# The Structure of the Lexical System: Evidence from Acquired Language Disorders

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Neuropsychologists have assumed that the relationship between patterns of performance in brain-damaged patients and normal cognitive systems takes the following form: The pattern of impaired performance is a function of the structure of a normal cognitive system and specifiable conditions of functional damage to that system (Figure 1).

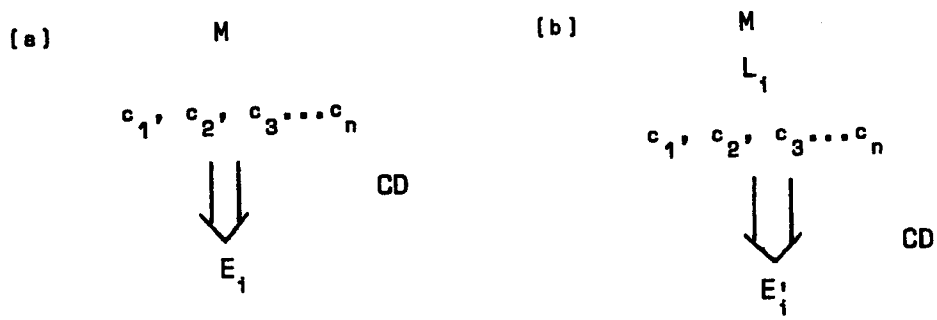


Figure 1. This diagram summarizes the principal difference in the assumed relationship between performance and a model of normal cognitive functioning for normal (a) and brain-damaged (b) subjects. For normal subjects we assume that a set of observations [E(i)] obtained under initial conditions c(1), c(2),...c(n), constitute relevant evidence in support of a model [M] if it is possible to derive the obtained observation from the model. For patients with acquired cognitive disorders we assume that a set of observations [E'(i)] obtained under initial conditions c(1), c(2), ...c(n), constitute relevant evidence in support of a model [M] if it is possible to derive the obtained observations from the model plus a hypothesized functional lesion [L(i)] to the model.

That is, unlike the case for research with normal subjects, the interpretation of impaired performance requires that we hypothesize a functional lesion to the cognitive system. Further, I would like to suggest that such hypotheses are necessarily <u>a posteriori</u> since they depend on the pattern of performance obtained with any individual patient. That is, L(i) is unknown and must be inferred from the pattern of impaired performance. If, in order to account for a pattern of impaired performance, we successfully postulate a functional lesion which allows us to account for that pattern of performance, we can consider the obtained results as providing evidence in favor of the proposed model. In this approach categories like Broca's aphasia, deep dyslexia, agrammatism, amnesia and so forth, do not play any role in research (see Caramazza, 1986 for discussion).

I take it that the analysis of patterns of cognitive dysfunctions serves to inform both the general architecture of cognitive systems and the internal structure of the components of processing that comprise these systems. In this paper I will briefly review some research that speaks to the structure of lexical processing. For this purpose, I will primarily draw from work that I have carried out with colleagues at The Johns Hopkins University and the Institute of Psychology of the CNR in Rome.

I will assume that the lexical component of the language processing system can be articulated into several independent but interconnected processing mechanisms. We distinguish between mechanisms for comprehending or producing words and within each of these components of processing we distinguish between phonololgical or orthographic processing mechanisms. Each subcomponent of the lexicon (e.g., the input phonological processing system) can be further articulated to capture modality specific lexical information (phonology in this example) as well as morphological (inflectional vs derivational; e.g., walked-ed vs walk-er) and grammatical class information (e.g., noun vs verb). Finally, we must assume a level of representation that captures the meaning of a word. This complex functional architecture of the lexical component constitutes a minimal description of the system. A schematic representation of the lexical system involved in oral reading of single words is shown, for expository purposes, in Figure 2. Please note that in this model I have introduced a new processing component which is concerned with oral reading of novel words.

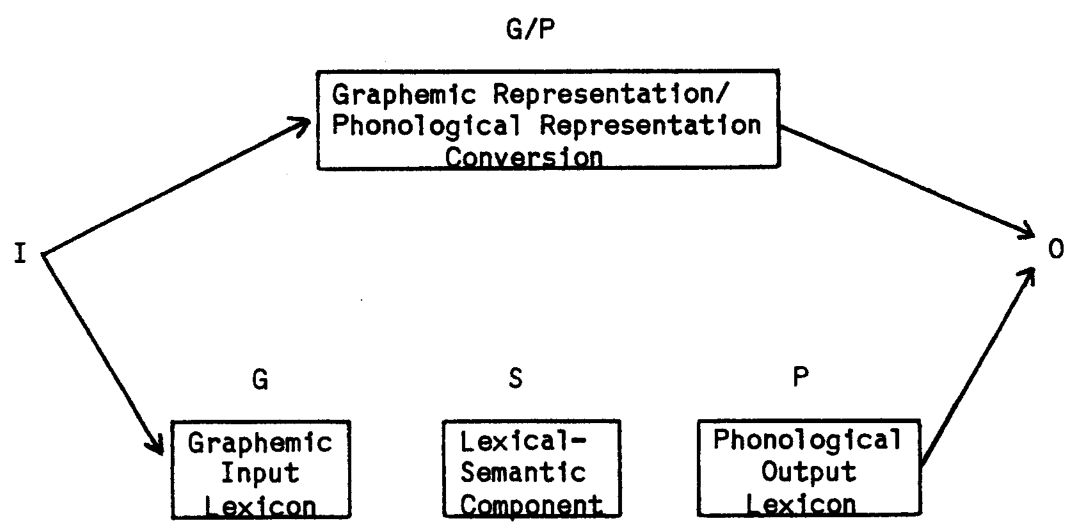


Figure 2. Schematic representation of a model of the reading process.

Brain damage can affect any one or any combination of the various components that make up a cognitive system. Thus, for example, there are reports of patients who have damage to just the mechanism that converts novel graphemic representations to phonological representations, as well as reports of patients who present with selective damage to specifically lexical mechanisms. These cases of highly selective dissociations of function are important because they provide empirical support for the functional autonomy of component processes of a cognitive system. However, we can go further than merely charting the functional architecture of a system. For any particular task, we can analyze the factors that determine the probability of making an error as well as the nature of the errors themselves to infer the processing structure of the cognitive mechanisms implicated in a specific cognitive performance. This is possible not only for patients who present with highly selective deficits but also for those patients with multiple damage to components of processing. I briefly discuss such a case here.

I am sure you are all familiar with cases of acquired dyslexia in which patients present with a complex combination of errors in oral reading. There are patients who make visual, semantic, and morphological errors in oral reading (Table 1). The interpretation of the source of these errors has not been without controversy. Nonetheless, I think that a careful analysis of such error patterns can inform the structure of the lexical system.

Table 1. Examples of errors produced by FM.

| Visual Errors | Semantic Errors | Derivational Errors | Inflectional Errors |
|---|---|---|---|
| dowry -> down | addict -> drug | achieve -> achievement | sew -> sewing |
| kind -> king | pedal -> bike | readily -> ready | decayed -> decays |
| notions -> lotion | female -> woman | naval -> navy | said -> say |

Patient FM (whom I have studied with Barry Gordon and Roberta Goodman) was asked to read aloud a large number of words. His responses were scored either as correct or as an error of one of the following types: visual, semantic, inflectional, derivational, or other--where this last category consists of ambiguous errors, visual-to-semantic errors or word responses that could not be classified in any of the previously listed error categories. The pattern of correct and incorrect performance for this patient is shown in Table 2. Here I wish to focus on the evidential role of visual and semantic errors to constrain a model of the lexical system.

*A priori* it is unlikely that these two types of errors have a common basis: A semantic error can only occur if the correct lexical entry has been activated; that is, in order to produce "minister" for "bishop," the lexical entry for "bishop" had to be activated. There is no such constraint for visual errors. This latter type of error most likely arises from damage to the input graphemic lexicon where an inappropriate lexical representation is activated. To explore this issue consider the following argument. A word that is read correctly is one that successfully activates a lexical entry in the input graphemic lexicon and the output phonololgical lexicon. In contrast a word that gives rise to a visual error is one that fails to activate its lexical entry in the input graphemic lexicon and instead activates a visually similar entry in this lexicon. Similarly, a word that gives rise to a semantic error is one that successfully activates a correct lexical entry in the input graphemic lexicon, but fails to activate its lexical entry in the output phonological lexicon, and instead activates a semantically related entry. Note that this argument makes two obvious, but important, assumptions: 1) The access procedure for the input graphemic lexicon is orthographically based; 2) The access procedure for the output phonological lexicon is semantically based.

Table 2. Baseline single word oral reading (4300 words) - FM.

| ANALYZABLE RESPONSES | PERCENT | NUMBER | |
|---|---|---|---|
| CORRECT | 43% | 1778 | |
| INCORRECT | 57% | 2393 | |
| Derivational errors | 5% | | (202) |
| Inflectional errors | 12% | | (478) |
| Visual errors | 13% | | (556) |
| Semantic errors | 11% | | (461) |
| Other classifiable errors | 17% | | (709) |

This proposed architecture of the lexical system and, more specifically, the assumptions we have made about the address procedures for the input graphemic lexicon and the output phonological lexicon allow us to make a precise prediction about FM's performance on rereading words read correctly, incorrectly produced responses, words to which he made visual errors and words to which he made semantic errors on the first reading. The prediction is that he should read very well words he read correctly the first time as well as the incorrectly produced responses (Table 3) but should read poorly words to which he previously made errors (Table 4). Furthermore, the new errors for words that gave rise to visual errors should predominantly be visual whereas those for words which gave rise to semantic errors should predominantly be semantic. These predictions were borne out.

To further substantiate the claim that visual and semantic errors arise because of difficulties in addressing lexical representations in the input graphemic lexicon and the output phonological lexicon, respectively, we assessed FM's ability to comprehend words which were on a previous occasion read correctly or had resulted in visual or semantic errors. The model of the lexical system proposed here leads to the prediction that FM should understand both the words he previously read correctly and those to which he made semantic errors, but he should fail to comprehend the words to which he had made visual errors. This prediction too was borne out (Table 5).

There are many issues concerning the structure of the input and output lexicons we could consider here. We could consider the lexical factors that determine the probability of making an error. Identification of these factors would serve to constrain hypotheses about the organization of these lexical processing components. Or, we could discuss the possibility of a paradoxical result--namely, that it appears that there are patients who make visual errors in reading who, nonetheless, seem to perform very well in lexical decision tasks. If this latter result obtains when careful controls are implemented it could undermine the model of lexical processing proposed here. However, I wish to turn to another aspect of lexical organization--morphology.

Table 3. Words originally given as responses, re-presented as stimuli-FM.

| STIMULUS Original reading: | RESPONSE Response Type: | Session 1 | 2 |
|---|---|---|---|
| 1) Correct (n = 235) | Correct | 71% | |
| | Visual error | 5% | |
| | Semantic error | 12% | |
| 2) Visual error (n = 235, 268) | Correct | 75% | 68% |
| | Visual error | 6% | 5% |
| | Semantic error | 7% | 12% |
| 3) Semantic error (n = 268) | Correct | | 65% |
| | Visual error | | 8% |
| | Semantic error | | 16% |

Note. (Matching for all stimuli was by length, number of syllables, frequency, concreteness, and part of speech.)
All the stimuli used in this task consist of responses produced by the patient: The "correct" stimuli consist of correct responses; "visual error" consist of responses that were scored as visual errors; and, "semantic error" consist of responses that were scored as semantic errors (see Table 1).

Table 4. Re-presentation of stimuli originally read correctly, or with visual or semantic errors-FM.

| STIMULUS Original reading: | RESPONSE Response Type: | Session 1 | 2 | 3 |
|---|---|---|---|---|
| 1) Correct (n = 167, 167, 83) | Correct | 69% | | 60% |
| | Visual error | 7 | | 8 |
| | Semantic error | 8 | | 12 |
| 2) Visual error (n = 167, 167, 82) | Correct | 19% | 18% | 6% |
| | Visual error | 41 | 43 | 52 |
| | Semantic error | 7 | 6 | 10 |
| 3) Semantic error (n = 167, 167, 83) | Correct | 32% | 38% | 23% |
| | Visual error | 10 | 11 | 10 |
| | Semantic error | 28 | 23 | 42 |

Note. (Matching for all was within word triplets, for length, syllables, frequency, concreteness, and part of speech.)
The stimuli in this task consist of words the patient had previously read correctly, words that had given rise to visual errors, and words that had produced semantic errors.

Table 5. Oral comprehension of matched sets of stimuli originally read correctly, or with visual or semantic errors - FM (excluding homophones).

| STIMULUS Original reading: | COMPREHENSION | | |
|---|---|---|---|
| 1) Correct (n = 87) | Correct comprehension | 86% | (72%) |
| | Visually-based comp. error | 14 | (8%) |
| 2) Visual error (n = 87) | Correct comprehension | 36% | (16%) |
| | Visually-based comp. error | 52 | (52%) |
| 3) Semantic error (n = 87) | Correct comprehension | 80% | (65%) |
| | Visually-based comp. error | 16 | (10%) |

We have already seen that FM makes morphological errors. Although we have not yet carried out carefully controlled studies on the factors that give rise to these errors, some preliminary results (analyzed jointly with William Badecker) are highly suggestive. Thus, consider the following breakdown of reading errors for the agentive -er (as in hunter), the comparative -er (as in taller), and the adverbial -ly (as in quietly) (Table 6).

Table 6. Morphological errors - FM.

| | Agentive -er (hunter) | Comparative -er (taller) | -ly (slowly) |
|---|---|---|---|
| Correct | 28 | 1 | 1 |
| Insertion | 21 | 0 | 1 |
| Deletion | 24 | 41 | 20 |
| Substitution | 5 | 0 | 0 |

The patient had greater success in correctly reading agentive -er words than comparative -er words and adverbial -ly words. Furthermore, he was much more likely to incorrectly insert an agentive -er than either a comparative -er or adverbial -ly. These results, and comparable ones for the plural -s (e.g., boys) versus the 3rd person -s (e.g., eats)--that is, better performance with the plural -s (Table 7)--suggest that a major dimension along which the lexical system is organized is morphology. Presumably, the locus of morphological organization must be both at the input and output lexicons.

Table 7. Morphological errors - FM.

| | Plural -s | 3rd person -s |
|---|---|---|
| Correct | 75 | 2 |
| Deletion | 165 | 26 |
| Insertion | 103 | 2 |

There is now a substantial body of research on the issue of morphological processing. My impression is that evidence is converging in favor of a model of the lexicon which assumes that lexical entries are represented in morphologically decomposed form. At the same time there is evidence that access to these lexical entries takes place through both whole-word address procedures and a morphological "parsing" procedure. One such source of evidence is the oral reading performance of a patient who presented with damage to the mechanism for converting novel graphemic representations into phonological representations.

Patient LB, an Italian acquired dyslexic, could essentially read all words but had great difficulty in reading nonwords. This dissociation, also documented by Funnell (1983), contrasts importantly with a different pattern of dissociation reported by Beauvois and Dérouesné (1979) and by Patterson (1982). They have reported patients who could not read nonwords and function words but could read all other words except that they made morphological errors. These contrasting patterns of dissociations, as well as the occurrence of morphological errors in the absence of visual and semantic errors, suggest an autonomous level of morphological structure in the lexical system.

My colleagues and I (Caramazza, Miceli, Silveri, and Laudanna, 1985) investigated the hypothesis that the input lexicon can be accessed not only through an all-word address mechanism, but also through a morphological parsing procedure. Consider our patient LB. Since he could read words we can assume that lexical access procedures are intact in this patient. However, he had difficulties reading nonwords, which we interpret to reflect damage to the print-to-sound conversion procedure for novel words (or nonwords). Now, if the only procedures for oral reading are through the use of the all-word access mechanism or the nonlexical conversion mechanism, then LB's performance in reading nonwords should not be affected by morphological structure in these letter strings. That is, the patient should present with equal difficulties in reading stimuli such as WALKEN (morphologically legal) and WOLKED (morphologically illegal). By contrast, if a morphological parsing procedure is available to the patient, then he should perform better for the former (WALKEN) than the latter (WOLKED) type of nonword. Results obtained with LB suggest the hypothesis that we can access lexical entries through a morphological parsing procedure in addition to an all-word access procedure.

LB read more accurately nonwords that have a morphological structure (Table 8). Furthermore, an analysis of the reading errors for nonwords shows that he made "simpler" errors in reading "morphologically" legal than "morphologically" illegal nonwords (Table 9) and that he produced more word responses to the former than the latter type of nonword (Table 10).

Table 8. Summary of LB's reading of Morphologically "Legal," Morphologically "Illegal," and Other nonwords.

| | | Correct | Incorrect | Total |
|---|---|---|---|---|
| Set A: | Morphologically "Legal" | 76 | 24 | 100 |
| Set B: | Morphologically "Illegal" | 51 | 49 | 100 |
| Set C: | Other | 34 | 46 | 80 |

Table 9. LB's reading errors on nonwords: degree of similarity between stimulus and response for errors produced when attepting to read Morphologically "Legal," Morphologically "Illegal" and Other nonwords.

| | | Simple* | Complex** | Total |
|---|---|---|---|---|
| Set A: | Morphologically "Legal" | 19 (79.2%) | 5 (20.8%) | 24 (100%) |
| Set B: | Morphologically "Illegal" | 20 (40.8%) | 29 (59.2%) | 49 (100%) |
| Set C: | Other | 21 (45.7%) | 25 (54.3%) | 46 (100%) |

*Errors involving substitution, insertion or deletion of a single letter in the stimulus.

**Errors involving transposition of two or more letters; multiple substitutions and/or deletions and/or insertions; unrelated; fragments.

Table 10. LB's errors on reading nonwords: incorrect word and nonword responses to Morphologically "Legal," Morphologically "Illegal" and Other nonwords.

| | | Word Responses | Nonword Responses | Total |
|---|---|---|---|---|
| Set A: | Morphologically "Legal" | 13 (54.2%) | 11 (45.8%) | 24 (100%) |
| Set B: | Morphologically "Illegal" | 8 (16.3%) | 41 (83.7%) | 49 (100%) |
| Set C: | Other | 2 (4.4%) | 44 (95.6%) | 46 (100%) |

My colleagues (Alessandro Laudanna and Cristina Romani) and I have also obtained support for the dual access hypothesis in a series of lexical decision experiments with normal subjects. Subjects were slower and made more errors in rejecting morphologically legal than morphologically illegal nonwords. Furthermore, we have found that the access procedure is sensitive to subtle morphological information. In Italian there are three conjugation types of verbs--(PORT)-ARE, (CORR)-ERE, and (COPR)-IRE verbs. Consider the following three nonwords.

CORRUTO same conjugation
CANTEVI different conjugation
CANZOVI morphologically illegal

The first two nonwords consist of morphologically legal nonwords; one (CORRUTO) is an overregularized form "CORSO" (the verb "correre") (e.g., bringed), the other ("copruto") consists of a regular root morpheme plus a conjugation inappropriate affix. The last stimulus is a morphologically illegal nonword. Subjects were slower to reject the first than the second type of nonword, suggesting subtle use of morphological information in lexical access (Table 11).

Table 11.

| | A<br>CORRUTO | B<br>CANTEVI | C<br>CANZOVI |
|---|---|---|---|
| mean reaction time | 850 | 788 | 666 |
| percentage of errors | 38.1 | 17.6 | 5.2 |

The results for LB as well as those with normal subjects support the hypothesis that the input lexicon is organized morphologically. We have evidence that the output lexicon is similarly organized. Of course, there are already various indications in the literature for this latter hypothesis (e.g., speech errors - Garrett, 1980). Our results strengthen and enrich this data base.

Gabriele Miceli and I have studied a patient, RS, whose language production is characterized by morphological errors (Table 12). This difficulty extends to repetition of single words where the great majority of errors are morphological in nature. Thus, he makes many errors in repeating verbs--the morphologically most complex words in Italian--nouns, adjectives, and function words (many of which are inflected in Italian), and, as indicated, most of the errors are morphological transformations. A striking feature of this patient's performance is that the deficit is most severe for inflectional as opposed to derivational morphology. Thus, in a repetition test of matched inflectionally and derivationally complex words, his errors were primarily inflectional in kind. Indeed, of over 400 morphological errors he produced in various tasks, 97% were inflectional and only 3% were derivational errors. These results suggest that the output lexicon, like the input lexicon, is organized morphologically and that the inflectional/derivational distinction is honored in this lexicon.

Table 12. Morphological errors in obligatory contexts - FS.

| | | |
|---|---|---|
| Violations of Det/N agreement<br>(e.g., Il bimba<br>The (masc.sing.) child (fem.sing.)) | 19/138 | (14%) |
| Violations of N/Adj. agreement<br>(e.g., La ragazza biondo<br>The (fem.sing.) girl (sing.) blond (masc.sing.)) | 11/55 | (20%) |
| Violations of N/V agreement<br>(e.g., Io ritorna...<br>I (masc.sing.) return (fem.sing.)) | 45/82 | (55%) |

I would like to conclude by reiterating a point I made earlier in this talk. The lexical system is a highly articulated system with various autonomous components each with a rich internal structure. The pattern of performance of brain-damaged patients contributes importantly to the development of theories of the functional architecture of the lexical system as well as to the development of hypotheses about the internal functioning of the proposed components of the system. One thing is certain--the functional architecture of the lexical system cannot be any simpler than that proposed here.

## ACKNOWLEDGMENT

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## DISCUSSION

Q: When one works with brain-damaged adults, one gets data a lot of which is not analyzable. Are you at all concerned about that?

A: The proportion of a patient's performance that is amenable to analysis depends on two factors: the detail of explicitness of our theories and the complexity of the disorder investigated. The more richly articulated our theories, the greater the range of observations that may be subsumed by the theories. However, even as we make progress in enriching our theories of language processing, there remains the problem of explaining the performance of patients with multiple, interacting cognitive deficits. The performance of a patient who has damage to several processing components of a cognitive system will have a complex, relatively opaque relationship to the normal cognitive system. These latter cases may be beyond the explanatory range for some time to come.

Q: You had an amazing patient (FM) who sat through approximately 5000 words. What was the patient's attitude during the time, particularly when he got to the last 1000 words? And, did his performance change during the first 1000 as compared to the last 1000 words?

A: We study our patients when their performance is relatively stable. Of course, performance levels fluctuate during the course of our experimental analyses. But, these fluctuations are quantitative in nature. Should we observe qualitative changes in performance, we would record this and explore the reason for the change in performance.