Computational Demand and Resources in Aphasia*

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This paper presents evidence from a brain-damaged patient's production of English multimorphemic words. It is argued that the patterns of impairment displayed by this patient are best explained as an interaction between the computational demands of English morphology and the limitation of working memory resources resulting from damage to the brain.

The patient's particular disability involved a sensitivity to affixation processes in English word formation. He could not repeat phrases containing unusual morphological sequences such as those found in the expression "no ifs ands or buts". He was also unable to repeat words which contained both a non-neutral prefix (e.g., "un-") and a non-neutral suffix (e.g., "-ity"). Although the patient's morphological deficit could be related to specific types of affixation, his performance was dependent on the overall complexity of the word formation process. It was therefore reasoned that an explanation framed in terms of the representation of linguistic constructs in the brain could not adequately capture the nature of the patient's impairment. The alternative processing explanation accounts for the data and points to a research program in which language pathology research would be brought into closer proximity to the research on language production in normals.

A major goal of the linguistic study of language disorders is to understand the functional architecture of language competence. This paper presents evidence from the study of a brain-damaged patient 's production of English multimorphemic words. It is suggested that the patterns of impairment observed in this patient have significant implications for linguistic and psycholinguistic models of language competence.

Since the development of the doctrine of Phrenology in the late eighteenth century by John Gall, in which a fractionation of the brain was proposed to accommodate a theoretically-motivated fractionation of mind, there has been a countermovement such as that spearheaded by Flourens in the early nineteenth century, in which it was contended that the relevant property of the brain is that it functions as a whole. The debate, of course, is still with us.

The last couple of decades have witnessed a great renaissance of various relatives of Faculty Psychology. Thus, against the background of generative grammar, modularity of mind, human intelligences, and numerous versions of the left-brain, right-brain dichotomy, it is not surprising that putative syndromes such as agrammatism receive much attention in both the aphasiological and linguisitic literature.

The term agrammatism has been used to describe a deficit associated with Broca's aphasia which is characterized by halting, laboured speech and the relative absence of function words and inflectional affixes in speech production. This impairment is often seen in the presence of intact comprehension.

The study of agrammatism has attracted the interest of a number of linguists who have proposed characterizations of the deficit in terms of linguistic theory. Kean (1977, 1980, 1982) has proposed an account of agrammatism which claims that the nature of the deficit can be captured by the formalism of generative phonology (Chomsky and Halle 1968). The approaches taken by Grodzinsky (1983) and Rizzi (1985) have suggested that the deficit can be characterized in terms of Chomsky's (1981) theory of syntax.

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Agrammatism has also attracted the attention of investigators who have seen the association between the linguistic deficit termed Broca's aphasia and lesions of the posterior third of the left third frontal convolution (known as Broca's area) as pointing to a significant relationship between brain structure and language structure (Ojemann and Whitaker 1978; Whitaker and Ojemann 1977).

The existence of such a relationship encourages a research program in which units of linguistic theory could be employed in the characterization of the functions of discrete cortical areas.

In this paper, an alternative view of the relationship between linguistic theory and language impairment resulting from damage to the brain is presented. It is argued that it may not be necessary to postulate a modular language-dedicated brain mechanism to account for the relationship between patterns of aphasia and linguistic theory. The observed patterns may well reflect an interaction between general processing factors and the formal properties of language. This view is presented on the basis of evidence obtained from a patient observed in early 1985.

Case 118501: L. J.

History

L. J., a 64 year-old right-handed male, suffered a stroke due to an aneurism of the right middle cerebral artery. The patient was a native speaker of English with some command of conversational French. Immediately following the stroke, he was completely unable to speak, although comprehension seemed intact. His expressive abilities improved greatly within 24 hours of hospitalization, and he was diagnosed as dysarthric rather than dysphasic by the attending neurologists. It should be noted that this diagnosis was largely based on the fact that the cerebral infarction was located in the area of the right pre-central gyrus. Had the infarction been left-hemispheric in a right-handed patient, then a diagnosis of aphasia would have been more likely.

As it turned out, the patient's general language ability had recovered within ten days of the stroke, so that it was comparable to its general pre-morbid state. This general recovery, however, is to be contrasted with a perplexing and persistent difficulty that the patient had with two particular sets of words.

Pluralized Function Words

The first set of words might be termed -- for want of a better descriptor -- pluralized function words. They result from the affixation of plural markers to words such as "the" , "and", "if", etc. Such forms are practically non-existent in samples of English speech. Where they are found, their use is restricted to metalinguistic reference, as in (1)

(1) "A common error is to type two *the's* in a row."

The forms are also found in a highly restricted set of idiomatic expressions, as in (2).

(2) "No ifs ands or buts"

The evidence relating to the patient's performance on such items emerged during a routine examination in which the patient was asked to repeat the phrase in (2). L.J. was unable to repeat the phrase and showed no recognition of it as an idiomatic expression. This appeared not to be an unsystematic performance error. Over a two-week period, the patient was asked to repeat this phrase roughly 50 times. None of his repetitions were correct. Moreover, it appeared that, on each trial, he was hearing the phrase for the first time. An inspection of his erroneous repetitions suggests that his errors reflect an attempt to arrange and/or alter the component words so that some meaning could be attached to the phrase. A representative sample of such attempts are given in Table 1.

Table 1
Oral Repetition of an Idiomatic Expression

TARGET:	No ifs ands or buts
REPETITIONS:	No ifs and buts
	But no ifs and buts
	No ifs and no buts
	Ends and buts

The inability of L.J. to repeat correctly was revealed not to be limited to either the idiomatic phrase "no ifs ands or buts" or to the task of repetition. In fact, he was unable to correctly repeat any string of pluralized function words. Samples of his repetition performance for random function-word strings are given in Table 2.

Table 2
Oral Repetition of Function-word Strings

TARGET:	The's of's and's
REPETITIONS:	Ends
	Of the end
	And the office [Of's]
	Ends and buts

L.J.'s inability to repeat pluralizations was restricted to those cases in which the pluralization would be normally blocked by the constraints of English morphology. In contrast to his function word performance, he showed no difficulty repeating series' of concrete nouns such as "dogs, houses, chairs, cards" .

As far as the task-specificity of the impairment is concerned, the patient showed all signs of what is popularly termed a 'central impairment'. He manifested an inability to process pluralized function words in any modality. He could not write them to dictation; he was unable to read them aloud, and he showed a 65% error rate when required to copy individual pluralized function words from one sheet of paper to another.

It should be pointed out that L.J.'s impairment was accompanied by virtually unimpaired language production and comprehension. In terms of communicative competence, his linguistic ability was well within the normal range. He did, however, display an articulatory disability which turned out, upon closer inspection, to be limited to a narrowly-defined class of multimorphemic words.

Non-neutral Affixation

In the study of English morphology and phonology, a distinction has been drawn between two types of affixation. The first type may result in sound changes at the point of contact between the stem and the affix and/or a re-assignment of stress internal to the stem. The phenomenon has been termed 'weak' or 'non-neutral' affixation (Kiparsky, 1982) and can be seen in the attachment of the suffix [-ity] to a word such as [legal]. In the resulting form [legality], stress has been moved from the first syllable of the word to the second syllable . The characteristics of non-neutral affixation can also be seen in the attachment of the prefix [in-] to words such as [legal]. In this case, phonetic characteristics of the last segment of the prefix assimilate to the phonetic characteristics of the first segment of the stem. The resulting form is [illegal].

Non-neutral affixation can be contrasted, in English, with neutral affixation in which a strong boundary is said to exist between the affix and the stem. Examples of neutral suffixation

are [-ment] attachment (e.g. govern --> government), and [-ness] attachment (e.g. happy --> happiness). The neutral prefixation associated with the attachment of [un-] to adjectives shows no assimilation (e.g. unlikely).

L.J.'s linguistic impairment seemed to include a sensitivity to the distinction between neutral and non-neutral affixation. This sensitivity was related to cumulative effects of non-neutral affixation processes. Specifically, he was unable to repeat, read, or write any word which contained both a non-neutral prefix and a non-neutral suffix. He could not, for example, correctly repeat words such as "inseparable", "illegal", or "irregularity", as is displayed in Table 3.

Table 3
Non-neutral Prefixes and Suffixes

	TARGET	REPETITION
(a)	inseparable	insepudible
(b)	irrefutable	inrefutable
(c)	irregularity	regulalarity
(d)	illegality	legality
(e)	incomparable	incompArable
(f)	irreparable	irrepAIr able

The patient's productions were impaired only in those cases in which both a non-neutral suffix and a non-neutral prefix were present in the target word. He had no difficulty with forms such as "penetrate" or "penetrable". He could not, however, repeat "impenetrable". Similarly, although he could not repeat the word "illegality", he had no difficulty with the words "legal", "illegal", or "legality".

As can be seen in Table 3, the patient also showed a failure to assimilate the [in-] prefix to the stem, producing forms such as "inrefutable". This "unassimilation" occurred in roughly 15% of the erroneous repetitions across forms such as "illegality", "irrefutable", and "irreversible".

In those few cases in which L.J.'s repetitions were partially successful, there was a tendency, as shown in (e) and (f) of Table 3, to improperly assign stress to the multimorphemic word. This was also common in his repetitions of simple non-neutral suffixation. When asked to repeat the word "reputable", where stress is on the first syllable, his pronunciation was typically "repUtable" with stress on the second syllable. Thus, he seemed to be treating non-neutral affixes as though they were neutral.

Again it should be noted that L.J.'s impairment with respect to these words was evident across tasks and across modalities. In fact, the repetition glosses in (a), (b) and (c) of Table 3 correspond exactly to his spelling of these words in a dictation task.

L.J.'s performance in repetition and dictation showed a negative correlation between word length and accuracy. This effect, however, seemed only to be evident in cases of non-neutral affixation. He had no difficulty in the oral or written repetition of other multisyllabic words such as "minimization", "encouragement" etc.

Implications

The linguistic deficit manifested by this particular patient is both puzzling and challenging. The following explanation seemed to best account for the obtained data.

1. The productions of L.J. suggest that , at least in his case, certain morphologically complex items were generated online in the production process for each repetition, reading and writing trial.
2. There is a psychological cost associated with [in-] attachment (and the required assimilation).
3. There is similarly a cost associated with the attachment of non-neutral suffixes which appears to be related to the accompanying stress adjustments.
4. There is a cost associated with the "unblocking" of blocked affixation. This accounts for the patient's difficulty with "no ifs ands or buts".

5. The costs appear to be additive. The notion of additivity is required to account for L.J.'s ability to produce "legal", "legality", "illegal", but not "illegality".

Explanations of the sort given above point to a relationship between the computational resources required to attach non-neutral affixes, and the limitation of those resources caused by the infarction in the non-dominant hemisphere. Put another way, in this patient, online morphology requires unavailable working memory for its execution. A characterization of the deficit in terms of the interaction of working memory as a subject variable and affixation as a linguistic variable, gives rise to the hypothesis that the limitations imposed by working memory would be manifest in other tasks.

As it turned out, the patient performed quite poorly in immediate recall tasks, considering his overall functional ability. He could recall no more than 3 single-digit numbers, and no more than 2 three-digit numbers.

He could recall a maximum of 4 concrete nouns, 3 function words, and a maximum of 2 nonsense words.

There seemed, therefore, to be a considerable amount of converging evidence that an explanation stated in terms of working memory resources and the computational demands of English morphology would turn out to be revealing of properties of English morphology and functional properties of computation in the brain.

It is noteworthy that the patient did not show a dominant hemisphere lesion or major language impairment. One would expect that further investigation of such cases, in addition to the more dramatic cases of aphasia, would bring language pathology research into closer proximity to the normal speech error research and models of speech production of the type suggested by Garrett (1982, 1984).

Finally, it should be emphasized that the approach to linguistic deficits in aphasia which is presented in this paper differs radically from one which views neurolinguistics as the search for the cerebral receptacles of theoretically-motivated constructs. The patient's pattern of impairment maps in a non-trivial manner onto linguistically-motivated characteristics of English morphology. However, it is argued here that the nature of L.J.'s impairment cannot be captured by references to "the representation of morphology in the brain". Rather, the impairment must be captured in terms of a processing account which reflects the interaction between linguistic properties of English morphology and computational properties of the brain.

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