frequency-related variables, most notably Heritage Frequency, were important predictors of reading performance in most analyses: words of low Heritage Frequency resulted in more erroneous productions. Heritage Frequency was a significant predictor when all patients were considered together. When patients were grouped in terms of Fluency or Agrammatism, Heritage Frequency predicted the reading performance of the Nonfluent/Agrammatic group. When the Fluent group was divided into Poor Comprehension and Good Comprehension subgroups, Heritage Frequency predicted the reading performance of the Good Comprehension subgroup. Written and Spoken Frequency did not predict reading performance when the effect of Heritage Frequency was taken into account, although both correlated significantly with word score in the Nonfluent group. Age of Acquisition predicted the reading performance of the Nonfluent group in one analysis (using the 75-word list without the Toglia and Battig variables), subsuming the Heritage Frequency effect.

A side methodological issue concerned the use of lexeme versus lemma frequencies as predictors of aphasic reading performance. Although both types of frequency measures were significant predictors of performance, lemma frequencies added no predictive power over that of lexeme frequencies.

Grammatical variables were important predictors of reading performance along with frequency-related variables. Words that are adjectives were read better than words from other grammatical categories when all patients were considered together. More specifically, verbs were read worse than adjectives and nouns by Nonfluent/Agrammatic patients and adjectives were read better than nouns and verbs by Fluent patients (those in the Poor Comprehension subgroup). Note, however, that whereas Nonfluent patients read both adjectives and nouns better than verbs, Fluent patients showed no noun-verb difference in their reading as a group.

ii. Referential aspects:

Imageability was the only referential variable that attained significance in any analyses when the Toglia and Battig variables were included. Concreteness and Pleasantness failed to reach significance; in fact, neither variable correlated significantly with word score in either the Nonfluent or the Fluent group. The difference between the two very related variables of Concreteness and Imageability (as reflected in their high intercorrelation) in predicting reading score underscores the importance of Imageability as a predictor of reading performance. As expected, words that are difficult to image resulted in more erroneous productions. Imageability was an important predictor of the reading of the Fluent/Non Agrammatic groups, only (both Poor and Good Comprehension subgroups). It predicted reading performance in addition to Adjective, thereby accounting for independent portions of the variance.

iii. Associative aspects:

Ease of Association was the only associative variable that attained significance in any analyses when the Toglia and Battig variables were included. Number of Associates correlated significantly with word score in the Nonfluent group; however, it failed to reach significance in multiple regression analyses. As expected, words that are associated to with difficulty resulted in more erroneous productions. Ease of Association was the most important predictor of reading performance in Nonfluent/Agrammatic patients, suppressing the effects of frequency-related, grammatical and phonological variables. Indeed, was the only variable that achieved significance in these groups when the Toglia and Battig variables were included. Ease of Association was not important for the Fluent/non-Agrammatic groups, showing no significant correlation with word score.

iv. Phonological/Orthographic variables:

Word Length was a significant predictor of Nonfluent/Agrammatic reading performance. Presence of Consonant Cluster, a related variable, achieved significance for the Nonfluent group in one analysis (in the subset of words without the Toglia and Battig variables). As expected, words that are relatively long and contain consonant clusters resulted in more erroneous productions for the Nonfluent group. No phonological variable achieved significance when the Toglia and Battig variables were included.

Consistency of pronunciation just failed to reach significance in the Good Comprehension subgroup of the Fluent group. It was not significant in any other group. Furthermore, no other orthographic variable (Bigram Frequency, Neighborhood) was a significant predictor of reading performance for any group. A further investigation of Consistency effects in a better-controlled set of words confirmed the finding of Consistency just failing to reach significance in the Good Comprehension subgroup. Note, however, that this is the subgroup with the best reading performance of all three groups and therefore with a relatively limited corpus of errors. As expected, words that are inconsistent (that is, have many enemies), tended to result in more erroneous productions.

3. Regression analyses by neuroanatomical criteria:

a. Analyses by Site of Lesion and Lesion Size:

Reading performance was examined with respect to Site of Lesion for those 13 patients who had scans available. There were nine patients in the Mixed group and four patients in the Posterior group.

Table 15: Multiple regression analyses of word variables by Site of Lesion (all words)

MIXED

Y = 1.465 + ADJECT (-.195)
(.0178)

POSTERIOR

Y = 1.148 + CONSIST (.171) +	HERIT (-.058)
(.0101)	(.0262)

Table 15 shows that for the Mixed group, words other than adjectives resulted in more erroneous productions. For the Posterior group, words that have inconsistent pronunciations and are of low Heritage Frequency resulted in more erroneous productions. The larger intercept of the Mixed group reflects the group's greater reading impairment.

The findings were replicated for the Mixed group and partly replicated for the Posterior group using the subset of 75 words. For the Mixed group, words other than adjectives continued to result in more erroneous productions. For the posterior group, words that are verbs and inconsistent resulted in more erroneous productions. Thus, the orthographic effect persisted in the Posterior group in this subset of words. The regression equations for the 75-word list are provided in Appendix C13.

Patients in the Mixed group have larger lesions than those in the Posterior group. Reading performance was, therefore, examined with respect to Lesion Size for the same 13 patients. There were seven patients in the Small group and six patients in the Large group.

Table 16: Multiple regression analyses of word variables by Lesion Size (all words)

LARGE

Y = 1.679 + ADJECT (-.259)	
	(.0000)

SMALL

Y = 1.111 + HERIT (-.055) + CONSIST (.100)		
	(.0015)	(0243)

Table 16 shows that for patients with relatively large lesions, words that are other than adjectives resulted in more erroneous productions. For patients with relatively small lesions, words of low Heritage Frequency that have inconsistent pronunciations resulted in more erroneous productions. Note that the regression equations for patient groups by Lesion Size are very similar to the regression equations for patient groups by Site of Lesion.

Analyses using the subset of 75 words partly replicated the above findings. For the Large lesion group, verb rather than adjective achieved significance: words that are verbs resulted in more erroneous productions. For the Small lesion group, words of low Heritage Frequency resulted in more erroneous productions. The regression equations for the 75-word list are provided in Appendix C14.

b. Summary of regression analyses by neuroanatomical criteria:

Different variables predicted the performance of patients in the Mixed and Posterior groups. For the Mixed group, words that are other than adjectives resulted in more erroneous productions. For the Posterior group, words that have inconsistent pronunciations and are of low Heritage Frequency resulted in more erroneous productions. The finding of a clear Consistency effect in the Posterior group is followed up at an individual patient level in the next section on individual regression analyses.

Patients in the Posterior group are overall less impaired (in both reading and severity of aphasia) and have smaller lesions. Patients in the Mixed group, on the other hand, are more impaired and have larger lesions. Indeed, when analyses were conducted in terms of lesion size, patients in the Small lesion group showed an effect of Heritage Frequency and Consistency of pronunciation, similar to the patients in the Posterior group. Patients in the Large lesion group showed an effect of Adjective, consistent with patients in the Mixed group. Given the overlap between the two classifications in the present patient sample, it is not possible to distinguish between predictors of reading performance in patients grouped by lesion site versus by size of lesion.

C. Individual regression analyses:

The regression analyses conducted so far raise the questions of predictors of the reading performance of individual subjects as well as of the relationship of individual predictors to group predictors. To answer these questions, regression analyses were conducted for each patient using the same predictor variables as in the group analyses. Only variables showing a significant or near significant correlation with word score for each individual patient were entered as predictor variables for that patient. Similar to previous analyses, regression analyses were also conducted using the subset of 75 words.

1. Multiple regressions using the complete set of words:

Regression analyses were first performed for individual patients using the complete set of words. Table 17 lists individual patients showing an effect of a variable in order of severity of reading impairment, as reflected by the size of the individual intercepts (I). Predictor variables achieving significance at .05 and below are listed under the broad variable categories, with a sign next to them (+ or -) indicating the direction of the relationship. Variables achieving significance at levels between .05 and .06 are listed in parentheses. Percent of the variance accounted for by variables achieving significance (%) is provided in the last column.

Table 17: Multiple regression analyses for individual patients (all words)

PATIENT	I	FREQ.	GRAMM.CAT.	PHONOL.	ORTHOGR.	%
NFBS	3.760	HERIT -	ADJECT- (NOUN-)			20.7
FLRT	2.556		VERB +			6.3
NFBM	2.245	WFREQ-		CLUSTER +		8.4
NFIT	2.320	SFREQ -				5.2
NFMA	2.130	(AOA +)	VERB +			7.8
NFHM	1.759		VERB +			10.8
NFJE	1.281	WFREQ-				5.7
NFRB	1.263	WFREQ-			CONSIST +	13.9
FLHR	1.134	HERIT -			CONSIST +	14.4
NFGG	1.098	HERIT -				3.4
FLCD	1.052				CONSIST +	4.1
FLCG	1.037	HERIT -				4.6
NFAG	1.029		VERB +		NEIGH -	8.9

As Table 17 shows, frequency-related variables were important predictors of reading performance for most patients regardless of severity or fluency status. Heritage and Written Frequency were the most prevalent predictors of the frequency-related variables. Grammatical Category was an important predictor for the more impaired patients, both Fluent and Nonfluent. Orthographic variables, on the other hand, were important predictors for the less impaired patients, only. Phonological factors were important for only one patient in these analyses. All effects were in the predicted direction: words of low Heritage, Written and Spoken Frequency resulted in more erroneous productions (negative sign). Words of late AOA resulted in more erroneous productions (positive sign). Adjectives and nouns resulted in less erroneous productions (negative sign), and verbs in more erroneous productions (positive sign). Words with high Consistency (that is, with many enemies) resulted in more erroneous productions (positive sign) but words from large neighborhoods resulted in fewer erroneous productions (negative sign). Finally, words with Consonant Clusters resulted in more erroneous productions (positive sign). Appendix D2 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

Percent of the variance accounted for by linguistic variables in individual patient analyses was considerably greater (3.4 to 20.7 percent) than percent of the variance accounted for by linguistic variables in group analyses (.05 to 2 percent). The difference may be attributed to the greater within group variability in the group than individual analyses.

Five of the 11 Fluent patients (FLHT, FLWZ, FLWL, FLNG, FLHW) made too few errors to enter the individual analyses and two showed no significant effect of any variable (FLMC, FLJM).

2. Multiple regressions using the 75-word list:

Analyses were also conducted using the subset of words in order to replicate the individual patient findings from the complete set of words. Table 18 lists all individual patients showing an effect of a variable in order of severity of reading impairment, as reflected by the size of the individual intercepts (I).

Table 18: Multiple regression analyses for individual patients (75-word list)

PATIENT	I	FREQUENCY	GRAMM.CAT.	PHONOL.	ORTHOGR.
NFBS	3.909	AOA +	ADJECT - NOUN -		
FLRT	2.601		VERB +		
NFIT	2.241			LENGTH +	
NFHM	1.921		VERB +		
FLMC	1.328		VERB +		
NFRB	1.315	HERIT -			
FLHR	1.155	HERIT -			
NFGG	1.102	HERIT -			
NFAG	1.025				CONSIST +

As Table 18 shows, Heritage Frequency continues to be an important predictor of reading performance for many patients. Grammatical Category continues to be important for the more impaired patients. Note, however, that three of the nine Nonfluent patients (NFMA, NFBM, NFJE) showed no significant effect of any variable even though two of them are very impaired. Seven of the 11 Fluent patients (FLHT, FLWZ, FLCG, FLWL, FLNG, FLHW & FLCD) made too few errors to enter the analyses and one showed no significant effect of any variable (FLJM). Appendix D3 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

A comparison of Table 18 with Table 17 reveals that out of the eight patients (six Nonfluent & two Fluent) showing an effect of any variable in both the complete and the shorter list of words, six revealed similar results in both analyses. Of the two patients who show an effect of different variables, NFIT showed a Spoken Frequency effect in the complete list and a Length effect in the subset of words, and NFAG showed a verb and Neighborhood effect in the complete list and a Consistency effect in the subset of words. Some variability in performance between the two sets is expected given the smaller number of words in the second set, which also contains fewer verbs. Nevertheless, findings of verb effects even in the smaller set underscore the importance of grammatical variables in the reading performance of certain patients. The results thus largely replicate those of the complete set of words.

Table 19 lists all individual patients showing any variable effect with the Toglia and Battig variables included.

Table 19: Multiple regression analyses for individual patients

(75-word list, Toglia & Battig variables)

PATIENT	I	FREQ.	GRAMM.	SEM./ASSOC.	PHONOL.	ORTHOGR.
NFBS	3.727		ADJECT - (NOUN -)	EOA -		
FLRT	2.873		ADJECT -	IMG -		
NFBM	2.267			EOA -		
NFIT	2.268				LENGTH +	
NFHM	2.065			IMG -		
NFMA	2.053			EOA -		
FLMC	1.328		VERB +			
NFRB	1.227	HERIT -				
FLHR	1.155	HERIT -				
FLJM	1.057			IMG +		
NFGG	1.053	FAM -		CON -		
NFAG	1.028					CONSIST +

As Table 19 shows, semantic and associative variables attained significance for many patients, Nonfluent and Fluent, in this subset of words. The effects were in the expected direction: words of low Ease of Association and Imageability resulted in more erroneous productions (negative sign), with the exception of one relatively unimpaired patient (FLJM) who showed a weak positive effect of Imageability. A comparison of

Table 19 with Table 18 reveals that Ease of Association and Imageability suppress frequency-related and grammatical variables in some of the more impaired patients (e.g., NFBS & NFHM). Importantly, two of the three Nonfluent patients who showed no effect of any variable in the previous analysis despite their numerous reading errors (NFBM, NFMA), now show an Ease of Association effect. Grammatical variables, however, remained significant for certain patients (e.g., NFBS, FLMC) and frequency-related variables remained significant for the less impaired patients. Appendix D4 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

The findings indicate that Ease of Association is a particularly important variable in predicting reading performance in the more impaired Nonfluent patients. No Fluent patient shows an effect of any associative variable. Imageability is an important predictor of the reading performance of the more impaired patients, both Fluent and Nonfluent; Concreteness, however, is a significant predictor of the performance of only one patient (NFGG), a relatively good reader.

There were five patients who showed no change when the Toglia and Battig variables are introduced (NFIT, FLMC, NFRB, FLHR & NFAG). Two of these (NFRB, FLHR) showed a Heritage Frequency effect, one (FLMC) showed a verb effect, one (NFIT) showed a Length effect and one (NFAG) showed a Consistency effect.

3. Multiple regressions using orthographic variables:

The observation of an orthographic effect (NEIGH, CONSIST) in certain patients warrants the investigation of orthographic factors in a better-controlled way. Similar to group analyses, the reading scores of all four-letter words were entered into multiple regression analyses for each individual patient. There were 79 such words for each patient (65 words for four patients.) As previously, both Heritage and Written Frequency were included to control for possible frequency effects.

Table 20: Multiple regression analyses of orthographic variables for individual patients (all 4-letter words)

Y(NFRB)= 1.295 + WFREQ (-.305) + NEIGH (.041) + CONSIST (.441) (.0019) (.0265) (.0571)
Y(NFBS)= 3.601 + HERIT (-.414) + CONSIST (-.862) (.0048) (.0094)
Y(FLCG)= 1.069 + BIFREQ (-.005) (.0202)
Y(FLHR)= 1.137 + CONSIST (.468) + HERIT (-.164) (.0016) (.0107)
Y(FLCD)= 1.054 + CONSIST (.229) (.0478)

Table 20 lists the five patients who show an orthographic effect. Four of the five patients showed a Consistency of pronunciation effect and one a frequency of orthographic patterns (BIFREQ) effect. The patient showing an effect of frequency of orthographic patterns (FLCG) and one of the patients showing a Consistency effect (FLCD) made very few errors. Overall, patients showing an orthographic effect are not very impaired, either in terms of severity of aphasia or in terms of reading impairment (as reflected by their intercepts). One patient, however (NFBS), actually showed a reverse consistency effect.[30] The three patients who showed a positive Consistency effect in analyses using the complete set of words (NFRB, FLCD, FLHR) also showed a positive consistency effect in the subset of four-letter words. The results thus corroborate orthographic effects in individual patients in analyses using the complete set of words. Appendix D5 provides the following information about the regression analyses in addition to the slopes: the standard errors of the slopes, the t values and the levels of significance.

An inspection of errors made by individual patients showing a Consistency effect confirmed the statistical findings. FLHR, a letter-by-letter reader, showed a particularly strong consistency effect. Examples of his reading of highly inconsistent words include: dull→ *full*, deaf→ */dif/*, doze→ */dʌv/* and toll→ */tɔɪl/*, */tɔl/*. FLCD, who made few errors overall, read tomb→*/tom/.*

4. Summary of individual regression analyses:

i. Representational aspects:

Written and especially Heritage Frequency were important predictors of reading performance in both Nonfluent and Fluent patients of all levels of severity of reading impairment or of aphasia. Words of low Written and Heritage Frequency resulted in more erroneous productions for patients showing an effect of these variables. Heritage Frequency remained significant in the subset of 75 words with AOA, a variable related

[30] This patient, who is the most impaired one of the sample, had great difficulty decoding words phonologically, as evidenced by her being able to read only seven of the words correctly, 16 with a score of 2, and by her numerous phonologically unrelated semantic errors. A close inspection of her reading performance revealed that she succeeded in reading words with a high number of enemies like "doll", "mood" and "bowl".

to Heritage Frequency, achieving significance in one Nonfluent patient. Note that although AOA and Written Frequency correlated significantly with reading score for a number of patients, they were suppressed by Heritage Frequency in multiple regression analyses.

Grammatical variables were important in the more impaired Nonfluent and Fluent patients. Although three of the seven Agrammatic patients showed a Grammatical Category effect, the effect was not limited to these patients: a severely impaired Wernicke's aphasic and a Conduction aphasic also showed a verb effect. Words that are adjectives and nouns were read better than words from other grammatical categories and words that are verbs were read worse.

ii. Referential aspects:

Imageability was a significant predictor of reading performance in two of the more impaired patients, one Nonfluent and one Fluent, suppressing a verb effect in the Nonfluent patient. Words that are not very imageable resulted in more erroneous reading performance. Note that Imageability was a stronger variable than Concreteness in predicting individual reading performance. In fact, Concreteness showed no significant correlation with reading score in correlation analyses for individual patients.

iii. Associative aspects:

Ease of Association was an important predictor of reading performance in the more impaired Nonfluent patients, who made more errors on words which are difficult to form associates to. Ease of Association suppressed a frequency-related variable in one patient and became a significant predictor of reading performance in two quite impaired Nonfluent patients, who showed no effect of any variable in analyses that excluded the

Toglia and Battig variables. Number of Associates was not a significant predictor of individual reading performance in multiple regression analyses, although it correlated significantly with reading score in individual patients. No Fluent patient showed an associative variable effect.

iv. Phonological/Orthographic variables:

Word Length (in the range of 3 to 5 letters) and presence of Consonant Cluster were of lesser importance as predictors of individual reading performance when the effects of other variables were taken into account. Consonant Cluster was significant in one Nonfluent patient only in the complete set of words and Length was significant in a different Nonfluent patient in the subset of 75 words. Phonological variables were not predictive of reading performance in any of the Fluent patients, as would be expected.

Consistency of pronunciation was an important predictor of reading performance in some less-impaired patients: words with many inconsistent pronunciations resulted in more erroneous productions than words with few or none at all. Patients showing a consistency effect were mostly found in the Fluent-Good Comprehension group. One Nonfluent subject, the most impaired one in the sample, showed a reverse consistency effect. She was unaffected by the inconsistent pronunciation of the words that she succeeded in reading, possibly because she did not appear to use phonological decoding to read them.

D. Comparison of individual and group regression analyses:

1. Using the complete set of words:

No individual Nonfluent/Agrammatic patient showed an effect of all three variables that were significant in group regression analyses, namely verb, Heritage Frequency and

Length. This is expected given the different number of words that enter the two types of analyses. A few Nonfluent patients showed an effect of two of the three variables, such as a frequency-related and a grammatical (or phonological) variable. Nevertheless, a number of Nonfluent patients showed an effect of one of the three variables that reached significance in the group analyses: one showed a Heritage Frequency and Grammatical Category effect, one a Heritage Frequency effect and three a verb effect. Table 21 provides a summary of individual and group variables that reach significance, with patients listed in order of severity of reading impairment.

Table 21: Comparison of individual and group predictor variables

	ALL WORDS	75-WORD LIST	WITH T & B VARS.
NFBS	HERIT, ADJECT, (NOUN)	ADJECT, NOUN, AOA	ADJECT, EOA, (NOUN)
NFIT	SFREQ	LENGTH	LENGTH
FLRT	VERB	VERB	ADJECT, IMG
NFMA	VERB, (AOA)	n.s.	EOA
NFBM	WFREQ, CLUSTER	n.s.	EOA
NFHM	VERB	VERB	IMG
FLMC	n.s.	VERB	VERB
NFJE	WFREQ	n.s.	n.s.
NFRB	WFREQ, CONSIST	HERIT	HERIT
FLHR	HERIT, CONSIST	HERIT	HERIT
NFGG	HERIT	HERIT	FAM, CON
NFAG	VERB, NEIGH	CONSIST	CONSIST
FLCD	CONSIST	few errors	few errors
FLCG	HERIT	few errors	few errors

	ALL WORDS	75-WORD LIST	WITH T & B VARS.
NF	VERB, HERIT, LENGTH	VERB, AOA, CLUSTER	EOA
FL	ADJECT	ADJECT	ADJECT, IMG
FL-PC	ADJECT	ADJECT	ADJECT, IMG
FL-GC	HERIT, (CONSIST)	HERIT	IMG, NOUN, (HERIT)

Perhaps a more meaningful way to link individual to group predictor variables is by severity of impairment. The more impaired Nonfluent patients showed a Grammatical Category effect, a Frequency effect or both. These patients displayed either worse reading of verbs or better reading of adjectives and nouns. Since the more impaired patients contributed most of the variance in group analyses, it is these patients who largely influenced the group results. The less impaired Nonfluent patients tended not to show a Grammatical Category effect. Although a Length effect was present in individual correlations with word score in many patients, it became suppressed by other variables in multiple regression analyses. In fact, only one Nonfluent patient showed a phonological variable effect (Cluster).

No individual Fluent patient showed an Adjective effect, the only variable reaching significance in the group analyses. A more meaningful way to describe the Fluent patient findings, however, appears to be in terms of the Poor and Good Comprehension groups (Table 21). Heritage Frequency and Consistency, the variables achieving significance in the group analysis for the Good Comprehension group, indeed described the reading performance of the three patients who belong to the group (FLHR, FLCD, FLCG). A Grammatical Category effect described the performance of the patient in the Poor Comprehension group, the only patient in the group who showed an effect of any variable (FLRT). Note, however, that this patient showed worse reading of verbs than of words in other grammatical categories rather than better reading of adjectives than of words in other grammatical categories.

2. Using the subset of 75 words:

The only variable that predicted the reading performance of Nonfluent patients when the Toglia and Battig variables were included was Ease of Association. As Table 21 reveals, three Nonfluent patients, among the most impaired ones (NFBS, NFBM, NFMA), showed this effect. Since these patients made numerous reading errors they contributed the most to the error variance in the group analyses. The less impaired Nonfluent patients essentially showed frequency-related effects, with no effect change when the Toglia and Battig variables were introduced. The variables that predicted the reading performance of Fluent patients were adjective and Imageability. Of the three Fluent patients showing an effect of any variable, one (FLRT) showed an adjective and Imageability effect. Since this patient is the most impaired one, he contributed the most to the group results. Note that FLRT belongs to the Poor Comprehension subgroup, which is the subgroup that shows an adjective and Imageability effect. The two patients in the Good Comprehension subgroup (FLMC, FLHR) show a Grammatical Category and Heritage Frequency effect, partly consistent with the subgroup's findings. Thus, a division of the Fluent group in terms of Poor and Good Comprehension subgroups captures individual performance patterns more accurately.

IV. DISCUSSION

A. The three research questions of the study:

To recapitulate, the three questions that the present investigation aimed to address are: 1. Which word characteristics influence aphasic reading?; 2. Do different word characteristics account for the performance of different types of aphasics?; and 3. Does the performance of individual aphasics reflect the pattern of performance obtained from group data?

1. Which word characteristics influence aphasic reading?

To address this question, word variables predicting the reading performance of all patients were examined by aggregating the reading scores across patients. Thus it was possible to investigate which linguistic variables predicted the likelihood of a given word being read correctly by aphasic patients as one group.

When 10 word variables (4 frequency-related, 1 grammatical category, 3 orthographic and 2 phonological) were entered as predictors of all patients' reading performance together with 4 subject variables (Fluency, Agrammatism, Diagnostic Category and Severity), only 2 word variables predicted reading performance: Adjective and Heritage Frequency. Words that are adjectives and of high Heritage Frequency were read more accurately than words belonging to other grammatical categories or of low Heritage Frequency.

A Grammatical Category effect is consistent with the literature on reading in aphasia and especially in deep dyslexia. What differs, however, is the order of the effect: studies including adjectives (e.g., Coltheart, 1980a; Marshall & Newcombe, 1966) reported that nouns were read better than adjectives which, in turn, were read better than verbs. In the present investigation, adjectives were read better than nouns. What might account for the superior reading of adjectives in this study?

In the present study, adjectives belong to more than one grammatical category (primarily noun). This is typical of most English monosyllabic adjectives. One interpretation, therefore, is that the adjectives of the present investigation are multidimensional in nature, incorporating linguistic and psychological characteristics of both adjectives and nouns. Furthermore, adjectives have an entirely different semantic organization from that of both nouns and verbs. Unlike the hierarchically organized nouns and to a lesser extent verbs, they are organized in terms of opposition as their function is to express values of attributes (Miller & Fellbaum, 1991). Such a semantic organization may (somehow) facilitate access by aphasic patients. Although no similar effect has been reported in the literature, no other study has specifically examined monosyllabic adjectives.

Differences between adjectives and words from other grammatical categories were found along a range of dimensions. The adjectives in the present sample were, on average, higher in Written, Spoken and Heritage Frequency and lower in Age of Acquisition than nouns and verbs (see Appendix B3).[31] Although the inclusion of the 4 frequency-related variables in multiple regression analyses controlled for such differences, the fact remains that adjectives differed from words belonging to other grammatical categories along multiple dimensions. As such, it is not surprising that they

[31] The order of frequency in this study was (1) adjectives, (2) nouns and (3) verbs. More specifically, the adjectives were significantly higher than the nouns and verbs in Written, Spoken and Heritage Frequency and lower than the verbs in Age of Acquisition.

accounted for most of the variance in reading performance. Note that the adjectives of the present study were selected simply for being monosyllabic and for matching nouns and verbs in initial and/or final stop consonant. The question is, are these adjectives unusual in any way that is unaccounted for or are the observed differences between adjectives and words from other grammatical categories intrinsic to monosyllabic adjectives in general? Evidence for intrinsic differences between words of different grammatical categories exists in the literature: verbs are often acquired later than nouns (Bates et al. 1994) and are broader in meaning than nouns (Gentner, 1982). Similarly, monosyllabic adjectives may instantiate multidimensional variables that differ from both nouns and verbs in a number of ways. This issue is addressed further in the third question of the study by examining the relationship between grammatical category and semantic/associative variables. However, replication of the present findings using a different set of monosyllabic adjectives would provide evidence in favor of a special role of such adjectives in predicting reading performance.

A frequency variable, Heritage, also predicted reading performance in all patients' productions. This underscores the importance of controlling for frequency in investigations of aphasic reading. That it was Heritage rather than Written Frequency, suggests that the frequency of words in school texts is a stronger predictor of reading performance than the frequency of words appearing in adult reading material. Words appearing frequently in school texts, probably earlier-learned words, are particularly resistant to disruption due to brain injury.

The variable Consonant Cluster just failed to reach significance (.05 level) in analyses including all the patients. Words with consonant clusters tended to result in more erroneous reading productions than words without consonant clusters. Consonant Cluster correlates with Word Length, since four- and five-letter words are the only possible places where consonant clusters can be found. In this analysis, Consonant Cluster was a stronger variable than Length when all patients' productions were considered together. The fact that Consonant Cluster encompasses Word Length (most five-letter words contain consonant clusters) may be why it is a stronger predictor of performance in analyses including all the patients.

A striking finding, however, is the extremely limited role that word variables played in predicting reading success. As Table 5 showed, subject variables, especially Severity of Aphasia and Agrammatism, played a considerably more important role in predicting word reading accuracy than word variables, together accounting for 33 percent of the variance. Word variables added less than one percent to the outcome variance accounted for by Severity of Aphasia and Agrammatism. Clearly, knowledge of patient characteristics is a considerably more important predictor of reading success than knowledge of word characteristics.

The relationship between reading performance and subject variables is shown in Table 22, which lists patients by severity of reading impairment (% words read correctly) and also provides Severity of Aphasia and Agrammatism status information.

Table 22: Patient reading performance in order of Severity of Aphasia

PATIENT	SEV.*	% CORRECT		PATIENT	SEV.*	% CORRECT
NFBS	1 A	5.2		FLJM	3	91.1
NFIT	1 A	12.6		NFGG	3	93.3
FLRT	1	17.5		NFAG	3	94.8
NFMA	1 A	23.0		FLCD	3	95.6
NFBM	1 A	35.6		FLCG	3	96.3
NFHM	1 A	46.6		FLWZ	2.5	97.8
FLMC	2	60.7		FLWL	3.5	97.8
NFJE	1 A	74.1		FLNG	3.5	97.8
NFRB	2 A	77.7		FLHT	3	98.5
FLHR	5	87.4		FLHW	3	100

*Severity (Sev.) is rated 1-5; A=Agrammatism

As Table 22 shows, Severity of Aphasia corresponded closely to severity of reading impairment: more impaired patients (low scores) had the fewest correct responses. Also, the most impaired readers tended to be Agrammatic.[32] Fluency status, the third significant subject predictor of reading performance, is also reflected in the table. Nonfluent patients performed considerably worse than Fluent patients, with only two

[32] An exception is FLHR, who has Alexia without Agraphia. A letter-by-letter reader, FLHR showed minimal discernible speech difficulty; in fact, his only area of deficit appeared to be mild word-finding difficulties on the Boston Naming Test. Reading was even more difficult for FLHR than his accuracy percentage reflected, because he required an exceptionally long time to read words, including those he succeeded in producing correctly.

exceptions: FLRT, a severely impaired Wernicke's aphasic and FLMC, a Conduction aphasic.

In conclusion, when productions from all patients are pooled, adjectives and words of high Heritage Frequency are read more accurately than other types of words. Nevertheless, the proportion of the error variance accounted for by these two variables is very small compared with the proportion of the error variance accounted for by the subject variables. Put in a different way, the level of impairment of a patient is a stronger predictor of success in activating the phonology of a word than the type of word a patient is presented with. This finding suggests that to evaluate the role of linguistic variables in predicting reading success it is necessary to examine productions from a homogeneous sample.

2. Do different word characteristics account for the performance of different types of aphasics?

The finding that Severity of Aphasia, Agrammatism and Fluency are significant predictors of reading performance leads to the second question of the investigation: Which word variables account for the performance of different aphasic groups? Fluency status and the presence of Agrammatism, the two traditional ways of classifying aphasic patients, are each useful classification criteria and lead to very similar results.

When patients were examined by Fluency, different word variables predicted the reading performance of Nonfluent and Fluent patients. Verb, Heritage Frequency and Word Length accounted for independent portions of the variance in the reading performance of Nonfluent (and Agrammatic) patients. The findings were largely replicated in a subset of stimulus words, with AOA taking the place of Heritage

Frequency. Ease of Association was the only variable that accounted for the performance of the Nonfluent (and Agrammatic) patients when the semantic and associative variables (the Toglia and Battig ratings) were included.

Adjective was the only variable that accounted for the performance of Fluent patients when all the stimulus words were analyzed, replicated in the subset of stimulus words. When semantic and associative variables were added, Imageability also achieved significance. In fact, Imageability was the only Toglia and Battig variable that correlated significantly with word score in the Fluent group. Consistency of pronunciation was significant for the Good Comprehension subgroup of the Fluent group, the group with the fewest errors, overall.

Grammatical Category is an important predictor of reading performance in Nonfluent patients, especially those diagnosed as deep dyslexic, who are often also agrammatic (Coltheart, 1980a). Grammatical category effects are consistent with the dual-route theory of reading. As seen in the Introduction, most models of word reading (e.g., Coltheart, Curtis, Atkins & Haller, 1993; Seidenberg & McClelland, 1989) propose two main ways of pronouncing written words: one deriving phonology from meaning (the lexical route) and another deriving phonology directly from orthography (the sublexical route). When the sublexical route ceases to be operational, grammatical category effects arise because words like functors and verbs have weak semantic representations. Single-route, analogy models, do also predict grammatical category effects (e.g., Friedman & Kohn, 1990). Note, however, that although Friedman and Kohn's (1990) model uses a single, analogy mechanism for deriving phonology from orthography, it is in fact a dual-route model: It proposes a lexical, analogy route using a word's orthographic neighbors and a semantic route. The results of the present investigation are consistent with the reported pattern of more impaired reading of verbs than of words from other grammatical categories in Nonfluent/Agrammatic patients.

Nevertheless, Grammatical Category effects are not reported exclusively in nonfluent aphasics (see Caramazza & Hillis, 1991; Glosser & Friedman, 1990). In the present investigation, patients in the Fluent group also showed a Grammatical Category effect. Similar to Nonfluent aphasics, they read adjectives better than words from other grammatical categories; however, unlike Nonfluent aphasics, they showed no difference between noun and verb reading (see Figure 6, also Appendix C5 which shows no correlation between noun or verb and word score for the Fluent group). Consequently, patients in the Nonfluent group read verbs worse than words from other grammatical categories, whereas patients in the Fluent group read adjectives better than words from other grammatical categories.

Frequency (Heritage) was an important predictor of reading performance in the Nonfluent group. Dual-route models of reading predict frequency effects when the lexical route to reading is engaged but not when the sublexical route is operational (Monsell et al. 1989). Consistent with this prediction, the Nonfluent/Agrammatic group (i.e., those most likely to engage the lexical route due to impaired grapheme-phoneme decoding skills), showed a Heritage Frequency effect. Note, however, that frequency effects were also found in the subset of the Fluent group most likely to engage the sublexical route, the Good Comprehension group, inconsistent with the above prediction. Single-route models can account for this finding in two ways: Parallel distributed models (e.g., Seidenberg & McClelland, 1989) attribute the frequency effect to sublexical factors since high frequency words have stronger orthography-phonology connections than low frequency words. Analogy models (e.g., Andrews, 1989) also account for the frequency effect by a single route but attribute the effect to lexical similarity. Single-route models, therefore, can account for frequency effects in a wider range of reading deficits. That Nonfluent patients were not the only ones who showed a frequency effect, but patients in the Fluent-Good Comprehension group, the least impaired group, also showed such an effect, suggests that the effect arises at least at times at the sublexical level.

Heritage Frequency was a stronger predictor of reading performance than other frequency measures, despite the significant correlation of all four frequency measures (Written, Spoken, Heritage Frequency and AOA) with word score in the Nonfluent group. Heritage frequency is related to Age of Acquisition: when Heritage Frequency was entered as the dependent measure in multiple regression analyses, it was predicted by Written Frequency, AOA and non-verbs. When AOA was entered as the dependent measure, it was predicted by Heritage Frequency, Written Frequency, non-verbs and Neighborhood size (results of the regression analyses are provided in Appendix B4). The present investigation employed a direct AOA measure of the educational grade in which a word is first introduced instead of the more commonly employed adult ratings of when the word is introduced. The results of this investigation indicate that patients' reading is more sensitive to school text frequency than to the time at which a word was acquired (within a range of primer to sixth grade). Heritage Frequency is rarely employed in studies of adult reading, so there are no studies that directly compare Heritage Frequency and AOA. In this investigation, AOA replaced Heritage Frequency in the analyses using the subset of words. Given the close relationship between Heritage Frequency and AOA, the finding is consistent with studies showing AOA to be a stronger predictor of reading performance than written frequency and familiarity in normal readers (e.g., Brown & Watson, 1987).

Consistency of pronunciation is a measure of the degree to which a word is pronounced consistently with its rhyme neighbors. A Consistency effect in addition to a Heritage Frequency effect in the Fluent-Good Comprehension group provides support for analogy models of reading (e.g., Glushko, 1979; Jared et al. 1990), which propose that the pronunciation of a word is synthesized from the phonological codes of the word's neighbors. In the present investigation, however, sublexical variables such as orthographic regularity were not directly controlled for. Thus, it cannot be concluded that Consistency of pronunciation plays a role independent of orthographic regularity. Some control for orthographic regularity was provided through the inclusion of Bigram Frequency or commonality of spelling patterns, with which Consistency correlates. The correlation of Bigram Frequency with Heritage Frequency for words in this study is consistent with PDP models (e.g., Seidenberg & McClelland, 1989), which propose that high-frequency words have stronger orthography-phonology connections than low-frequency words.[33] However, lack of a Bigram Frequency effect for any patient group in the presence of a Consistency effect in regression analyses indicates that the Consistency effect cannot be attributed to commonality of spelling patterns. Thus, I tentatively conclude that Consistency does play a role in the reading performance of

[33] Heritage Frequency was the only frequency-related variable correlating significantly with Bigram Frequency.

certain groups of patients, without at this point excluding an orthographic regularity effect. Bigram Frequency is not an important predictor of reading performance, in agreement with lexical decision and reading speed studies of normal processes (Andrews, 1992; Gernsbacher, 1984).

Length was a significant predictor of reading performance in the Nonfluent/ Agrammatic group only, as expected. This is the group most likely to experience motor output problems in reading and therefore to be affected by word length over and above other variables.

Ease of Association was the most important predictor of reading performance for the Nonfluent and Agrammatic groups. This variable suppressed grammatical category, frequency and phonological variables. The importance of associative variables is particularly stressed in network models (e.g., Plaut & Shallice, 1993). Jones (1985) proposes a mechanism that relates associative variables to grammatical category. He shows that ease of predication (number of features associated with a given word, a concept similar to Number of Associates) varies according to grammatical category: nouns have more features than adjectives and adjectives than verbs. This mechanism may explain why associative variables suppressed grammatical category variables in the Nonfluent group. Indeed, partly consistent with Jones' (1985) proposal, adjectives in the present investigation showed higher Ease of Association and Number of Associates scores than both nouns and verbs (see Appendix B5).[34] When EOA was entered as a

[34] In the present study, the pattern observed was adjectives>nouns>verbs (Ease of Association) and adjectives>verbs (Number of Associates). The order is consistent with reading performance. This finding further suggests that there are intrinsic differences between (monosyllabic) adjectives and words from other grammatical categories.

dependent variable in a multiple regression analysis, it was predicted by Number of Associates, Adjective, AOA, Familiarity and Heritage Frequency (see Appendix B4). Thus, EOA appears to be a complex, multidimensional variable. In the present investigation, although Number of Associates correlated significantly with word score in the Nonfluent group, Ease of Association was a stronger variable. Nevertheless, EOA is rarely included in investigations of aphasic reading performance. The one study that employed associative measures in examining the reading of a single nonfluent, deep dyslexic patient (Barry & Richardson, 1988) used multiple regression analyses, and showed that associative difficulty, concreteness and frequency each had independent predictive capacity. Consistent with the present investigation, length and emotion-related variables had no independent effect.

Imageability accounted for an independent portion of reading performance variance, over and above that predicted by Grammatical Category (adjective) in the Fluent group. A comparison of the Imageability and Concreteness of words from different grammatical categories revealed that the adjectives in the present study have lower imageability and concreteness scores than nouns. Verbs have the lowest scores in all variables, being significantly lower than nouns (see Appendix B5). This finding contrasts with adjectives scoring higher in Ease of Association and Number of Associates than nouns and, most notably, verbs. Although Jones (1985) proposes that ease of predication (a concept similar to Number of Associates) is closely related to imageability (and indeed, Number of Associates and Imageability correlated significantly with each other in the present study), Number of Associates did not reach significance in the present sample of Fluent patients. The results suggest that semantic and associative variables relate to different constructs (this hypothesis is addressed in question 3).

The finding of an Imageability effect but not a Concreteness effect in the Fluent group underscores the importance of Imageability as a variable in its own right. Imageability and Concreteness have not been compared in the aphasia literature, which typically uses the two interchangeably. The present investigation suggests that Imageability is a more important variable to include or control for than Concreteness.

Aphasic performance was also examined with respect to lesion site and size of lesion. Findings using the two classifications were in close agreement: the reading performance of patients in the Mixed/Large lesions group was predicted by the variable Adjective. The reading performance of patients in the Posterior/Small lesion group was predicted by Consistency and Heritage Frequency. Because of lack of patients in some categories (such as Large-Posterior), it is not yet possible to partial out the effects of the two variables. Nevertheless, the findings suggest that orthographic effects are more likely to occur in patients with relatively small, posterior lesions.

3. Does the performance of individual aphasics reflect the pattern of performance obtained from group data?

Individual Nonfluent patients showed effects arising from a range of predictor variables. Table 23 summarizes those variables for individual Nonfluent patients (listed by order of severity of reading impairment). Variables reaching significance between .05 and .06 are listed in parentheses.

Table 23: Individual results for the Nonfluent patients

	SEVER.	ALL WORDS	75-WORD LIST	WITH T & B VARS
NFBS	1	HERIT, ADJECT, (NOUN)	ADJECT, NOUN, AOA	ADJECT, EOA, (NOUN)
NFIT	1	SFREQ	LENGTH	LENGTH
NFMA	1	VERB, (AOA)	n.s.	EOA
NFBM	1	WFREQ, CLUSTER	n.s.	EOA
NFHM	1	VERB	VERB	IMG
NFJE	1	WFREQ	n.s.	n.s.
NFRB	2	WFREQ, CONSIST	HERIT	HERIT
NFGG	3	HERIT	HERIT	FAM, CON
NFAG	3	VERB, NEIGH	CONSIST	CONSIST

Table 23 reveals that more impaired patients tended to show effects of grammatical, semantic/associative and phonological variables, whereas less impaired patients showed orthographic effects. Frequency-related effects were evident in patients regardless of severity of reading impairment. A number of Nonfluent patients showed an effect of one or two of the three variables that were significant in group analyses using the complete set of stimulus words, namely verb, Heritage Frequency and Length. Three patients showed an Ease of Association effect when the Toglia and Battig variables were included.

Individual Fluent patients also showed effects of a range of predictor variables. Table 24 summarizes those variables for individual Fluent patients (listed by order of severity of reading impairment), grouped by comprehension level.

Table 24: Individual and group results for the Fluent patients by comprehension level

POOR COMPREHENSION

GROUP	PT.	ALL WORDS	75-WORD LIST	WITH T & B VARS.
FLRT	1	VERB	VERB	ADJECT, IMG

GOOD COMPREHENSION

GROUP	PT.	ALL WORDS	75-WORD LIST	WITH T & B VARS.
FLMC	2	n.s.	VERB	VERB
FLHR	5	HERIT, CONSIST	HERIT	HERIT
FLCD	3	CONSIST	few errors	few errors
FLCG	3	HERIT	few errors	few errors

Table 24 shows that individual patterns of patients in the Poor Comprehension and Good Comprehension groups were mostly consistent with group patterns. The one patient in the PC group showed Grammatical Category and Imageability effects, consistent with group results. Patients in the GC group showed Heritage Frequency and Consistency effects, consistent with group results.[35]

[35] Note that not all patients entering the group analyses are listed in the individual analyses because of too few errors: FLHT, FLNG, FLJM and FLHW are not included in the PC group and FLWZ and FLWL are not included in the PC group.

a. Theoretical implications:

Two competing theories aim to account for the effects of grammatical and semantic variables in the reading of aphasic patients, with different predictions about the effects. According to one theory (Caramazza,1997; Caramazza & Hillis, 1991), lexical-semantic and syntactic properties of words are represented independently in the lexicon.[36] Word meanings are represented in the lexical-semantic network as sets of semantic properties, features or predicates. These properties are distinct from syntactic features such as grammatical category, which are represented in an independent, modality-specific lexical-syntactic network. Syntactic information forms one of the organizing dimensions of the lexicon. Selective impairments in grammatical category occur because nouns and verbs are processed by separate neural mechanisms. They do not occur because verbs are more difficult to process nor because verbs are more closely related to grammatical processing. The theory makes three critical predictions. First, grammatical category and concreteness effects can occur independent of each other in reading. Second, the two effects are not necessarily linked to severity of impairment as grammatical category represents an independent organizational principle of the lexicon. Third, both a verb deficit and a verb superiority should be observed in reading (when a verb deficit versus a verb superiority are expected is addressed in the section on neuroanatomical implications, which follows).

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[36] The present study does not address the proposition that syntactic properties of words are represented independently in semantic memory as well as in different output modalities but limits its theoretical implications to written input and spoken output, as manifested in oral reading.

According to the second theory (Friedman, 1996; Friedman & Kohn, 1990), both grammatical category and semantic effects reflect the basic structure of the semantic system: words with less densely interrelated associative networks (such as verbs and abstract nouns) have weaker representations than those with dense associative networks (such as adjectives and concrete nouns). Symptoms appear as a consequence of strength of association. The existence of grammatical category effects, semantic effects, or both, are a function of severity of impairment, with symptoms following a consistent and predictable succession: a word class effect (nouns>functors) appears before a grammatical category effect (nouns>adjectives>verbs) and that, in turn, appears before a concreteness effect (concrete>abstract). The production of semantic paralexias is the last symptom to appear in this sequence. According to Friedman (1996), most content words have sufficiently strong semantic representations for the semantic route to render the correct response. When the semantic route is very impaired, however, even content words become affected. Semantic paralexias appear in words that do not receive sufficient activation in the semantic lexicon but which have richly connected associative semantic nets. When a target word fails to become activated, a high-frequency word closely related to the target may become activated, instead. The theory also makes three critical predictions. First, symptoms should appear as a function of severity of the impairment to the semantic route. Second, symptoms should follow a specific order of emergence, with a symptom later in the sequence, e.g., a concreteness effect, presupposing the existence of a symptom earlier in the sequence, e.g., a grammatical category effect. Third, factors pertaining to degree and strength of association should account for both grammatical category and semantic effects.

The presence of individual grammatical category effects without concomitant concreteness effects is consistent with both theories. Such effects have been reported in the aphasia reading literature (e.g., Caramazza & Hillis, 1991). A more stringent test of the independence of grammatical category, a verb superiority in reading, has been reported infrequently (e.g., Hillis & Caramazza, 1995).[37] According to Friedman (1996), word meanings and syntactic features are components of the same system, both represented in terms of density of interrelated associative networks. Category specific impairments in a direction opposite to that indicated by strength of association are not predicted by this model. Furthermore, a concreteness effect should always be accompanied by a grammatical category effect and semantic paralexias should be accompanied by both grammatical category and concreteness effects.

The methodology that an investigation employs can influence the direction of the findings, with important theoretical implications. The two contrasting theories are based on collections of single case studies. Such studies have become the preferred format in the aphasia literature. They typically employ factorial designs through which they examine the effects of a limited number of variables while controlling for the effects of others, often using separate word lists for doing so (e.g., Caramazza & Hillis, 1991; Hillis & Caramazza, 1995; Friedman & Kohn, 1990). Multiple regression analyses, which were used here, control for a range of variables that cannot be controlled in factorial designs. In order to compare the findings of the present investigation with the

[37] Nevertheless, studies using different tasks that engage the phonological output lexicon, e.g., naming, often report both verb and noun superiority (e.g., Daniele et al. 1993; Miceli et al. 1994; Zingeser & Berndt, 1990).

predictions of the two theories, patients showing an effect of grammatical category, semantic or associative variables are listed in Table 25. Variables correlating with word score and the presence or absence of semantic paralexias are also listed next to each patient. The variables are listed in order of magnitude of significance level, provided in Appendix D6 together with p values. The patients are presented in order of severity of reading impairment, beginning with the most impaired.

Table 25: Patients showing a grammatical, semantic or associative effect

PATIENT	MULT. REGR.	CORRELATIONS	SEM. ERRORS
NFBS	ADJECT, EOA	EOA, ADJECT, HERIT, AOA, WFREQ, SFREQ, FAM, NOA, N/V	YES
FLRT	IMG, ADJECT	IMG, CON, VERB	YES
NFMA	EOA	VERB, AOA, EOA, ADJECT	YES
NFBM	EOA	EOA, FAM, CLUSTER, NOA, WFREQ, HERIT, AOA	NO
NFHM	IMG	VERB, IMG	NO
FLMC	VERB*	VERB	NO
NFGG	FAM, CON	FAM, IMG, CON, HERIT	NO
NFAG	VERB, NEIGH	VERB, NEIGH	NO

* Found in 75-word set, only

Table 25 shows that predictor variables do follow an order of severity of impairment. The three most impaired patients (NFBS, FLRT, NFMA) showed a grammatical category effect and a semantic-associative effect. They also made semantic errors. These patients had great difficulty with grapheme to phoneme conversion and their symptoms were characteristic of deep dyslexia. Their pattern of performance is consistent with Friedman's (1996) hypothesis of the co-occurrence grammatical category and semantic-associative effects in patients making semantic paralexias. Examples of semantic paralexias for the patients are provided below, with percent of words read correctly in parentheses next to each patient as an indication of severity of reading impairment:

NFBS (5.2 %)   wed→*married*; taste→*eating*; cab→*/pæti/* (taxi)

FLRT (17.5 %)   tomb→*cold, dead .. /dom/, /dum/*; lad→*/bɛdi/ /bɛdi/ boy*

NFMA (23 %)   deaf→*hearing .. what?*; deep→*sea*;
gull→*/hɑki/ .. no, no, no, fly.. OK /gɔlts/*

The next five patients (NFBM, NFHM, FLMC, NFGG, NFAG) made no semantic paralexias. They also showed an effect of a range of grammatical and semantic-associative variables. According to Friedman's hypothesis, patients showing a concreteness effect should also show a grammatical category effect. As the table reveals, this was not the case for all the patients. NFHM (46.6 % correct) often produced phonological approximations (e.g., lip→*tip*) and occasionally did not respond. Consistent with Friedman's (1996) hypothesis, he showed both a grammatical category and an imageability effect. However, NFBM (35.6 % correct) showed an associative effect but neither concreteness-imageability nor grammatical category effects. This patient gave a large number of no responses or indicated an inability to read many words. FLMC (60.7 % correct), a Conduction aphasic who produced many phonological approximations (e.g., bean→*bill, bet, ben, bean, bean*), showed a verb effect, only. (However, because he failed to show a verb effect or any other effect in the expanded set of words, which includes a greater number of both verbs and adjectives, the findings must be interpreted with caution). Finally, NFGG (93.3 % correct) showed a semantic effect but not a verb effect and NFAG (94.8 % correct) showed a verb effect. (Because of their small number of errors, the findings should also be interpreted with caution).

On balance, the results of the present investigation are consistent with some of the predictions of each theory. Clearly, variables achieving significance individually follow some measure of degree of reading impairment, consistent with Friedman (1996). The three most impaired patients showed all three predicted symptoms: grammatical category effects, semantic/associative effects and semantic paralexias. The two patients who followed, however, presented a more mixed picture. One patient showed both a semantic and a grammatical category effect but the other showed an associative effect without a grammatical category effect. If density of associative networks were the underlying principle of the continuum, then associative variables should account for all the symptoms in multiple regression analyses. Although Ease of Association does account for Nonfluent reading performance in group regression analyses, it does not account for the reading performance of every patient (nonfluent or fluent) who shows a grammatical category or semantic effect.

The above discrepancies raise two possibilities: either grammatical category effects are independent of other effects or the proposed order of symptoms requires reconsideration. Caramazza and Hillis (1991) and Hillis and Caramazza (1995) offer some evidence for the independence of grammatical category in their reports of complementary deficits in the spoken and written output of nouns and verbs in two patients using the same stimuli. Indeed, the present findings might be interpreted in terms of the independence of grammatical category.

b. The relationship between semantic and associative variables:

Nevertheless, it is also possible that semantic (e.g., Imageability) and associative (e.g., Ease of Association) variables relate to different constructs. Differences in number/strength of associates between abstract and concrete words have been emphasized by a number of models (e.g., Allport, 1985; Jones, 1985; Plaut & Shallice, 1993). However, Concreteness (and Imageability) capture an additional, non-linguistic dimension. Paivio and colleagues (1968) observed an asymmetrical relationship between Concreteness-Imageability and Ease of Association: many items low in concreteness-imageability were high in Ease of Association ("meaningfulness"), but never the other way around. They explained this asymmetrical relationship in terms of dual coding theory: abstract words derive their meaning through verbal associates whereas concrete words can be associated with both sensory and linguistic experience.[38] Some degree of independence of concreteness-imageability and associative variables is consistent with the present findings. In multiple regression analyses, Ease of Association accounted for Number of Associates, frequency (and related variables) and grammatical category (NFBS, NFMA & NFBM) but not for Concreteness and

[38] In this study, Imageability is predicted by Concreteness and Ease of Association when it is entered into multiple regression analyses as the dependent variable (see Appendix B4).

Imageability (NFHM & FLRT). In fact, for the last two patients Ease of Association did not even correlate with word score.

Concreteness effects (abstract word deficits) are conceptualized as examples of category-specific deficits, found in brain-damaged subjects (e.g., Warrington & McCarthy, 1987). Such deficits are commonly interpreted in terms of fine-grained distinctions in the representation of semantic knowledge in the brain (Hillis & Caramazza, 1991; Warrington, 1981). The rare reports of reverse concreteness effects (concrete word deficits) are interpreted as further evidence for a categorical organization in the representation of meaning (e.g., Warrington, 1981; Warrington & Shallice, 1984). Alternatively, such deficits have been attributed to loss of perceptual aspects of word meaning (Breedin et al. 1994; Plaut & Shallice, 1993). Thus, the more commonly reported concreteness effects may imply a considerable reliance on perceptual aspects of meaning.

The importance of different variables as predictors of reading performance may vary as a function of subject characteristics. Associative variables do not account for the performance of any individual Fluent patient in simple or multiple regressions. Ease of Association is a very important variable in the performance of Nonfluent patients, however. Speculatively, this finding might be accounted for by a slowed or diminished activation of lexical information in Broca's aphasics (e.g., Milberg, Blumstein, Katz, Gershberg, & Brown, 1995; Prather, Zurif, Love, & Brownell, 1997). In the present study for Broca's aphasics who are very impaired readers, words that facilitate the activation of lexical information (words with high Ease of Association values) are read with greater accuracy. By contrast, Wernicke's aphasics might be affected by a disruption of mechanisms involved in inhibition (Prather, Zurif, Love, & Brownell, 1997), which results in activation of an imprecise sense of a word or of multiple senses of word meanings. In the present sample for the Wernicke's aphasic who is a very impaired reader, words associated with narrower or clearer meaning (words other than verbs, high imageability words) are read with greater accuracy. Verbs tend to be broader in meaning and to have more meanings than nouns (Gentner, 1982; Miller & Fellbaum, 1991).

c. The role of frequency:

Patient characteristics such as severity of aphasia and severity of reading impairment (percent correct) are not sufficient predictors of grammatical category and semantic effects without considering type of error. For example, NFIT, a nonfluent agrammatic patient with very impaired reading (12.6 % correct) and considerable motor output problems approximated the words phonologically to varying degrees (e.g., post→*/ros/*; wit→*bit*). He showed a Spoken Frequency effect but no grammatical category or semantic-associative effects and made no semantic errors. NFJE, a nonfluent agrammatic patient with less impaired reading than other agrammatic patients (74.1 % correct), showed a Written Frequency effect but no grammatical category or semantic-associative effects. She made many morphological errors (e.g., weep→*weeping*; weed→*weeds*) but no semantic errors. Thus, although both a large number of reading errors in and certain patient characteristics may be associated with grammatical category and semantic effects, a deficit in the phonological pathway (irrespective of whether it is attributed to a lexical or sublexical level) seems a necessary condition. In the present study, such a deficit is reflected as a large number of reading errors with little or no phonological similarity to the target.

Neither the independence of grammatical category model nor the strength of semantic relationships model make explicit predictions concerning the relationship of frequency effects to other effects in reading. For Caramazza and Hillis (1990), word frequency has a computational role in the phonological output lexicon (in addition to grammatical category). For Friedman (1996), high frequency words simply have higher levels of activation, similar to nouns and concrete words. Network models of lexical organization (e.g., PDP models) predict the co-occurrence of frequency and associative effects because frequency is linked to number and strength of connections between units. In the present investigation, frequency effects were observed in most patients (in correlations) regardless of level of impairment.[39] In the most impaired patients (e.g., NFBS, NFBM), such effects were accounted for by associative variables, consistent with PDP models. In both the less impaired (e.g., FLCG, FLHR, FLCG) and the more impaired patients (NFIT, NFJE), however, frequency effects were found in the absence of grammatical, semantic or associative effects. Thus, frequency effects are predicted throughout the continuum of impairment and can co-occur with any type of variable. When associative variables are also present, however, they tend to subsume frequency variables.

[39] Note, however, that the present investigation employed a range of frequency measures not usually employed in aphasia studies.

d. Neuroanatomical implications:

Selective impairments in nouns and verbs are typically interpreted in terms of separate brain structures that subserve their processing for written and spoken language (e.g., Caramazza, 1997). Specifically, nouns are hypothesized to be represented in the left anterior and middle temporal regions and verbs in the left frontal region. Patients with Broca's aphasia, who typically have lesions spanning anterior areas, have more difficulty naming verbs whereas patients with Wernicke's and Anomic aphasia, who typically have posterior lesions, have more difficulty naming nouns (e.g., Daniele et al. 1993; Damasio & Tranel, 1993). Although the brain area associated with Broca's aphasia extends over a larger area than initially proposed (Mohr, Pessin, Finkelstein, Funkenstein, Duncan, & Davis, 1978), it appears to be neuroanatomically distinct from that associated with Wernicke's aphasia (Benson, 1985). Some naming studies do report findings based on patients with focal lesions; however, such patients are rare in studies on grammatical and semantic effects in reading. Patients who show grammatical effects have deficits in the phonological pathway and tend to have lesions spanning both anterior and posterior areas (e.g., Glosser & Friedman, 1990; Hillis & Caramazza, 1995). Indeed, in the present investigation patients who showed grammatical category and/or semantic effects (for whom scans were available) had lesions extending to both anterior and posterior brain areas. The reading of patients in the posterior group was much less impaired. No patient in the present sample had a strictly anterior cortical lesion. Thus, the claim that nouns and verbs are subserved by different areas could not be tested. Appendix D7 lists individual patient results under groups divided by lesion site and size.

B. Conclusions:

The word variables that predicted reading performance are multifaceted. Adjectives in the present study have denser associative links, higher frequency (Written, Heritage and Spoken) and lower Age of Acquisition than verbs. Furthermore, frequency of occurrence of words in school texts (Heritage Frequency) was a stronger predictor of reading performance than frequency of occurrence of words in adult reading material (Written Frequency).

Ease of Association only accounted for grammatical category, frequency and phonological effects in group analyses and in a number of individual analyses for the Nonfluent patients. The finding is consistent with the hypothesis that strength of association is the underlying dimension in observed grammatical category effects in reading. Ease of Association did not predict the reading performance of a Fluent patient and of a Nonfluent patient who showed grammatical category and imageability effects, however, inconsistent with the above theory. Two explanations have been examined: either grammatical category has independent status in the lexicon or strength of association is not the underlying principle in all types of patients. Although the independence of grammatical category cannot be refuted on the basis of the present findings, the possibility that different processes account for the performance of different patients is a viable alternative. The second explanation differs from an explanation based on the distinct organization of nouns and verbs in the brain: a verb deficit, for example, may have different underlying dimensions in different patients.

The present findings indicate that the traditional variable that most studies control for in investigations of grammatical category effects in reading, namely concreteness, may not be the critical variable to control for. Given the theoretical importance of associative variables, it is surprising that few studies have included such variables in the investigation of aphasic reading. Furthermore, concreteness effects may not apply to all types of words. Eviatar and colleagues (1990), for example, found a concreteness effect only for nouns. If this is the case, testing for concreteness effects (particularly through the administration of separate reading lists) does not control for possible factors to which differences between nouns and verbs might be attributed.

The present findings also point to a method for the investigation of reading in aphasia. The interrelation among predictor variables make it very difficult to control for a number of them in order to investigate grammatical category or any other variable of theoretical interest using a factorial design. The conduction of both individual and group analyses using the same stimuli is crucial for comparing patterns of performance at the two levels of analysis. Furthermore, the incorporation of both linguistic and subject variables at the group level provides important information about their relative importance. In the present investigation, linguistic variables accounted for a very small proportion of the reading performance, considerably smaller than subject variables.

C. Future directions of research:

The present findings need to be replicated using either the same set of words or monosyllabic words that are phonologically similar to each other and including more Wernicke's aphasics that are impaired readers. However, fewer word predictor variables need to be included in future investigations of aphasic reading. Pleasantness, for example, did not reach significance in any individual or group analyses and does not seem promising. Nevertheless, Pleasantness may be non-linearly related to word score and the inclusion of a variable reflecting degree of emotional salience, either positive or negative, may be more appropriate.

The relationship of type of error (e.g., semantic, morphological) to predictor variables can be investigated in more detail by computing an index of semantic or morphological errors for each patient. The index can be calculated as a ratio of number of semantic (or morphological) errors over all errors that the patient makes. To increase the error corpus, all productions can be counted and not just the ones receiving a word score. According to Freedman (1996), semantic paralexias are associated with greater levels of impairment; morphological errors, on the other hand, are predicted for less impaired patients. Furthermore, different types of words may be associated with different types of errors. Some investigators (Caramazza & Hillis, 1990; Hillis & Caramazza, 1995) found that the probability of making a semantic error in reading was affected by grammatical class: patients made more semantic errors on nouns but more omission errors on verbs.

The stimulus words of the present study are designed to form minimal pairs that differ in initial and/or final voicing (e.g., *bath-path*) and/or place of articulation (e.g., *bed-beg*). This aspect allows for feature-level analyses of patient productions in a phonologically controlled environment. Such analyses may provide important information about the incidence of different types of single-feature errors (voice, place or manner) in different patients or groups of patients. Furthermore, they may provide information about the relationship of such errors to the phonological environment of the word. Are, for example, nonfluent patients more likely to make assimilation errors (e.g., bean→*mean*) than fluent patients, and if so of what kind?

Finally, the effect of type of orthography of a language ("deep" vs. "shallow") on lexical (frequency, grammatical category, etc.) and sublexical (phonological, orthographic) predictors of reading performance and on type of error is theoretically interesting. Most reading studies report findings based on speakers of English and French, both languages with "deep" orthographies. According to Ardila (1991), semantic errors are rarely observed in languages with "shallow" orthographies. What is the role of lexical and sublexical variables in the reading of aphasic patients who are speakers of languages with "shallow" orthographies? Research on normal processes offers evidence for a limited importance of some lexical variables in languages with "shallow" orthographies. Speakers of orthographically transparent languages show no facilitation of high-frequency words; the greater the orthographic depth of the language, however, the greater the facilitation of high-frequency words (Frost et al. 1987).

Greek is a particularly interesting language for investigating the contribution of lexical and sublexical factors in reading. It is (for the most part) orthographically transparent for reading. A unique feature of its orthography is that a phoneme can be represented by a range of orthographic forms. The presentation of any of the orthographic forms, however, always results in the same pronunciation.[40] Furthermore,

[40] Greek is orthographically "opaque" for writing: the selection of the orthographic forms that correspond to the phonemes that make up a word is a complex process that utilizes grammatical and morphological knowledge.

different orthographic forms of a phoneme can be associated with different grammatical categories and morphological structures.

The following example illustrates the case: the letters (and diphthongs) η, ι, υ, οι, ει all correspond to the sound /i/. The different ways of spelling /i/ can be associated with different grammatical categories and morphological forms. The grapheme "ει" is linked with verb endings; "η" is linked with noun and adjective endings in singular form; and "οι" is linked with noun and adjective endings in plural form, as in:

λύνει /ˈlini/ (solves)

λύση /ˈlisi/ (solution)

λίθοι /ˈliθi/ (stones -noun)

Moreover, different orthographic forms of phonemes can also be found independent of grammatical and morphological factors, as in the following two nouns:

λύση /ˈlisi/ (solution)

λήψη /ˈlipsi/ (receipt)

Also seen in the following two verbs:

λύνω /ˈlino/ (to solve)

λείπω /ˈlipo/ (to be absent)

Thus it is possible to study the contribution of different orthographic forms to reading in words with similar phonological structure focusing on the function of orthography to signal grammatical category and morphological forms as well as the contribution of different orthographic forms independent of higher level lexical factors.

Furthermore, it is possible to select nouns, verbs and adjectives that are unambiguous for grammatical category membership and are derived from the same word meaning, as in:

εργάζομαι /εrˈɣazomε/ (to work -verb)

εργατικός /εrɣatiˈkos/ (hard-working -adjective)

εργασία /εrɣaˈsia/ (work -noun)

The three words belong to different grammatical categories. Although they have different stress patterns, they are very similar phonologically and have the same number of syllables.[41] These properties allow for the investigation of the role of grammatical category in reading while controlling for ambiguity in grammatical category assignment, phonological factors and word meaning.

The investigation of lexical and sublexical factors in the reading of Greek-speaking aphasic patients is currently underway. If lexical factors are of lesser importance in such patients, then variables such as grammatical category should not predict reading performance, even for very impaired readers. Different orthographic forms are expected to show an effect independent of lexical factors. If, on the other hand, Greek-speaking aphasic patients, especially the very impaired readers, employ a lexical route, then grammatical category effects should be present and different orthographic forms should not show an effect independent of grammatical category.

[41] According to Greek rules of syllabification, "εργασία" consists of four syllables (ερ-γα-σί-α).

V. APPENDICES

A. Patient description

1. Patients tested (partly/fully) but excluded:

Patient	Classification (if known)	Reason(s) for exclusion
NFAM	Broca's	Difficulty speaking clearly pre-CVA. Learning problems as a child, as per spouse.
NFDG	Broca's	No spontaneous speech. Unable to perform any of the reading tasks.
NFJH	Broca's	More than one CVA.
FLAV	Anomic	Scan showed bilateral lesion.
FLJB	Anomic	Spoke Croatian as a child at home.
FLLA	Anomic/Progressive language impairment	No focal lesion on MRI.
JH	Transcortical Motor	Refusal to continue. (Could not be classified in terms of fluency due to type of aphasia).
CA	N/A	More than one CVA.

2. Evaluation results:

Results of language and neuropsychological evaluation not included in Table 1.

MMSE= Mini Mental State Examination, Edinburgh= Edinburgh Handedness Inventory.

2. Evaluation results (Nonfluent Patients)

	NFAG	NFHM	NFRB	NFGG	NFMA	NFBS	NFBM	NFJE	NFIT
Classification	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's
Severity	3	1	2	3	1	1	1	1	1
Age/Gender	50 F	63 M	63 M	50 F	64 M	34 F	58 M	75 F	84 M
T.P.O.	9 yrs	24 yrs	10 yrs	3 yrs	5 yrs	3 yrs	3 yrs	5 yrs	9 mo.
BDAE:									
Verbal Agility (/14)	10	5	7	7	9	1	7	4	4
Comprehension:									
Word Discr. (/72)	70	60	72	71	58	59	65.5	62.5	60.5
Body-Part Ident. (/20)	16	13.5	20	20	7	12.5	16	15	14.5
Commands (/15)	10	5	15	14	6	6	13	7	14
Complex Ideat. (/12)	11	4	9	10	1	0	6	1	6
Respons. Naming (/30)	28	18	25	30	5	5	16	14	15
Reading:									
Word Reading (/30)	27	24	27	30	15	0	18	24	15
Sent. Reading (/10)	8	1	3	10	0	0	1	6	1
Repetition:									
Repet. Word (/10)	10	7	10	10	9	7	4	9	
High Prob. Sent. (/8)	6	0	5	8	2	2	6	2	
Low Prob. Sent. (/8)	4	0	1	8	1	0	1	1	
Autom. Sequences (/8)	8	4	5	8	5	3	5	6	6
MMSE (/30)	23	20	23	28	25	24	20	18/22	24
Edinburgh (R/20)	20	20	20	19	20	19	20	19	19

2. Evaluation results (Fluent Patients)

	FLHT	FLWZ	FLCG	FLMC	FLHR	FLRT	FLWL
Classification	Tra-Sens.	Anomic	Anomic	Conduction	Alexia w/o Agr.	Wernicke's	Tra-Sens.
Severity	3	2.5	3	2	5	1	3.5
Age/Gender	69 M	74 M	73 F	69 M	63 M	61 M	70 M
T.P.O.	2 yrs	3 yrs	2 yrs	1 yr	1 yr	3 yrs	1 yr
BDAE							
Verbal Agility (/14)	14	12	8	8	14	(paraphasias)	13
Comprehension:							
Word Discr. (/72)	69	68	72	69	70.5	27.5	71
Body-Part Ident. (/20)	14.5	19	20	18	19	3	16
Commands (/15)	10	14	14	14	15	0	11
Complex Ideat. (/12)	6	9	8	10	10	0	10
Respons. Naming (/30)	18	30	30	27	30	0	30
Reading:							
Word Reading (/30)	30	30	30	17	29	11	30
Sent. Reading (/10)	10	8	8	2	10	0	9
Repetition:							
Repet. Word (/10)	10	9	8	7	10	3	10
High Prob. Sent. (/8)	8	8	7	2	8	0	8
Low Prob. Sent. (/8)	7	3	2	0	8	0	5
Autom. Sequences (/8)	8	7	7	8	8	1	8
MMSE (/30)	25	23	25	18	24	14	30
Edinburgh (R/20)	19	20	17	18	18	20	20

2. Evaluation results (Fluent Patients-cont'd)

	FLNG	FLJM	FLHW	FLCD
Classification	Tra-S/Anomic	Tra-Sens	Wernicke's	Anomic*
Severity	3.5	3	3	3
Age/Gender	62 M	49 M	83 M	70 F
T.P.O.	6 yrs	4 mo.	5 yrs	7 mo.
BDAE				
Verbal Agility (/14)	14	14	10	14
Comprehension:				
Word Discr. (/72)	69.5	67	67	65
Body-Part Ident. (/20)	15	19	19	17
Commands (/15)	10	11	12	12
Complex Ideat. (/12)	8	6	4	8
Respons. Naming (/30)	18	23	12	20
Reading:				
Word Reading (/30)	25	27	30	27
Sent. Reading (/10)	7	7	9	10
Repetition:				
Repet. Word (/10)	10	10	9	10
High Prob. Sent. (/8)	6	8	2	8
Low Prob. Sent. (/8)	3	6	0	4
Autom. Sequences (/8)	8	8	8	8
MMSE (/30)	23	21	27	23
Edinburgh (R/20)	20	20	19	17

**initially Wernicke's*

3a. Lesion analysis:

Large Lesion: NFAG, NFHM, NFBM, FLCG, FLRT, FLNG

Small Lesion: NFGG, FLWZ, FLMC, FLHR, FLJM, FLHW, FLCD

Mixed Group: NFAG, NFHM, NFGG, NFBM, FLWZ, FLCG, FLRT, FLNG, FLJM

Posterior Group: FLMC, FLHR, FLHW, FLCD

The three pages that follow show examples of two plotted and scored scans (NFHM, FLMC, in that order) as well as the template employed to obtain the measurements. A lesion occupying less than 25 percent of the total area was assigned a score of 1; between 25 and 75 percent a score of 2; more than 75 percent a score of 3. Measurements involved the affected lobe(s) for assignment of lesion size and the specific neuroanatomical area for more precise measurements (not used in the present study).

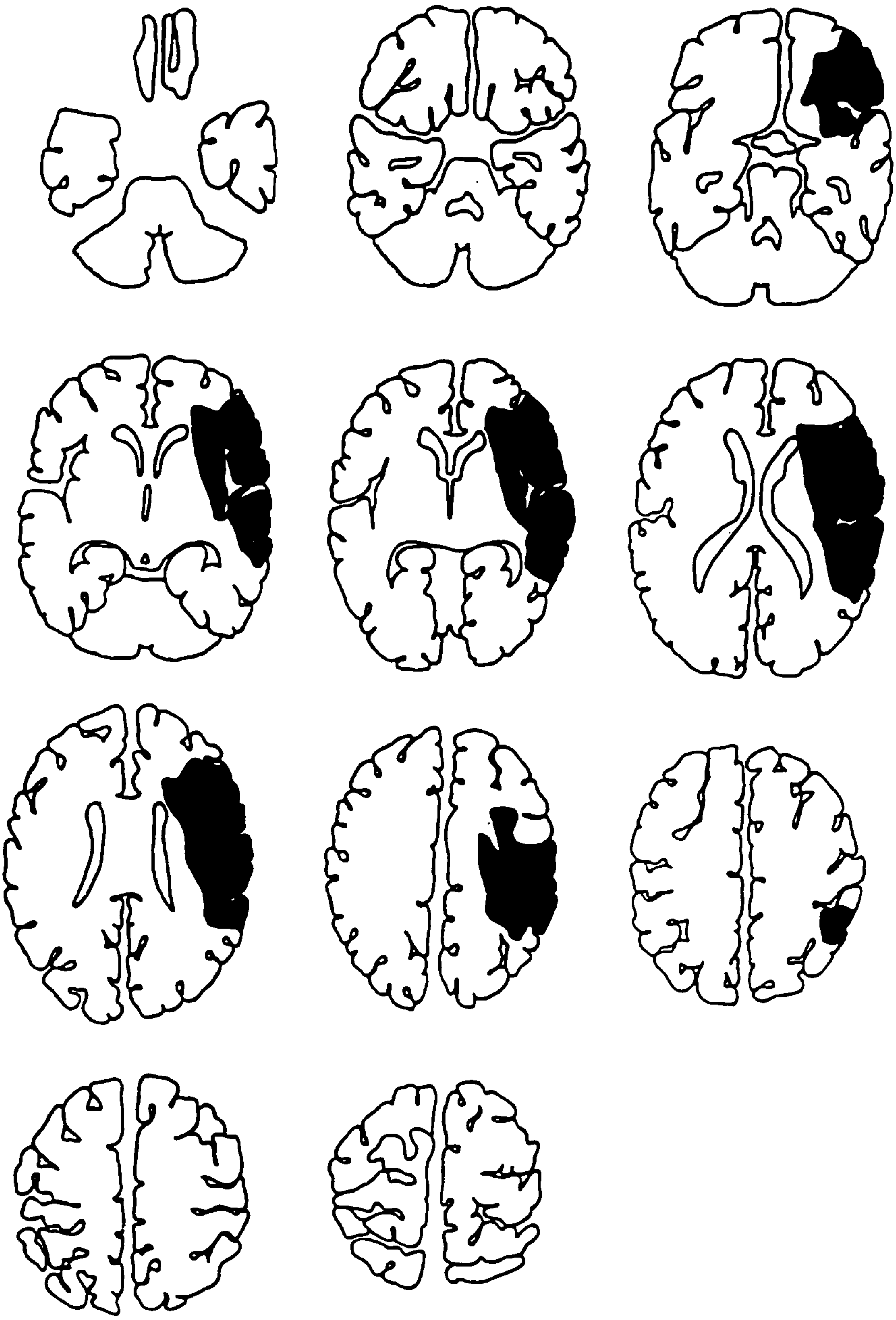
Scans with a lesion size of 1 comprised the Small Lesion group. Scans with lesion sizes of 2 and 3 comprised the Large Lesion group (only one patient, NFAG, had a size of 3).

3b. Examples of two scored scans:

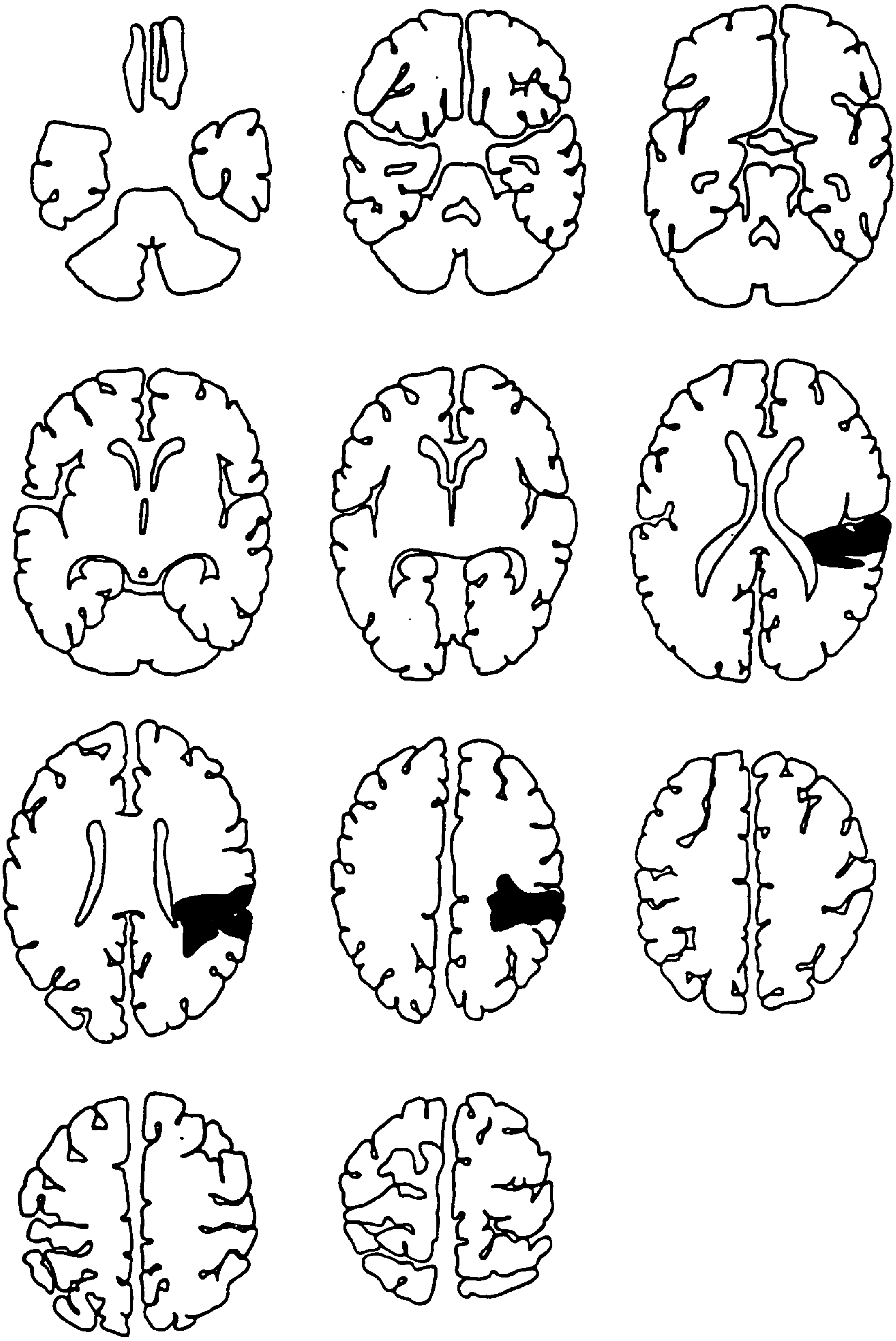
NFHM: Size: 2, Mixed Group — FLMC: Size: 1, Posterior Group

Individual areas		Size (NFHM)	Size (FLMC)
Frontal Lobe:			
Medial Aspect:	F01 Cingulate gyrus, anterior	1	
Lateral Aspect:	F06 Frontal operculum	3	
	F07 Prefrontal (pre-motor)	1	
	F08 Rolandic (pre-motor)	2	
	F09 Paraventricular	2	
	F10 Supraventricular	1	
Orbital Aspect:	F14 Subventricular	2	
Temporal Lobe:			
Lateral/Superior Aspect:	T03 Mid. Temporal gyrus-ant.	1	
	T04 Mid. Temporal gyrus-post.	1	
	T07 Auditory region	3	2
	T08 Anterior to auditory region	1	
	T09 Posterior to auditory region	3	1
Parietal Lobe:			
Inferior Parietal Lobule:	P01 Supramarginal gyrus	2	1
	P02 Angular gyrus	2	1
Superior Parietal Lobule:	P06 Supraventricular area	2	1
Occipital Lobe:			
Lateral Aspect:	O06 Paraventricular area	1	1
Insula:		3	
Central Gray and Adjoining White Matter:			
Basal Ganglia:	BG3 Lenticular Nucleus-Putamen	1	
Internal Capsule:	IC1 Anterior Limb	1	
	IC2 Posterior Limb		1

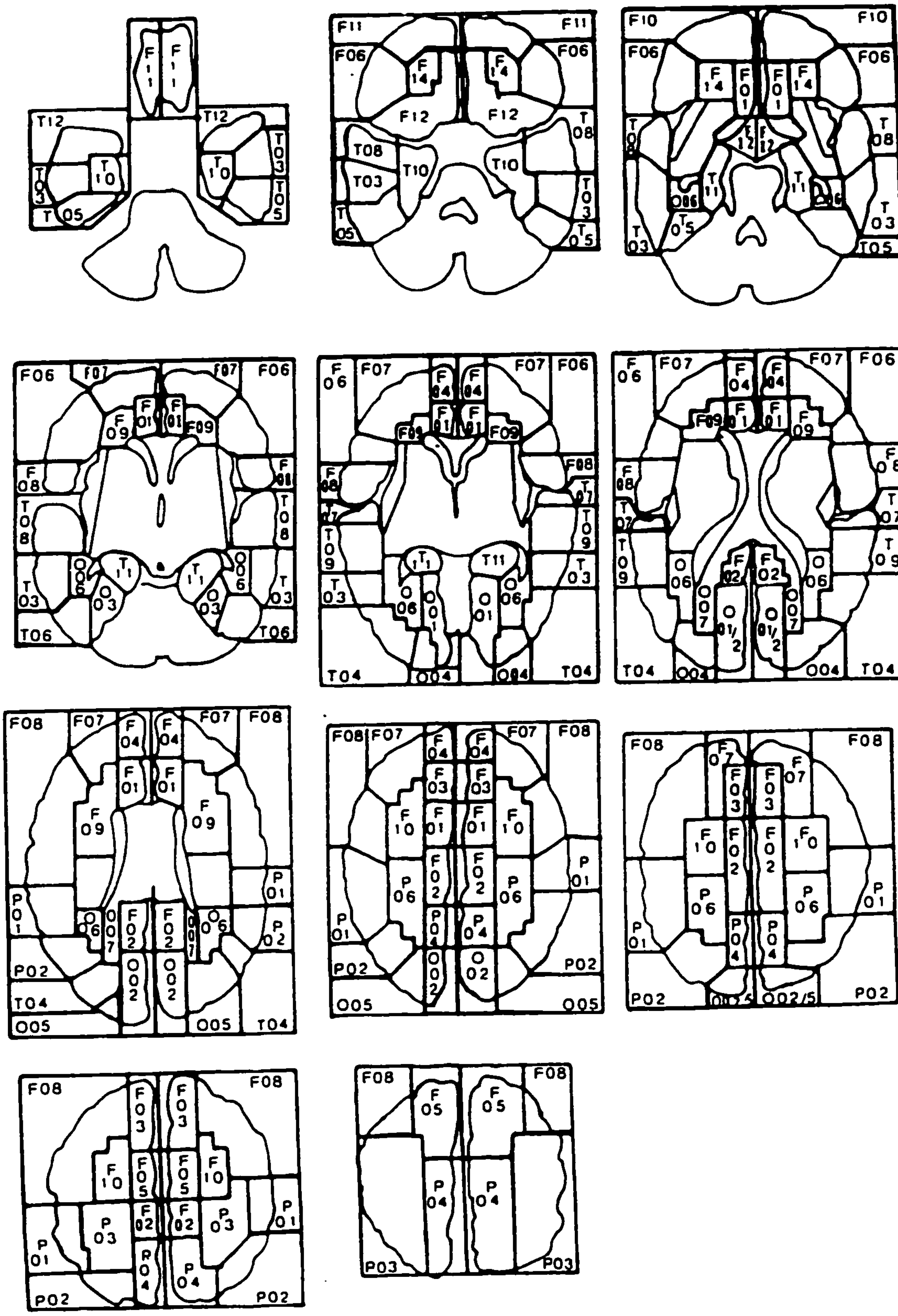
3b. Examples of two scored scans(cont'd):



3b. Examples of two scored scans(cont'd):



3b. Examples of two scored scans (template):



4. Patient histories:

NFAG

NFAG is a 50 year-old right-handed woman who suffered a cerebrovascular accident in 1984, nine years prior to the evaluation, following a hysterectomy. A neurological examination revealed a right hemiparesis, upper extremity greater than lower, with serious sensory loss. NFAG was essentially nonverbal with slow and exaggerated articulation, as per initial speech and language evaluation. She showed inconsistent identification of common objects and did not recognize letters. She also had difficulty following simple commands. A carotid angiogram taken shortly after her CVA revealed a complete embolic occlusion of the internal carotid artery at its origin. A CT scan also taken shortly after showed a massive left middle cerebral artery infarct with a large hypodense area in the left frontal and temporal regions without mass effect. EEG taken in 1984 was abnormal, with marked left fronto-temporal, particularly left frontal slow wave focus, consistent with a destructive white matter lesion. Subsequent EEGs taken in 1985,1986 and 1987 continued showing left frontal temporal slow wave focus but no epileptiform activity. NFAG's aphasia improved in the course of her hospitalization, which lasted two months, and was later described as expressive. A psychological evaluation conducted a month after her CVA as part of weekly psychotherapy sessions reported mild to moderate deficits in perceptual-motor tasks. NFAG showed increased lability and frustration as she became more aware of her deficits but was able to display a sense of humor. At discharge NFAG had improved considerably with speech and mobility and was transferred to a rehabilitation facility.

MRI scans in the coronal, sagittal and axial projection and Magnetic Resonance Angiography performed in 1995 showed a large area of cystic encephalomalacia in the left cerebrum related to the left internal carotid occlusion. There was extensive infarction in the arterial territory of the left A1 segment of the anterior cerebral system and left middle cerebral territory. This was manifested by an infarction within the caudate nucleus and anterior limb of the internal capsule. The left lateral ventricle showed dilatation. Some residual gliosis was seen at the watershed areas between the anterior and middle and middle and posterior cerebral territories of the left hemisphere.

Prior to her CVA, NFAG worked as freelance editor. She holds a Bachelor's degree in English and Poetry and has completed part of a doctorate degree in Medieval literature at a University in France. NFAG first took French in high school; however, having lived and worked in French-speaking countries for eight years as an adult she attained an excellent command of the French language. After her CVA she lost her ability to speak French almost entirely and now understands only some basic French. NFAG has had a number of years of physical and speech and language therapy and has taken classes in writing. Her aphasia has improved and she is now able to speak in sentences using a range of grammatical structures. She uses a relatively large vocabulary but experiences problems with word finding and speaks slowly. She shows good comprehension of spoken language. However, she continues to experience great difficulty writing, including writing numbers to dictation. For the past couple of years she has been working on a children's book with the aid of a specialized computer. She corresponds with her friends by speaking to a tape recorder and having someone transcribe the tape into a letter. Her right-sided hemiparesis and sensory loss of the hand persist though she is able to use her right hand. She walks with the aid of a leg brace and cane, but has recently experienced a worsening of her ability to ambulate.

NFHM

NFHM is a 63 year-old right-handed man who suffered a cerebrovascular accident in 1969, 24 years prior to the evaluation. A CT scan taken in 1992 showed a large area of low attenuation within the left frontal, temporal and parietal regions with associated dilation of the frontal horn and body of the left lateral ventricle, compatible with remote infarct in the territory of the left middle cerebral artery. NFHM reported some numbness and weakness of the right hand and right facial side but was able to use his right hand without apparent difficulty. He currently shows no motor problems.

NFHM holds Bachelor's and Master's degrees in History and has completed half of the requirements for a Ph.D. in the same field. Prior to his CVA he had been working for an agency training teachers. NFHM has been in speech therapy for a number of years. He continues to suffer from considerable language difficulties: his speech is halting and telegraphic and his comprehension limited, though superior to his spontaneous speech.

NFRB

NFRB is a 63 year-old right-handed man who suffered a cerebrovascular accident about 10 years prior to the evaluation. No medical records could be located for this patient in the hospital where he was treated. As a result medical information was obtained from his family and the Speech and Hearing department of a College where he has been receiving speech and language therapy. According to family and self reports NFRB was completely unable to speak for about a month after his CVA. After his hospitalization he spent four months in a rehabilitation facility. NFRB suffers from right hemiparesis, both upper and lower extremities, but is able to ambulate with a cane.

NFRB has completed two years of College and worked as an industrial salesman prior to his CVA. Since his CVA he has tried to remain as independent as he can, and drives a specially-fitted car. He has been an active and vocal participant in a stroke group despite his persistent communication difficulties. Although he continues to experience considerable expressive difficulties and his sentences are deficient in grammatical structure he is able to communicate a range of ideas and to understand language considerably better than he can express it.

NFGG

NFGG is a 50 year-old right-handed woman who suffered a cerebrovascular accident in 1991, three years prior to the evaluation, during an exercise session at a gym. A speech and language evaluation performed a month and a half post-CVA reported initial severe, nonfluent expressive-receptive aphasia. NFGG however showed increasing improvement in fluency, information content of message and comprehension. She produced a mixture of telegraphic speech and more complete, appropriate, automatic phrases and sentences. She showed right hemiplegia and used her left hand to write. No report was located for her CT scan taken in 1991, which is analyzed for the present study. A magnetic resonance angiography performed in 1994 showed a paucity of vessels in the left middle cerebral artery, trifurcation branches, suggestive of terminal branch occlusions.

NFGG, who has had a year of College education, worked as medical transcriber prior to her CVA. She used to go to the gym daily and continues to do so, working especially on her right arm mobility. However, she is able to write relatively clearly using her left hand. NFGG has been receiving speech and language therapy. Although she has briefly participated in stroke groups she prefers to associate with people higher-functioning than her as she finds it more challenging. She speaks slowly and haltingly but is able to express her ideas effectively and to use different grammatical structures.

NFMA

NFMA is a 64 year-old right-handed man who suffered a cerebrovascular accident in 1990, five years prior to the evaluation. Upon admission to the hospital he showed global aphasia, right facial weakness, right upper extremity hemiparesis, a dense homonymous hemianopsia and a left gaze preference. Upper extremity hemiparesis improved in the course of hospitalization. A CT scan taken shortly after showed a large area of attenuation in the left fronto-parieto-temporal and lateral basal ganglia regions involving both gray and white matter. There was effacement of the adjacent cortical sulci but no shift in midline structures. According to an initial speech and language evaluation NFMA had a profound receptive impairment, being unable to follow any verbal or written directions or point to objects upon request. His expressive speech was also extremely limited and he was only able to produce a restricted number of vowel sounds with maximal prompting. Vocal parameters (e.g., pitch, intensity, resonance) were judged to be within normal limits; however, initiation and execution of nonverbal oral movements was impaired. He was able to swallow but was at risk for aspiration. NFMA was discharged to a rehabilitation facility.

NFMA holds a Bachelor's degree in accounting and an LLB and is a CPA. He is a founding member of the accounting firm where he worked as tax attorney prior to his CVA. NFMA still goes to his office every day but his position in the firm is honorary and he holds no responsibilities of any kind. He has been in ongoing speech therapy but continues to show severe difficulties in expressive and to a lesser extent receptive language. He currently experiences no motor difficulties and is active in sports such as swimming and golf.

NFBS

NFBS is a 34 year-old right-handed woman who suffered a cerebrovascular accident in 1991, three years prior to her evaluation. She is reported to have suddenly collapsed with loss of consciousness while being on the subway. NFBS uttered no words, making only few sounds, and was diagnosed as globally aphasic. She showed no movement in the right upper and lower extremities and had a right facial droop. CT and MRI scans taken shortly after admission showed occlusion of the left internal carotid artery just distal to anterior carotid artery take-off. NFBS had no significant past medical history prior to her CVA, which is considered most likely of transcardiac embolic etiology. Neuropsychological screening, limited to non-verbal measures because of her global aphasia, showed relatively well-preserved spatial-analytic and spatial integrating skills. Cognitive remediation initially involved primarily non-verbal communication.

NFBS, who has a Bachelor's degree, worked as systems analyst for a large firm prior to her CVA. She described her work environment as very stressful. Just prior to her CVA she had entered an MSW program to pursue her interest in social work and psychology. NFBS has been receiving physical therapy and speech and language therapy but continues to experience severe language difficulties, primarily expressive. Her speech consists mostly of single words with some automatized expressions (e.g., "make sense?").

Her right arm is in a sling and she uses her left hand to write. She has limited movement in her right leg but ambulates independently.

NFBM

NFBM is a 58 year-old right-handed man who suffered a cerebrovascular accident in 1992, three years prior to the evaluation, following a second of bilateral carotid endarterectomies. He was initially profoundly aphasic and had virtually no intelligible speech. He showed right upper and lower extremity hemiparesis, with no use of the right arm. No report was available for his CT scan taken in 1992, an analysis of which is provided in Appendix A2. NFBM was transferred to a rehabilitation hospital upon discharge.

NFBM, who holds a Bachelor's degree, worked as vice president and manager of operations for an apparel company prior to his stroke. A speech and language evaluation conducted in 1995, shortly before NFBM's participation in the current study, reported severe expressive aphasia (Broca's type), agrammatic sentence structure and disturbances of speech pre-motor and motor planning. His comprehension was adequate for everyday discourse. NFBM showed reading deficits consistent with deep dyslexia. He continued being functionally agraphic. NFBM still has no use of his right arm, which has serious sensory loss, and uses his left hand to write. He walks independently but with difficulty. He is very frustrated and depressed by his disabilities and the effect they have had on his life.

NFJE

NFJE is a 75 year-old right-handed woman who suffered a cerebrovascular accident five years prior to the evaluation while on vacation overseas. As a result no medical record of her CVA is available and medical information was obtained from her husband. He reported that she was initially unable to speak and showed right sided hemiparesis. NFJE is being followed up at a medical facility but no records were available from there.

NFJE is a retired high school English teacher who holds Bachelor's and Master's degrees in Education. She has had ongoing speech and language therapy since her stroke. Although she is able to use her right hand to write and perform a variety of tasks she experiences reduced dexterity. After her stroke she lost her ability to play the piano, which she played for 50 years. NFJE walks short distances without apparent difficulty but cannot walk very far (she uses a cane outside the house). She is able to communicate using short, agrammatic phrases, but is never left alone or unsupervised.

NFIT

NFIT is an 84 year-old right-handed man who suffered a cerebrovascular accident in 1992, nine months prior to the evaluation. According to his medical records he remained lying on the floor in his house for three days before he was found. The CT scan showed a large left middle cerebral artery territory infarct. An initial speech and language evaluation revealed severe expressive aphasia, severe reading and writing impairment and a mild/moderate receptive aphasia. NFIT was only able to phonate vowels and consonant-vowel pairs and showed severe impairment in letter recognition. He showed right hemiparesis with preserved sensation and mild right facial droop.

NFIT is a retired merchant marine who is a high school graduate. Prior to his CVA he had been entirely independent and used to travel extensively. Since his stroke he has been living in a nursing home. NFIT is described by the nursing home staff as very alert, motivated and with a polite, gracious manner. He keeps track of his appointments and daily schedule on his own. NFIT has been receiving speech and language therapy daily during the week. He continues to present with considerable expressive difficulties: His speech is effortful, poorly articulated and consists primarily of single content words. NFIT is able to use his right hand to write but continues to show right-arm weakness.

FLHT

FLHT is a 69 year-old right-handed man who suffered a cerebrovascular accident in 1993, two years prior to the evaluation. He manifested sudden onset of difficulty finding words without any loss of consciousness. He presented with fluent, paraphasic speech, intact repetition and "intermittent" and "partial" difficulty in understanding and following commands. FLHT was diagnosed with Transcortical Sensory aphasia. Motor strength was unaffected and he had no difficulty swallowing. He was found to have right and some left upper quadrantanopsia. A CT scan taken shortly after hospital admission showed poorly defined heterogeneous low attenuation in the left temporal lobe and occipital areas. An MRI taken about a year later showed a left hemisphere infarct of the left middle cerebral artery distribution involving the mid and posterior temporal lobe and lateral occipital lobe. FLHT showed improvement in the course of his hospitalization.

FLHT, who attended College just short of a Bachelor's degree, worked in retailing as a fabric designer prior to his CVA. He has been receiving speech and language therapy but his treatment was being terminated at the time of his participation in the present study. A language evaluation conducted in 1994 reported a mild impairment in comprehension of simple yes/no questions and single words but significant impairment in following two- and three-step commands and in passage comprehension (complex ideational material). Reading comprehension was also impaired. Articulation, automatic speech and repetition were within normal limits and conversational speech was fluent with word finding difficulties but without literal or verbal paraphasias. FLHT showed deficits in ability to perform simple multiplication and division and his performance on the Raven's Progressive Matrices, a test of nonverbal reasoning, was deficient. Although his comprehension deficits and preserved fluency were considered characteristic of Wernicke's aphasia, his lack of phonemic paraphasias in conversational speech in combination with word finding deficits resulted in a diagnosis of Anomic aphasia. FLHT continues to experience difficulty finding words, comprehending syntactically complex language and performing certain numerical operations. He attends a stroke group.

FLWZ

FLWZ is a 74 year-old right-handed man who suffered a cerebrovascular accident in 1991, three years prior to the evaluation. He initially presented with right sided weakness, a right facial droop sparing forehead and eyelid and reduced sensory sensitivity on the right side (upper and lower extremities). He showed great difficulty finding the correct words. A CT taken in 1991 showed a large left basal ganglia (internal capsule) infarct. An MRI taken in 1994 showed a large area of encephalomalacia in the left frontal lobe and left basal ganglia including the caudate nucleus and lentiform nuclei. The left lateral ventricle adjacent to the area of encephalomalacia was dilated, compatible with a chronic infarction in the middle cerebral artery distribution. The left internal carotid artery was occluded or nearly occluded.

FLWZ is a retired watch repairman with a ninth grade education. He has worked in this field all his adult life and has owned his own store. He currently uses a wheelchair to ambulate. He is able to walk only to a limited extent with a walker because of inability to move his arm and leg. He uses his left hand to write. FLWZ lives alone with the aid of health care workers. He has been receiving speech and language services. Speech and language testing conducted in 1994 showed deficits in reading comprehension and naming. His speech is fluent, grammatical, and well articulated with considerable word finding problems. FLWZ attends stroke group meetings. Nevertheless, he tends not to participate in patient group discussions; as he himself explained, he prefers not to say anything rather than get stuck on a sentence because of not being able to retrieve a word.

FLCG

FLCG is a 73 year-old right-handed woman who suffered a cerebrovascular accident in 1992, two years prior to the evaluation, shortly after right shoulder (rotator cuff) surgery. On examination she was found to have "global" aphasia, a right homonymous hemianopia, right hemiparesis (arm greater than leg), a mild right central facial paresis and decreased sensation on the right side. A CT scan taken shortly after showed a left-sided infarction in the region of the middle cerebral artery. Her EEG was abnormal with excessive amounts of slow activity in the left frontotemporal region. FLCG was fed via a nasogastric tube because of an absent gag reflex. She quickly exhibited motor return in the right upper and lower extremities but continued to show "expressive" aphasia. After her hospitalization she attended a rehabilitation facility.

FLCG worked as head bank teller prior to her CVA. She received speech and language therapy for the first six months after her CVA. However, her daughter also worked with her intensively, about two hours a day for a year. According to her daughter's feedback, FLCG was initially unable to speak, comprehend or gesture. When she returned home from rehabilitation she uttered an occasional word but did not use sentences. Her speech subsequently increased in fluency, showing semantic substitutions and phonological errors. FLCG has made significant progress since her stroke. She is able to use grammatically complex sentences and expresses herself well although with some hesitancy due to word finding difficulties. She still makes occasional phonological errors. FLCG recalls her initial frustration at not being able to communicate but is actively engaged in improving her language skills through crossword puzzles and reading. She attends a stroke group, enjoys socializing and has developed a sense of humor about sometimes saying the wrong word. She has very mild residual weakness in the right leg.

FLMC

FLMC is a 69 year-old right-handed man who suffered a cerebrovascular accident in 1993, one year prior to the evaluation. He was taken to the hospital by his wife following an incident in which he suddenly slumped from the chair and had some difficulty speaking. On initial examination he showed a mild drift of the right upper extremity, mild right hemiparesis and fairly dense expressive aphasia. The CT scan showed a zone of low attenuation in the left parietal lobe extending from the white matter to the cortex. FLMC attended a rehabilitation facility after his CVA. He has been diagnosed as Conduction aphasic.

FLMC worked as salesman prior to his CVA. He has also held a variety of jobs, such as catering work and being a butcher. When he was young he left high school to join the marines. After his CVA, he received about 40 weeks of speech therapy. His spontaneous speech still contains numerous phonological paraphasias, which frustrates him greatly. He is not always successful in his successive approximations of target words but is aware of his errors. He exhibits no difficulty with movement.

FLHR

FLHR is a 63 year-old right-handed man who suffered a cerebrovascular accident in 1993, one year prior to the evaluation. He had sustained a myocardial infarction five months prior to his stroke. FLHR initially presented with right upper and lower extremity numbness, right upper extremity clumsiness, slight flattening of the right nasolabial fold and a right homonymous hemianopsia. A few weeks later he presented with a brief but sudden period of aphasia, characterized by word-finding difficulties. This deficit resolved but FLHR continued to be unable to read. He was, however, able to write. FLHR was thus diagnosed as having alexia without agraphia. His speech was fluent and by discharge it was considered normal. FLHR continued to have a right homonymous hemianopsia and mild, right-sided paresthesias, without any motor impairment. Sensation was intact. The CT scan showed an infarct in the medial portion of the left temporal lobe with some superior extension into the left posterior parietal and occipital region..

FLHR, who has had one and a half years of College, was president of a large company prior to his CVA. He has been with the same company for 47 years. He continues to go to work but his position is honorary with no real responsibilities, which he finds very difficult. FLHR still speaks publicly in company executive meetings but has to rely on his memory as he cannot read his own notes. FLHR remembers nothing unusual about his speech during his hospitalization except for some difficulty remembering things like people's names, which persists to this day. His biggest source of frustration is not being able to read, which he first noticed a week after his CVA. This difficulty is compounded by his great reluctance to say anything unless he is certain that it is correct. FLHR has been in speech and language therapy specifically working on his reading deficit.

FLRT

FLRT is a 62 year-old right-handed man who suffered a cerebrovascular accident in 1990, three years prior to the evaluation. He had sudden onset right-sided hemiparesis and difficulty speaking and was described as globally aphasic. At the time of his stroke FLRT was also diagnosed with paroxysmal atrial fibrillation. A CT scan taken in 1991 showed an area of low attenuation in the left parietal lobe and in the left frontal lobe which was wedge shaped and extended from the cortical surface to the lateral ventricular surface. The adjacent lateral ventricle was dilated. A neurological examination conducted in 1993 reported a completely compensated right sided hemiparesis with major return of function, mild right facial paresis, central type, right hemianoptic visual field defect and fluent aphasia. FLRT was initially diagnosed with Transcortical Sensory aphasia and subsequently with Wernicke's aphasia. He wears a pacemaker.

FLRT is a poor historian due to his severe aphasia. Personal information was, thus, obtained, from a friend of his who accompanied him in his sessions. FLRT holds a Bachelor's degree and has studied music and languages. He used to work as auditorium manager and as a result knows much about classical music and especially opera, which he still goes to and enjoys. His spontaneous speech is fluent with numerous neologisms and his comprehension remains very poor.

FLWL

FLWL is a 70 year-old man who suffered a cerebrovascular accident in 1994, one year prior to the evaluation. He initially presented with word- finding difficulty. A CT scan taken shortly after showed a small cortical hemorrhage high in the left parietal lobe. A repeat CT scan showed improvement. FLWL exhibited no motor or sensory dysfunction and his symptoms were reported to have resolved within 24 hours. However, he was re-admitted a couple of weeks later with confusion and nonfluent speech. On examination he showed difficulty with repetition, comprehension and reading. He had problems making calculations and exhibited right-left confusion and finger agnosia. He reported right lip and arm paresthesias. FLWL has a right eye enucleation secondary to a war injury with shrapnel, which precludes MRI imaging. Vision in the left eye is 20/25. A CT scan showed a left parietal lucency with possibly a small amount of hemorrhage. A subsequent CT scan showed a new area of increased attenuation in the left superior temporal lobe consistent with a parenchymal hemorrhage and a repeat CT scan showed a resolution of the hemorrhage. Because of his deteriorating condition, however, FLWL underwent multiple diagnostic tests to rule out a number of conditions such as subacute herpes encephalitis. These included a diagnostic brain biopsy, which revealed results consistent with a central nervous system vasculitis. FLWL was begun on Prednisone and Cytoxan and showed marked improvement. Towards the later part of his hospitalization he developed atrial fibrillation. He made moderate improvement in language function and was transferred to a rehabilitation facility.

FLWL holds a Bachelor's degree in Engineering. He was an executive in a major pharmaceutical company for 25 years. After the company relocated he became president of a smaller pharmaceutical company and eventually he and a colleague left to work independently in the drug market. After five years FLWL retired but later decided to go back to work for a federal agency as an engineer. He had his CVA during that time.

FLWL has been receiving speech and language and cognitive remediation services as a day patient in a rehabilitation facility, where there are extensive records of his performance. He has been diagnosed with Transcortical Sensory aphasia. According to initial speech and language reports at the rehabilitation facility, his speech was fluent but disorganized and not very coherent. His comprehension and attention were impaired and he made perseverative errors. His reading was slow and paraphasic and his spelling was poor. His reading comprehension was moderately impaired and he showed word-finding difficulties. As remediation progressed he showed improvement in reading, naming, written grammar, conversational skills, inferencing skills and comprehension of abstract information. He continued to need improvement in word-finding and categorization skills and to require cues to improve verbal specificity. Ability to perform numerical operations remained impaired, especially division and multiplication, and FLWL was unable to remember the multiplication tables. FLWL is currently able to communicate most ideas effectively despite word finding difficulties. He works diligently and independently on his areas of difficulty and wants to return to work.

FLNG

FLNG is a 62 year-old man who suffered a cerebrovascular accident in 1989, six years prior to the evaluation. He is a physician and head of a department in the hospital in which he was hospitalized. His hospitalization lasted almost three months due to his unstable medical condition. FLNG was brought to the hospital after being found unresponsive by family. He exhibited sudden onset right-sided hemiparesis, left gaze preference and focal right-sided seizure which generalized in the emergency room. He responded only to painful stimuli. A CT scan showed a large bleed in the left hemisphere including external capsule, basal ganglia and thalamus with midline shift, edema and bleeding into the lateral ventricle. The bleed was likely secondary to hypertension. FLNG was put on a ventilator and spent the next 55 days in the ICU. There he was reported to be intermittently responsive and lethargic, often responding to painful stimuli, only. Although he was sometimes arousable to verbal stimuli and was able to follow simple commands he did not show consistent improvement. At one point he developed acute respiratory distress, had a tracheotomy and was intubated. His condition started showing some improvement about a month after admission, at which time he started spending more time awake, following simple commands and attempting to verbalize. The change was not consistent, however, as he fluctuated from alertness to lethargy. When his condition allowed him to be tested he showed right-side neglect, impaired attention and concentration and left gaze preference. He was often confused and disoriented and his speech was aphasic. His right hemiparesis persisted, with the right upper extremity being flaccid and the right lower extremity being able to facilitate, somewhat. He showed right hemisensory loss. FLNG was transferred to PCU after about 55 days. According to a speech consult while in PCU he was able to complete automatized sequences but was unable to identify body parts or follow simple commands. His speech was intelligible but interspersed with jargon. FLNG was discharged to a rehabilitation facility 24 days later.

In rehabilitation FLNG was described as oriented to self and as having difficulty responding to complex questions. His speech was disjointed with paraphasic errors and jargon-like language. No change in his hemiparesis was noted. FLNG continued to receive a range of services such as speech and physiotherapy after his rehabilitation. With prolonged physiotherapy he became able to walk with a quad cane although no movement returned to the right arm or leg. Considerable cognitive improvement was also noted.

About four years after his initial admission, in 1993, FLNG was readmitted to the same hospital because of inability to bear weight after a fall at home. At his readmission it was thought that he may have sustained a cerebral embolus secondary to the new onset atrial fibrillation. His aphasia was noted to have worsened. FLNG was discharged for rehabilitation about two weeks after admission.

FLNG received a number of speech and language evaluations in the course of his rehabilitation. An evaluation conducted in 1992 using the Clinical Evaluation of Language Functions (CELF), the Minnesota Test of Differential Diagnosis of Aphasia (MTDDA) and the Boston Diagnostic Aphasia Evaluation (BDAE) described him as nonfluent with moderately impaired receptive language. He showed difficulty following oral directions involving three-level commands and comprehending abstract information. Performance on the Boston Naming Test indicated moderate to severe anomia (score of 18). Auditory memory and selective attention were also impaired and as stimulus items became increasingly lengthy and complex his comprehension deteriorated. Reading sentences and paragraphs and answering comprehension questions were relatively superior but FLNG required assistance to pay attention to detail within the text. His syntax was described as agrammatic and he used short phrases to get the meaning across. His language was decreased in organization and sequencing, something he was aware of. Nevertheless he initiated conversation freely and enjoyed talking. Despite moderate aphasia his social communication was adequate for conversation but self repair was inconsistent. His medical vocabulary was relatively preserved.

A speech and language evaluation conducted in 1993 using the BDAE reported continued moderate aphasia with anomia and moderately impaired receptive language. Improvements were noted in ability to follow directions. FLNG made paraphasic errors, showed lack of specificity and language disorganization. Verbal agility and automatic speech were unimpaired. Oral reading was unimpaired at the single word level and relatively unimpaired at the sentence level. A speech and language evaluation conducted a few months later using the MTDDA also reported moderate impairments in receptive language and anomia with substitutions, circumlocutions, hesitations and filler phrases. His speech was described as empty and agrammatic. (Note, however, that examples provided did not conform to the traditional definition of agrammatism, as he used a variety of grammatical constructions shown in the following example: "*..they're playing with - uh - uh - little children are throwing things in the ground - like uh - uh ...*").

A speech and language evaluation conducted in 1995 using the MTDDA (a month before he was evaluated for the present study) reported continued anomia, lack of verbal specificity, reduced comprehension (especially in following multi-step directions), and reduced memory. FLNG had difficulty repeating more than three digits accurately. On a sentence repetition task he changed or added words in the longer sentences, reflecting word retrieval problems. Although he used sentences and named some items on a picture description task he lacked specificity in describing the activities taking place. Oral reading of sentences and paragraphs was good.

FLNG continues to receive speech and language and physiotherapy services. He ambulates with the use of a motorized wheelchair. He uses his left hand to write due to hemiparesis. His speech is fluent with good prosody but continues to lack specificity.

Nevertheless, he is able to converse on a variety of matters and enjoys doing so. The quality of his language is observed to fluctuate with his level of alertness. FLNG teaches students on a voluntary basis in medicine at a University and lectures students on his specialty in hospitals.

FLJM

FLJM is a 49 year-old man who suffered a cerebrovascular accident in 1995, four months prior to the evaluation. He presented with slurred speech and right side weakness. Neurological report noted right facial droop, hyperreflexia on the right and notable weakness of the right upper extremity. He was alert and oriented but his speech was hesitant and dysarthric. The Initial CT scan and MRI were normal but his MRA showed some decreased flow in the intracavernous portion of the left internal carotid. FLJM improved somewhat and insisted on being discharged against medical advice. He returned to work but shortly thereafter he developed acute onset right side weakness (upper and lower extremities), diminished sensation throughout the right side and "expressive aphasia" and was readmitted. A CT scan showed an area of low density in the left basal ganglia and the left anterior and middle temporal cortex and white matter, consistent with ischemic infarct. There was increased mass effect on the left horn and the body of the left lateral ventricle. FLJM spoke hesitantly, had difficulty finding words and perseverated. His primary symptom in speech therapy was noted to be anomia. He was able to repeat simple phrases. On examination he was found to be plegic in the right upper extremity with reduced tone and paretic in the right lower extremity. He made double simultaneous stimulation errors on the right side of the body. He was fitted with an ankle-foot orthosis and at the time of discharge he was walking independently with the assistance of a cane.

FLJM has been receiving speech therapy, occupational therapy and physical therapy on an outpatient basis.

FLJM worked as an attorney and a judge (each part-time) prior to his stroke. He was active in numerous sports activities. At the time of his participation in the study he was still undergoing rehabilitation on an outpatient basis. Psychological and psychiatric evaluations described him as sad, anxious and frustrated. He was emotionally labile and impulsive and his safety awareness was reduced. Although FLJM showed word finding difficulties he was able to communicate effectively with others.

FLHW

FLHW is an 83 year-old man who suffered a cerebrovascular accident in 1990, five years prior to the evaluation. He presented with sudden onset of confusion and slurring of speech. Electrocardiogram showed atrial fibrillation. FLHW exhibited comprehension difficulties, made some paraphasic errors and was dysnomic. There was slight flattening of the right nasolabial fold but no motor deficits were noted. CT scan showed hemorrhagic infarct in the left temporal lobe, which improved in a subsequent CT scan. EEG was abnormal, with left hemisphere slowing.

According to a speech and language evaluation FLHW presented with fluent aphasia, characterized by impaired comprehension, naming and repetition and fluent but uninformative speech. He had difficulty following commands, pointing to objects consistently, and answering simple informational questions. Naming to visual stimuli was inconsistent, showing verbal paraphasias and neologisms. Repetition was impaired at both the single word and sentence levels, with paraphasias noted as the sentences became more difficult. His reading comprehension for low-level tasks was good. Articulation, prosody and sentence length were relatively spared. Discourse was severely impaired and FLHW lacked the ability to monitor his verbal output for his errors. His output was characterized by extreme press of speech, paragrammatism, paraphasias and neologisms. There was very little information conveyed for the amount of speech produced.

FLHW, who completed the 11th grade of high school, worked in the shipping business for the greatest part of his adult life. His most recent job before retiring was manager of operations in cargo shipping. He currently experiences no motor problems, is physically active and plays golf. He reports good memory, which he has always had, and is particularly good at remembering people's names. He enjoys engaging in conversation and is very loquacious, tending to go off on a tangent. He also enjoys writing and corresponds extensively with family members, writing long letters to keeping his relatives informed of family affairs. His letters contain grammatically complex sentences that are frequently paragrammatic. His spelling and penmanship are good.

FLCD

FLCD is a 70 year-old woman who suffered a cerebrovascular accident in 1995, seven months prior to the evaluation. She was found unresponsive on the floor of her home. Upon admission she exhibited right-sided weakness, disorientation and was only able to say "yes". She was alert but unable to follow simple commands and was diagnosed as global aphasic. Her CT scan showed left temporal lobe hemorrhage with mass effect and a small left occipital hemorrhage. In the course of hospitalization FLCD slowly started being able to follow one step commands but remained unable to repeat. Her speech became fluent with numerous semantic and phonemic paraphasias. According to a speech and language evaluation she had many comprehension problems, responding to yes/no questions with 60 percent accuracy and being unable to follow simple commands or identify objects. Neurological evaluations described her as having florid jargon (Wernicke's) aphasia. In the course of hospitalization her repetition and comprehension improved and she was able to follow simple two-step commands. She continued to show severe Wernicke's aphasia with jargon, however.

FLCD was also evaluated by the examiner during the acute stage of her illness for a different research project. As a result there are extensive records of her performance during her hospitalization. FLCD was unaware of her linguistic and cognitive deficits at the time. Her speech was fluent with numerous neologisms and paraphasias (semantic and literal). Her Cookie Theft picture description was replete with neologisms and contained no information. Picture naming, reading and repetition were very impaired with many neologisms. FLCD was only able to read and repeat a few single words, correctly. She had great difficulty carrying out two-step commands. Writing, including copying of sentences, was also impaired, with paraphasias and neologistic errors. Performance on fluency tasks, semantic and phonemic, was impaired: FLCD produced primarily neologisms and had to be reminded often of the target letter in the phonemic fluency task. On visual scanning tasks she showed some right-sided neglect and made perseverative errors on drawing tasks.

FLCD, a high school graduate, worked as administrative assistant until her CVA. After her hospitalization she spent three weeks in rehabilitation and continued receiving speech and language services on an outpatient basis after her discharge. Other than some initial difficulty walking, which improved quickly, she reported no motor problems. When seen for the present study, FLCD no longer exhibited symptoms consistent with

Wernicke's aphasia. Her comprehension had improved markedly and her most salient symptom was poor word retrieval. Her speech was fluent but hesitant due to considerable word-finding difficulties and she sometimes made word substitutions that were not semantically appropriate. She was aware, however, of her errors. Her chief complaint was not being able to remember the names of people, streets, etc. She recalled in retrospect her unawareness of her language problems and her belief that she spoke fine.

5. <u>Index of Grammatical Support for two patients</u>:

NFHM

Woman ... take table ... <u>a woman</u> - no! <u>son</u> .. um .. <u>cookies</u> .. uh .. <u>girl</u> ... cookies .. um ... oh, mm um ... yeah .. oh oh .. br ... m ... <u>water,</u> .. WATER! ... OK.

Time: 74" Syllables: 21 Syll/min: 17 Content Units: 5 CU/min: 4

Content Units	No. words in CU	Endings in CU
a <u>woman</u>	2	-
<u>son</u>	1	-
<u>cookies</u>	1	-es
<u>girl</u>	1	-
<u>water</u>	1	-
Total: 5	6	1

IGS: 6+1/5=1.4

FLMC

<u>The floor</u> is [ga] <u>the ... s-sink</u> <u>is overflowing</u>, clearin watching the [bɪč] <u>the [dɪ] plate</u> ... falling off the hole, po-stole, pole, stole, ... listen <u>taking</u> the coffee, [kʌ] [kɑ] <u>cookie</u> out, <u>he's falling</u> <u>over</u> s..t... <u>the stool</u>, the stool, the sink is running over, <u>she's washing</u> the bit- the [plɚt], [plɛt], plate ... (*E: anything else?*) <u>kid</u> <u>saying no</u>, the coffee - the [tu] cookie, she's falling over, all it is, ... cups.

Time: 76" Syllables: 86 Syll/min: 68 Content Units: 11 CU/min: 9

Content Units	No. words in CU	Endings in CU
the <u>floor</u>	2	-
the <u>sink</u>	2	-
is <u>overflowing</u>	2	-ing
the <u>plate</u>	2	-
<u>taking</u>	1	-ing
the <u>cookie</u>	2	-
he's <u>falling over</u>	3	-'s, -ing
the <u>stool</u>	2	-
she's <u>washing</u>	2	-'s, -ing
<u>kid</u>	1	-
<u>saying no</u>	2	-ing
Total: 11	21	7

IGS: 21+7/11=2.55

B. Stimulus description

1. Stimulus words classified by grammatical category:

NOUNS (52)

bath	cab	dean	fate	lab	pact	robe°	tact
bead	cake	debt	frock	lad	path	rod	teen
bean	cape	deck°	frog	lid	pole	rogue	toes
bed	cat	deed°	ghost	lip		rope°	toll
beep	coal	ditch	goal	mat		seed	tomb
bitch	case°	doll	god	mood		stag	tool
bowl	coast°		guest			soap	wheat
			greed				wit

VERBS (30)

beg	cope	doze	fade	lick	pat°	rob	told
boast		dig°	fret	lit	pose°	rove	tuck
bathe		dealt	gape		poke	seek	wed
bleed		deem	got			sit	weep
			greet			sag°	
			grope			soak	

ADJECTIVES (19)

best[1]	cold[1]	dead[1]	gold[1]	mad°	pure	sad	tall
bold	cool[1]	deaf	good[1]			sick	
bleak		dull[1]				sweet°	
big		deep[1]					
bad[1]							

NOUN/VERBS (33)

base	cap	doom	gull	lack	pace	seat	tap
bet	coat			lap	pad	shock	taste
bleat	code		joke		paste	shop	toast
	cure				peep	stab	
					pet	stack	weed
					pool	stock	whip
					post	stop	vote
						sweep	

FUNCTORS (1) could

TOTAL: 135

° : word with a frequency of 3 in 1 million (or less) in another grammatical category, based on Francis & Kučera (1982). (If the frequency in the main category is 8 in a million or less, the word maintains its dual category status).

[1] : adjective belonging to more than one grammatical category, based on Francis & Kučera (1982). Note that the English language contains very few monosyllabic words which are exclusively adjectives.

2. <u>Orthographic values of the stimulus words</u>:

Word	N-Metric	Consistency (enemies/rhyme neighbors)	Bigram Frequency (divided by no. of bigrams)
bad	19	1/10	2866
bed	13	0/5	360
beg	12	0/3	140
bet	19	0/11	1223
big	17	0/8	482
cab	13	0/6	1066
cap	19	0/11	1108
cat	19	0/11	1264
dig	15	0/8	812
god	9	0/5	592
got	14	0/9	3111
lab	15	0/6	257
lad	20	1/10	2938
lap	21	0/11	299
lid	13	0/8	710
lip	14	0/9	104
lit	14	0/9	265
mad	18	1/10	4048
mat	18	0/11	1566
pad	19	1/10	2826
pat	23	0/11	344
pet	22	0/11	1324
rob	16	0/9	218
rod	12	0/5	242
sad	21	1/10	3291
sag	19	1/11	639
sit	17	0/9	431
tap	22	0/11	176
wed	9	0/5	293
wit	12	0/9	247
base	13	2/3	1690
bath	11	0/5	3604
bead	13	3/5	2675
bean	13	0/5	3088
beep	11	0/6	2974
best	15	0/10	3600
bold	13	0/8	1496
bowl	7	4/4	1025
cake	18	0/9	2176

Word	N-Metric	Consistency (enemies/rhyme neighbors)	Bigram Frequency (divided by no. of bigrams)
cape	13	0/3	863
case	14	2/3	1774
coal	7	0/2	935
coat	9	0/3	5072
code	12	0/4	1280
cold	12	0/8	1405
cool	11	1/4	1850
cope	13	0/5	821
cure	11	0/3	2816
dead	11	4/5	1850
deaf	5	1/1	1460
dean	9	0/5	2263
debt	2	0/0	258
deck	9	0/5	861
deed	13	0/7	2442
deem	6	0/2	2686
deep	9	0/6	2149
doll	9	4/4	2983
doom	5	0/4	3615
doze	9	1/1	778
dull	15	3/9	2075
fade	12	0/5	1510
fate	17	0/9	1145
fret	2	0/0	2049
frog	3	0/2	3092
gape	10	0/3	440
goal	4	0/2	851
gold	13	0/8	1321
good	8	3/5	2030
gull	13	3/9	2035
joke	6	0/4	1225
lack	15	0/9	2165
lick	14	0/9	1677
mood	9	3/5	2854
pace	12	0/4	1985
pact	7	0/2	1739
path	7	1/5	3616
peep	11	0/6	1944
poke	10	0/4	1266
pole	14	0/6	990
pool	8	1/4	1559
pose	12	2/5	1284

Word	N-Metric	Consistency (enemies/rhyme neighbors)	Bigram Frequency (divided by no. of bigrams)
post	12	2/4	2959
pure	9	0/3	2817
robe	8	0/1	377
rope	14	0/5	692
rove	14	3/6	2420
seat	19	0/7	5933
seed	17	0/7	2586
seek	10	0/5	2231
shop	10	0/4	543
sick	14	0/9	1007
soak	3	0/0	1033
soap	6	0/0	1047
stab	7	0/3	218
stag	7	0/4	229
stop	5	0/3	310
tact	6	0/2	1530
tall	15	0/8	2720
teen	6	1/3	4641
toes	9	1/3	1197
told	10	0/8	1353
toll	10	2/4	2734
tomb	4	2/3	1475
tool	8	1/4	1797
tuck	12	0/8	1463
vote	5	0/5	703
weed	10	0/7	3962
weep	8	0/6	3669
whip	8	0/2	3399
bathe	2	0/1	602
bitch	8	0/4	1364
bleak	2	1/1	906
bleat	5	0/2	1035
bleed	2	0/1	1297
boast	6	0/3	1169
coast	3	0/3	1703
could	2	1/2	5196
dealt	1	0/0	1455
ditch	5	0/4	1335
frock	2	0/2	979
ghost	0	0/0	1585
greed	6	0/3	1918

Word	N-Metric	Consistency (enemies/rhyme neighbors)	Bigram Frequency (divided by no. of bigrams)
greet	4	0/0	1266
grope	3	0/0	1029
guest	2	1/1	1193
paste	7	1/5	1138
rogue	1	0/1	311
shock	5	0/2	1372
stack	10	0/4	2045
stock	5	0/1	1507
sweep	4	0/3	397
sweet	7	0/3	447
taste	6	1/5	1116
toast	3	0/3	1210
wheat	1	0/1	4391

3. <u>Written, Spoken, Heritage Frequency & AOA of nouns, verbs, noun-verbs and adjectives</u>:

	WFREQ	SFREQ	HERIT	AOA
nouns	1.11	.95	1.17	3.52
verbs	.78	1.05	.82	3.56
adjectives	1.85	1.61	1.94	2.39
noun-verbs	1.28	1.15	1.36	3.48

Significant differences at the .05 level using Modified LSD (Bonferroni) test:

WFREQ: adjectives >nouns, verbs, noun-verbs

verbs<noun-verbs

SFREQ: adjectives>nouns, verbs, noun-verbs

HERIT: adjectives>nouns, verbs, noun-verbs

verbs<noun-verbs

AOA: adjectives<nouns, verbs

4. Word predictors of Heritage Frequency, AOA, EOA & IMG:

HERIT = WFREQ (.63) + AOA (-.17) + VERB (-.21) R^2=.84
(.0000)   (.0000)   (.0024)

AOA = HERIT (-2.18) + WFREQ (.85) + VERB (-.60) + NEIGH (-.04) R^2=.53
(.0000)   (.0013)   (.0170)   (.0245)

EOA = NOA (.58) + ADJECT (.40) + AOA (-.10) + FAM (.41) + HERIT (-.20) R^2=.72
(.0000)   (.0001)   (.0038)   (.0087)   (.0375)

IMG = CON (.66) + EOA (.43) R^2=.82
(.0000)   (.0000)

5. EOA, NOA, IMG & CON values of nouns, verbs, noun-verbs and adjectives:

	EOA	NOA	IMG	CON
nouns	4.43	3.82	5.40	5.40
verbs	4.06	3.17	3.80	3.54
adjectives	4.97	3.84	4.63	3.82
noun-verbs	4.47	3.66	5.04	4.79

Significant differences at the .05 level using Modified LSD (Bonferroni) test:

EOA: adjectives >nouns, verbs, noun-verbs

NOA: verbs<nouns, adjectives

IMG: verbs<nouns, noun-verbs

adjectives<nouns

CON: nouns>verbs, adjectives

noun-verbs>verbs, adjectives

C. Group performance results

1. Distribution of word scores for the patients classified by Fluency and Agrammatism:

SCORE	NF (%)	FL (%)	AGR (%)	NON-AGR (%)
1	51.9	87.0	38.5	88.1
2	22.1	8.9	27.4	8.4
3	9.7	1.4	12.5	1.3
4	16.4	2.6	21.6	2.2

2. Multiple regression analyses of word and subject variables:

Variable	Beta	SE Beta	T	Sig. T
SEVERITY	-.354	.022	-16.10	.0000
AGRAMM	-.465	.070	-6.61	.0000
ADJECTIVE	-.141	.050	-2.83	.0046
FLUENCY	.152	.055	2.76	.0058
HERITAGE	-.066	.026	-2.58	.0098
Intercept	1.741	.038	46.22	.0000

R^2=.339

3. Multiple regression analyses of word and subject variables using IGS:

Variable	Beta	SE Beta	T	Sig. T
SEVERITY	-.342	.022	-15.27	.0000
IGS	-.236	.033	-7.14	.0000
ADJECTIVE	-.141	.050	-2.84	.0045
HERITAGE	-.066	.026	-2.58	.0099
FLUENCY	.11	.049	2.17	.0298
Intercept	1.465	.032	46.46	.0000

R^2=.341

4. <u>Inter-correlations of word variables</u> (all words):

	ADJ	NOUN	N/V	VERB	AOA	WFREQ	HERIT	SFREQ	CLUST	CONSIS	LENGTH	BIFREQ	NEIGH
ADJ	1.00	-.32 P=.000	-.23 P=.000	-.22 P=.000	-.27 P=.000	.38 P=.000	.39 P=.000	.32 P=.000	ns	ns	ns	ns	ns
NOUN		1.00	-.45 P=.000	-.42 P=.000	ns	ns	ns	-.23 P=.006	ns	ns	ns	ns	ns
N/V			1.00	-.30 P=.000	ns	ns	ns	ns	ns	ns	ns	ns	ns
VERB				1.00	ns	-.33 P=.000	-.37 P=.000	ns	ns	ns	ns	-.18 P=.033	ns
AOA					1.00	-.42 P=.000	-.65 P=.000	-.49 P=.000	.20 P=.032	ns	.25 P=.005	ns	-.33 P=.000
WFREQ						1.00	.85 P=.000	.76 P=.000	ns	ns	ns	ns	ns
HERIT							1.00	.71 P=.000	ns	ns	ns	.19 P=.031	.22 P=.011
SFREQ								1.00	ns	ns	ns	ns	ns
CLUSTER									1.00	ns	ns	ns	-.41 P=.000
CONSIST										1.00	ns	ns	-.19 P=.032
LENGTH											1.00	.17 P=.044	-.74 P=.000
BIFREQ												1.00	ns
NEIGH													1.00

4. <u>Inter-correlations of word variables</u> (all words-cont'd):

	CON	IMG	FAM	EOA	NOA	PLS
ADJECT	-.41 P=.000	ns	.23 P=.046	.40 P=.000	ns	ns
NOUN	.54 P=.000	.42 P=.000	ns	ns	ns	ns
N/V	ns	ns	ns	ns	ns	ns
VERB	-.38 P=.001	-.47 P=.000	ns	-.27 P=.017	-.34 P=.002	-.35 P=.002
AOA	ns	ns	-.53 P=.000	-.39 P=.001	ns	-.31 P=.009
WFREQ	-.46 P=.000	-.38 P=.001	.47 P=.000	.26 P=.023	ns	ns
HERIT	ns	ns	.58 P=.000	.35 P=.002	ns	.24 P=.035
SFREQ	-.55 P=.000	-.43 P=.000	.39 P=.001	ns	ns	ns
CLUSTER	ns	ns	ns	ns	ns	ns
CONSIST	ns	ns	ns	ns	ns	ns
NEIGH	ns	ns	ns	ns	ns	ns
LENGTH	ns	ns	ns	ns	ns	ns
BIFREQ	ns	ns	ns	ns	ns	ns
CON	1.00	.85 P=.000	ns	ns	ns	.32 P=.006
IMG		1.00	.24 P=.042	.29 P=.012	.31 P=.007	.26 P=.025
FAM			1.00	.61 P=.000	.30 P=.009	.25 P=.032
EOA				1.00	.69 P=.000	ns
NOA					1.00	.34 P=.003
PLS						1.00

5. Correlations of word variables with word score by Fluency (all words):

	NF		FL	
VAR	R	P	R	P
ADJECT	-.07	.016	-.08	.004
NOUN	ns		ns	
N/V	ns		ns	
VERB	.10	.001	ns	
AOA	.10	.001	ns	
WFREQ	-.10	.001	ns	
HERIT	-.11	.000	ns	
SFREQ	-.08	.011	ns	
CLUSTER	.07	.018	ns	
LENGTH	.07	.012	ns	
CONSIST	ns		ns	
NEIGH	ns		ns	
BIFREQ	ns		ns	

6. Correlations of word variables with word score by Fluency (75-word list):

	NF		FL	
VAR	R	P	R	P
ADJECT	ns		-.10	.006
NOUN	ns		ns	
N/V	ns		ns	
VERB	.08	.059	ns	
AOA	.09	.021	ns	
WFREQ	ns		ns	
HERIT	-.08	.059	ns	
SFREQ	ns		ns	
CLUSTER	ns		ns	
LENGTH	ns		ns	
CONSIST	ns		ns	
NEIGH	ns		ns	
BIFREQ	ns		ns	
CON	ns		ns	
IMG	ns		-.07	.039
FAM	-.13	.001	ns	
EOA	-.15	.000	ns	
NOA	-.09	.028	ns	
PLS	ns		ns	

7. Multiple regression analyses of word variables by Fluency (all words):

NONFLUENT

Variable	Beta	SE Beta	T	Sig. T
VERB	.204	.092	2.22	.0269
HERITAGE	-.125	.057	-2.19	.0292
LENGTH	.118	.056	2.10	.0358
Intercept	1.859	.038	49.03	.0000

R^2=.021

FLUENT

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.127	.048	-2.64	.0083
Intercept	1.215	.017	73.09	.0000

R^2=.006

8. Multiple regression analyses of word variables by Fluency (75-word list):

NONFLUENT

Variable	Beta	SE Beta	T	Sig. T
VERB	.396	.143	2.78	.0057
AOA	.082	.030	2.68	.0075
CLUSTER	.213	.108	1.96	.0501
Intercept	1.742	.049	35.38	.0000

R^2=.026

FLUENT

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.150	.054	-2.77	.0058
Intercept	1.221	.023	53.34	.0000

R^2=.010

9. <u>Multiple regression analyses of word variables by Fluency</u>:

(75-word list, Toglia & Battig variables)

NONFLUENT

Variable	Beta	SE Beta	T	Sig. T
EOA	-.297	.078	-3.83	.0001
Intercept	1.827	.041	44.49	.0000

R^2=.024

FLUENT

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.181	.056	-3.24	.0012
IMG	-.070	.025	-2.78	.0055
Intercept	1.227	.023	53.47	.0000

R^2=.020

10. Multiple regression analyses of word variables by Agrammatism (all words):

AGRAMMATIC

Variable	Beta	SE Beta	T	Sig. T
VERB	.314	.108	2.91	.0038
HERITAGE	-.159	.067	-2.35	.0188
LENGTH	.148	.066	2.24	.0251
Intercept	2.101	.044	47.52	.0000

R^2=.037

NON-AGRAMMATIC

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.105	.042	-2.53	.0115
Intercept	1.191	.014	82.79	.0000

R^2=.004

11. Multiple regression analyses of word variables by Diagnostic Category (all words):

FLUENT-POOR COMPREHENSION

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.205	.095	-2.17	.0308
Intercept	1.332	.033	40.58	.0000

R^2=.008

FLUENT-GOOD COMPREHENSION

Variable	Beta	SE Beta	T	Sig. T
HERITAGE	-.053	.018	-2.89	.0040
Intercept	1.112	.012	96.06	.0000

R^2=.012

12. Multiple regression analyses of word variables by Diagnostic Category (75-word list)

FLUENT-POOR COMPREHENSION

Variable	Beta	SE Beta	T	Sig. T
ADJECTIVE	-.229	.110	-2.08	.0383
Intercept	1.352	.046	29.29	.0000

R^2=.012

FLUENT-GOOD COMPREHENSION

Variable	Beta	SE Beta	T	Sig. T
CONSIST	.258	.079	3.27	.0012
ADJECT	-.093	.038	-2.47	.0139
Intercept	1.116	.016	70.16	.0000

R^2=.034

13. Multiple regression analyses of word variables by Site of Lesion (75-word list):

MIXED

Y = 1.468 + ADJECT (-.186)
(.0500)

POSTERIOR

Y = 1.111 + HERIT (.161) + CONSIST (.161)
(.0186) (.0300)

14. Multiple regression analyses of word variables by Lesion Size (75-word list):

SMALL

Y = 1.110 + HERIT (-.059)
(.0163)

LARGE

Y = 1.602 + ADJECT (.370)
(.0318)

D. Individual performance results

1. Distribution of word scores for individual patients:

	WORD SCORE (%)					WORD SCORE (%)			
Patient	1	2	3	4	Patient	1	2	3	4
NFAG	94.8	3.7	1.5	0.0	FLHT	98.5	1.5	0.0	0.0
NFHM	46.6	27.2	10.7	15.5	FLWZ	97.8	2.2	0.0	0.0
NFRB	77.7	19.4	1.9	1.0	FLCG	96.3	3.7	0.0	0.0
NFGG	93.3	6.7	0.0	0.0	FLMC	60.7	37.8	1.5	0.0
NFMA	23.0	42.2	23.7	11.1	FLHR	87.4	11.9	0.7	0.0
NFBS	5.2	11.9	7.4	75.6	FLRT	17.5	31.1	14.6	36.9
NFBM	35.6	22.2	10.4	31.9	FLWL	97.8	2.2	0.0	0.0
NFJE	74.1	23.7	2.2	0.0	FLNG	97.8	1.5	0.7	0.0
NFIT	12.6	48.5	33.0	5.8	FLJM	91.1	8.1	0.7	0.0
					FLHW	100	0.0	0.0	0.0
					FLCD	95.6	3.7	0.7	0.0

Patients in bold are Agrammatic. Patients underlined have a severity score of 1.

2. <u>Multiple regression analyses for individual patients</u> (all words):

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
NFAG	VERB	.168	.067	2.51	.0134	
	NEIGH	-.010	.005	-2.00	.0483	
	Intercept	1.029	.029	35.19	.0000	.089
NFHM	VERB	1.865	.247	3.50	.0007	
	Intercept	1.759	.105	16.74	.0000	.108
NFRB	WFREQ	-.249	.077	-3.24	.0017	
	CONSIST	.432	.203	2.13	.0362	
	Intercept	1.263	.044	28.86	.0000	.139
NFGG	HERITAGE	-.099	.036	-2.72	.0075	
	Intercept	1.098	.025	44.67	.0000	.083
NFMA	VERB	.445	.206	2.17	.0326	
	AOA	.116	.059	1.97	.0518	
	Intercept	2.130	.090	23.68	.0000	.078
NFBS	ADJECTIVE	-.743	.252	-2.95	.0039	
	HERITAGE	-.355	.123	-2.88	.0048	
	NOUN	-.317	.167	-1.90	.0596	
	Intercept	3.760	.108	34.81	.0000	.207
NFBM	CLUSTER	.631	.278	2.27	.0253	
	WFREQ	-.340	.165	-2.06	.0416	
	Intercept	2.245	.122	18.42	.0000	.084
NFJE	WFREQ	-.168	.066	-2.57	.0115	
	Intercept	1.281	.042	30.61	.0000	.057
NFIT	SFREQ	-.288	.131	-2.19	.0309	
	Intercept	2.320	.065	35.77	.0000	.052

2. Multiple regression analyses for individual patients (all words-cont'd):

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
FLCG	HERITAGE	-.060	.026	-2.31	.0229	
	Intercept	1.037	.016	64.79	.0000	.046
FLHR	CONSIST	.433	.121	3.59	.0005	
	HERITAGE	-.116	.047	-2.45	.0160	
	Intercept	1.134	.029	38.94	.0000	.144
FLRT	VERB	.688	.283	2.43	.0170	
	Intercept	2.556	.115	22.32	.0000	.063
FLNG	VERB	.090	.047	1.92	.0573	
	Intercept	1.010	.021	48.86	.0000	.032
FLCD	CONSIST	.194	.089	2.18	.0315	
	Intercept	1.052	.021	48.96	.0000	.041

3. Multiple regression analyses for individual patients (75-word list):

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
NFAG	CONSIST	.138	.067	2.05	.0438	
	Intercept	1.025	.018	55.95	.0000	.059
NFHM	VERB	1.347	.473	2.85	.0061	
	Intercept	1.921	.139	13.85	.0000	.125
NFRB	HERIT	-.285	.105	-2.72	.0086	
	Intercept	1.315	.060	21.89	.0000	.115
NFGG	HERIT	-.154	.047	-3.29	.0016	
	Intercept	1.102	.029	38.61	.0000	.139
NFBS	ADJECT	-1.205	.311	-3.88	.0002	
	NOUN	-.616	.244	2.53	.0138	
	AOA	.192	.077	2.48	.0157	
	Intercept	3.909	.182	21.44	.0000	.265
NFIT	LENGTH	.319	.137	-2.32	.0239	
	Intercept	2.240	.075	29.78	.0000	.161

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
FLMC	VERB	.422	.195	2.15	.0345	
	Intercept	1.328	.061	21.61	.0000	.065
FLHR	HERITAGE	-.155	.067	-2.32	.0237	
	Intercept	1.155	.041	28.42	.0000	.074
FLRT	VERB	1.016	.472	2.16	.0354	
	Intercept	2.601	.138	18.80	.0000	.075

4. Multiple regression analyses for individual patients:

(75-word list, Toglia & Battig variables)

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
NFAG	CONSIST	.151	.071	2.14	.0362	
	Intercept	1.028	.020	51.80	.0000	.064
NFHM	IMG	-1.156	.296	-3.91	.0003	
	Intercept	2.065	.122	16.99	.0000	.239
NFRB	HERIT	-.285	.105	-2.72	.0086	
	Intercept	1.227	.050	24.41	.0000	.115
NFGG	FAM	-.271	.058	-4.64	.0000	
	CON	-.051	.021	-2.47	.0158	
	Intercept	1.053	.022	47.21	.0000	.291
NFMA	EOA	-.338	.163	-2.07	.0426	
	Intercept	2.053	.089	23.12	.0000	.057
NFBS	ADJECT	-.962	.333	-2.89	.0052	
	EOA	-.564	.211	-2.67	.0095	
	NOUN	-.471	.240	-1.97	.0534	
	Intercept	3.727	.180	20.68	.0000	.275
NFBM	EOA	-.748	.255	-2.93	.0046	
	Intercept	2.267	.139	16.31	.0000	.109
NFIT	LENGTH	.389	.157	2.45	.0174	
	Intercept	2.268	.075	30.00	.0000	.099

4. Multiple regression analyses for individual patients (cont'd):

(75-word list, Toglia & Battig variables)

PT	VARIABLE	Beta	SE Beta	T	Sig. T	R^2
FLHR	HERIT	-.155	.067	-2.32	.0237	
	Intercept	1.155	.041	28.42	.0000	.074
FLRT	IMG	-.619	.155	-4.00	.0002	
	ADJECT	-.872	.345	-2.53	.0144	
	Intercept	2.873	.133	21.54	.0000	.255
FLMC	VERB	.422	.191	2.21	.0307	
	Intercept	1.328	.061	21.68	.0000	.065
FLJM	IMG	.067	.033	2.05	.0445	
	Intercept	1.057	.028	38.14	.0000	.059

5. Multiple regression analyses of orthographic and frequency variables for individual patients (all 4-letter words):

PT	VARIABLE	Beta	SE Beta	T	Sig. T
NFAG	CONSIST	.125	.042	2.97	.0040
	Intercept	1.007	.012	82.71	.0000
NFRB	WFREQ	-.305	.094	-3.25	.0019
	NEIGH	.041	.018	2.28	.0265
	CONSIST	.441	.227	1.94	.0571
	Intercept	1.295	.060	21.48	.0000
NFBS	HERITAGE	-.414	.142	-2.91	.0048
	CONSIST	-.862	.323	-2.67	.0094
	Intercept	3.601	.093	38.90	.0000
FLCG	BIFREQ	-.005	.002	-2.37	.0202
	Intercept	1.069	.025	43.15	.0000
FLHR	CONSIST	1.468	.142	3.29	.0016
	HERITAGE	-.164	.063	-2.62	.0107
	Intercept	1.137	.041	27.85	.0000
FLCD	CONSIST	.229	.114	2.01	.0478
	Intercept	1.054	.033	32.34	.0000

6. Patients showing a grammatical, semantic or associative effect:

PT.	MULT. REGR.	CORRELATIONS	SEM. ERRORS
NFBS	ADJECT, EOA	EOA (-.423), ADJECT (-.337), HERIT (-.369), (.000) (.000) (.000)	
		AOA (.321), WFREQ (-.296), SFREQ (-.279), (.000) (.000) (.001)	
		FAM (-.295), NOA (-.260), N/V (.182) (.010) (.024) (.035)	YES
FLRT	IMG, ADJECT	IMG (-.412), CON (-.336), VERB (.251) (.001) (.008) (.011)	YES
NFMA	EOA	VERB (.214), AOA (.197), EOA (-.240), (.013) (.032) (.038)	
		ADJECT (-.169), IMG (-.224) (.050) (.054)	YES
NFBM	EOA	EOA (-.330), FAM (-.294), CLUSTER (.219), (.004) (.010) (.011)	
		NOA (-.280), WFREQ (.201), HERIT (-.197), (.015) (.020) (.022)	
		AOA (.205) (.026)	NO
NFHM	IMG	VERB (.329), IMG (-.392), NOUN (-.188) (.001) (.002) (.057)	NO
FLMC	VERB*	VERB (.255) (.027)	NO
NFGG	FAM, CON	FAM (-.477), IMG (-.272), CON (-.264), (.000) (.018) (.022)	
		HERIT (-.183) (.034)	NO
NFAG	VERB, NEIGH	VERB (.235), NEIGH (-.189) (.006) (.028)	NO

*Found only in 75-word set

7. Individual results for patients divided by Site of Lesion and Lesion Size:

GROUP	PT.	ALL WORDS
MIXED/LARGE		ADJECT
	FLRT	VERB
	NFBM	WFREQ, CLUSTER
	NFHM	VERB
	FLCG	HERIT
	NFAG	VERB, NEIGH
POSTERIOR/SMALL		CONSIST, HERIT
	FLMC	n.s.
	FLHR	HERIT, CONSIST
	FLCD	CONSIST

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IMAGE EVALUATION TEST TARGET (QA-3)