CHAPTER 32

THE NEUROPSYCHOLOGY OF LANGUAGE

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I. INTRODUCTION

This chapter presents an account of the neurological organization of human language processing. It relies largely on studies of language disorder arising from brain damage-that is, on studies of aphasia. And within this research domain, we focus primarily on the fate of sentence comprehension. Recent findings suggest that linguistic inquiry and neuroscience most readily converge at the sentence level-that it is at this level that the relations between language structure, processing resources, and brain architecture are most apparent.

The studies that illuminate these connections build on aspects of clinical descriptions first provided in the 1870s, at the start of the modern era of aphasia research. We begin by briefly reviewing these early descriptions and continue in a roughly chronological fashion, pointing out along the way some false starts and controversies.

II. LANGUAGE ACTIVITIES AND CEREBRAL ORGANIZATION: RESEARCH IN THE I870S

The enduring clinical descriptions of the late 19th century (e.g., Lichtheim, 1885; Wernicke, 1874/1977)-the so-called "classical" descriptions-turn on two distinct kinds of language failure and the relation of each to a specific region of brain damage. One of these is most usually referred to as Broca's aphasia, after the 19th century neurologist Paul Broca who first brought attention to the disorder. It typically results from damage to at least the lower part of

the left frontal lobe (Broca's area).[1] Although patients with this form of aphasia show relatively good comprehension at the conversational level, they produce little speech and do so slowly, with effort and poor articulation. Also, their speech is telegraphic or AGRAMMATIC: They tend to omit articles, connective words, and grammatical inflections and they produce, at best, only simple syntactic forms (e.g., Goodglass & Kaplan, 1972; Lecours, Lhermitte, & Bryans, 1983).

The second of these classical aphasias, Wernicke's aphasia (attributed to Carl Wernicke's original observations), usually results from a lesion in the posterior region of the left hemisphere, specifically, to the area adjacent to that involved in hearing. Patients with damage to this area (Wernicke's area) produce a form of speech strikingly different from that of patients with Broca's aphasia, one that is rapid and effortless, with a superficially normal syntactic appearance. Yet their speech is remarkably empty of content and often contains errors of word choice (e.g., *boy* or *girl).* Moreover, patients with Wernicke's aphasia show a very apparent comprehension deficit at the sentence and conversational levels (Goodglass & Kaplan, 1972; Lecours et al., 1983).

Actually, sentence-level phenomena were hardly considered in the classical descriptions. That came later. Reflecting the theoretical ambiance of the time, the initial focus was on the individual word, and crucially on the distinction between MOTOR memory images of words and their SENSORY memory images-that is, on the processes used for producing words and for understanding them. Specifically, given the two kinds of aphasias and the brain site each implicated, Wernicke theorized that the brain organized language in the form of anatomically discrete interconnected centers: Broca's area was claimed to be the center for the memory representations implicated in producing words (for the storage of "rules" by which words were coded into articulatory form) and Wernicke's area was argued to be the center for the sensory memories of words (comprehension). These two centers were hypothesized to be connected to each other, and each, in turn, connected to a general conceptual center (Geschwind, 1970; Lichtheim, 1885; Wernicke, 1874/1977).

Notwithstanding the formal typology of aphasia that it generated, Wernicke's theory was criticized from its inception for, among other matters, its failure to do justice to the complexity of aphasic phenomena-most notably for its failure to account for disruptions of the capacity to "propositionalize" (Jackson, 1884). But given the comparatively restricted linguistic theorizing of the time, early attempts to shift analyses of aphasia from the word to the sentence level-to focus on such features as agrammatism-remained unsystematic and largely underdeveloped. Indeed, on some accounts agrammatism

[1] The pathologic lesion in Broca's aphasia was initially (and incorrectly) described by Broca as being confined to the pars opercularis of the third frontal convolution of the left hemisphere. It is now recognized, however, that lesions typically responsible for persisting Broca's aphasia as described here are more extensive. Such lesions occupy indeterminately sizable amounts of the area of supply of the upper division of the left middle-cerebral artery (Mohr, 1976). Although early workers, including Wernicke, seem to have accepted the original formulation, our own occasional use in this chapter of the term Broca's area should be taken to signify this larger territory, which is, nonetheless, distinguishable from the posterior Sylvian territory implicated in Wernicke's aphasia.

was considered to be the result only of a nonlinguistic disruption to the motor implementation of speech-a means of economizing effort. (See Goodglass, 1976, and DeBleser, 1987, for detailed reviews of this early work.)

III. LANGUAGE COMPETENCE AND CEREBRAL ORGANIZATION: RESEARCH IN THE 1970S

The shift in focus from word to sentence level phenomena began in earnest in the 1970s-about 100 years after Wernicke-with a number of studies of comprehension in Broca's aphasia (e.g., Caramazza & Zurif, 1976; Goodglass, 1968; Heilman & Scholes, 1976; Zurif, Caramazza, & Myerson, 1972). Given the prevailing influence of linguistic theorizing in the 1960s and its emphasis on the centrality of knowledge structures in the determination of both speaking and listening, these comprehension studies were impelled by the possibility that agrammatic output was something other than just an economizing effort; rather, that it was the most public manifestation of a disruption to syntactic knowledge or competence. If so, the reasoning went, careful observation should also reveal syntactic disruptions in comprehension. After all, although Wernicke's theory stressed the distinction between input and output centers, very few clinicians-even those of a decidedly classical bent-actually ever claimed the comprehension of Broca's aphasic patients to be entirely normal; the working phrase was always "relatively normal comprehension" (Geschwind, 1970).

To assess syntactic competence, these studies typically used a sentence-picture matching paradigm in which aphasic patients were presented with a sentence and asked to demonstrate their understanding of it by pointing to its correct depiction embedded in a multiple-choice array of pictures. By systematically manipulating the availability of semantic and pragmatic cues, these studies documented the Broca's patients' abnormal reliance on such cues and their corresponding inability to carry out normal syntactic analysis. At least this was so for sentences cast in noncanonical (non-active voice) form (e.g., Caramazza & Zurif, 1976). So, for example, even though they could interpret the passive sentence *The mouse was chased by the cat,* they could not interpret the passive sentence *The boy was chased by the girl;* it seems that this was so because-in-the former case there was only one pragmatically likely organization of the words, while in the second case there were no pragmatic constraints to help the Broca's patients decide who was the chaser and who was chased.

Other experiments demonstrated the Broca's patients' difficulty in situations in which interpretation depended on the processing of the article *the* (Goodenough, Zurif, & Weintraub, 1977; Heilman & Scholes, 1976). Thus, Heilman and Scholes (1976) observed that the patients were not able to distinguish the meaning of *He showed her baby the pictures* from the meaning of *He showed her the baby pictures.*

Taken together, these various analyses suggested important parallels between production and comprehension. Just as the Broca's patients' speech was

syntactically simplified and relatively devoid of function words, so, too, they appeared unable to process syntax normally during comprehension and to use function words for phrasal segmentation. In the sweeping terms used at the time, Broca's patients were said to be as agrammatic in listening as in speaking, and left anterior brain damage was claimed to produce an overarching syntactic limitation, even as it spared the capacity to carry out semantic inference (e.g., Caramazza & Zurif, 1976; Zurif & Blumstein, 1978).

Moreover, this seemed to be true only of Broca's aphasia and the brain tissue it implicated. Wernicke's aphasic patients appeared to be different. They made semantic errors and sentence-level errors; but, unlike the Broca's patients, their comprehension limitations could not be assigned solely to a syntactic component; rather, the Wernicke's problem also seemed importantly rooted to their inability to retrieve precise lexical semantic units (e.g., Heilman & Scholes, 1976; Zurif & Blumstein, 1978).

It appeared at thattime, then, that Wernicke and his colleagues had (approximately) correctly localized the language centers in the brain and that further research would serve simply to redefine their functions. Thus, by the mid 1970s Broca's area (see footnote 1) appeared to be a syntactic center-a center for the rules and representations defining syntactic competence and, optimistically, it seemed that Wernicke's area would be discovered to sustain semantic inference.

IV. CURRENT ISSUES: CONTROVERSY CONCERNING THE CLASSICAL CATEGORIES

The position that Broca's aphasic patients have an overarching syntactic limitation was soon challenged on empirical grounds. This came in the form of several case reports: several individually studied patients who showed a production impairment clinically categorized as agrammatism, yet who had no detectable sentence comprehension impairment (Miceli, Mazzucchi, Menn, & Goodglass, 1983; Kolk, VanGrunsven, & Keyser, 1985; Nespoulous, Dordain, Perron, Ska, Bub, Caplan, Mehler, & Lecours, 1988).[2] In the light of these three reports, the characterization of an overarching agrammatism patently did not apply to all Broca's patients.

But there was more. Even the homogeneity of agrammatic output was soon questioned. The evidence here was in the form of an analysis of speech samples of agrammatic (Broca's) aphasics-an analysis that revealed great quantitative variation across patients in their omission of grammatical morphemes (Miceli,

[2] Actually, most of the exceptional cases diverge noticeably from typical agrammatic Broca's patients in production, too. Case I of Miceli et al. (1983) was able to repeat and read aloud without any agrammatic limitation, and case 2 showed normal fluency and normal phrase length as did Kolk et al.'s (1985) patient. So it is not at all clear that these patients ought to even be counted as Broca's to begin with.

Silveri, Romani, & Caramazza, 1989).[3] For some, these data led to the view that not only was the overarching agrammatism notion unreliable, but also that there was not even a homogeneous category of agrammatic Broca's aphasics.

This view has since been enlarged and hardened by Caramazza and his colleagues into a philosophical stance-the SINGLE CASE ONLY position-that denies the legitimacy of any research that seeks to elaborate on a theory of a cognitive capacity and that uses clinically defined groups for this purpose (Badecker & Caramazza, 1985; Caramazza, 1986; Caramazza & McCloskey, 1988). The single case only position has received great play in the literature and warrants consideration here. Its linchpin is that the procedures in cognitive neuropsychology differ in a fundamental way from typical experimental procedures in other sciences. As Caramazza and his colleagues state it, in contrast to scientists in other domains, cognitive neuropsychologists cannot control all relevant experimental manipulations; brain-damaged subjects are experiments of nature in which one experimental condition (the "functional" lesion) cannot be determined in advance, but rather must be inferred from the individual patient's performance. Caramazza and his colleagues .take this to indicate that the a priori classification of patients into clinical categories is theoretically arbitrary and that the only nonarbitrary classification of patients possible is, thus, a posteriori. That is, in their account, the only classification that is possible is one that is based after the fact on those theoretically relevant performance characteristics that allow the identification of a functional lesion in a cognitive system. And this, they hold, is equivalent to the claim that patient classification cannot play any significant role independent of the single-patient research projects that are required to determine that each of the patients in question has the appropriate functional lesion for a posteriori classification. In short, "The basic unit of analysis in cognitive neuropsychology must be the individual patient" (Caramazza & Badecker, 1989).

There are a number of points about this general position that we think are highly problematic, however. The first is that the contrast made by Caramazza and colleagues of the "ideal" of experimental method as portrayed for other sciences compared with cognitive neuropsychology is far from realistic. Even when the "manipulated" variable (the strength of the scientific experimental method) is manipulable, as in standard experimentation, it is always an open question whether the experimenter has the right theory about that which he is manipulating. It is a truism of the philosophy of method that the theory of the experimental manipulation, as well as the theory that the experiment is designed

[3] We note that the Miceli et al. (1989) report refers to substitutions as well as omissions of inflectional morphemes, whereas we have characterized the disorder of agrammatic output only in terms of omissions. This difference corresponds to the fact that we have based our description on the performance of English-speaking patients, while Miceli et al. dealt with Italian-speaking Broca's. This cross-linguistic difference is accountable as follows: substitutions of inflectional morphemes are observed only if their omission violates lexical well-formedness.. In this respect, omission is almost always an option in English, but much less so in Italian (still less in Hebrew, where even the phonological status of a word presupposes inflection). In effect, the same underlying problem in the production of bound grammatical morphemes is manifested differently in the output of different languages. [A detailed account of such cross-linguistic variation is beyond the scope of this chapter, but can be found in Grodzinsky (1990).]

to test, can, in principle, be revised in the face of recalcitrant data. (This is an immediate consequence of the Duhem (1962)/Quine (1961) thesis, which argues that, in principle, any statement of a theory is revisable in the face of recalcitrant data.) The fact that the scientist claims, in all sincerity, to have performed a certain manipulation does not entail that he has actually done so. In this sense, then, the experimental conditions that are manipulated can never be "determined in advance" (i.e., in advance of the best explanation of the experimental outcome). So it is not at all clear, as Caramazza and his supporters would have it, that there is a principled difference between neuropsychology and other cognitive sciences with respect to control over experimental manipulations.

A more important consideration, however, has to do with the consequences of theoretically arbitrary a priori classification. Even where there is no prior theory to justify a particular taxonomy, there need be no impediment to rational inquiry. Our point here is that taxonomies in cognitive neuropsychology do not have to be theoretically motivated; they have to be empirically motivated. And this brings us to the heart of the matter: Cognitive neuropsychology, like, for example, astronomy, is an observational science. Its practitioners get by without actively manipulating functional lesions or, for that matter, brain lesions. In this framework, syndromes (even loosely defined ones like nonfluent, agrammatic Broca's aphasia) are what the world gives us; they are there to constrain theory and, to this end, to allow groups to be formed for research purposes. And the basic questions in this observational enterprise necessarily concern only empirical matters (e.g., Zurif, Swinney, & Fodor, 1991).

Thus, the only question that can count in this approach to science is whether the data do or do not sustain the classification of Broca's aphasia. In particular, the issue comes down to whether we ought to retain the category of Broca's aphasia for research purposes in the face of the two empirical challenges mentioned earlier: (a) the failure to find an overarching agrammatism in all cases of Broca's aphasia, and (b) the quantitative variation in agrammatic output. Of the two, the point about patient quantitative variation is without merit. The numerical values Miceli et al. (1989) cite are simply irrelevant to the issue of categorizing this patient group for the exploration of most linguistic and psycholinguistic issues. By examining whether agrammatic output in Broca's aphasia can be characterized as a quantifiable entity, they end up entering the factor of severity which most theories of processing and structure necessarily abstract over. They also enter some critical statistical issues. [See Bates, Appelbaum & Allard (1991) for a critique of Miceli et al. along statistical lines which appears to prove their particular analysis to misrepresent the situation.] But perhaps most importantly, by focusing on differences among agrammatic Broca's patients, they miss the point that these patients nonetheless share grammatical output features that allow categorization in the first place-features that allowed categorization even for their own study. They miss the point that every Broca's patient they examined showed abnormal control of grammatical morphemes. And this is one of the crucial qualitative features that define the category of Broca's aphasia-indeed, the syndrome is really only defined qualitatively (Grodzinsky, 1991).

The other empirical challenge-the challenge that not all Broca's patients show an overarching agrammatism-cannot be so easily dismissed. On the contrary, it is an important one. It establishes that the observation of agrammatic

output in Broca's aphasia need not entail a co-occurring syntactic limitation in their comprehension. But that said, it remains the case that the number of Broca's patients that do show syntactic comprehension problems (the patients included in the group studies) far outweigh the few that have been reported not to. In effect, the small number of exceptional cases must be considered as checks that cannot yet be cashed. They may be anomalous (outlier) subjects, perhaps because of some subtly different lesion properties that we cannot yet detect. (After all, very little is known of the precise nature of the lesions implicated in Broca's and Wernicke's aphasia, other than that they are grossly differentiable.) Or, they might constitute an important disproof of the notion that lesions that cause agrammatic output also cause parallel syntactic problems in comprehension (Zurif et al., 1991).

Partly as a response to this last possibility, very few, if any, researchers still focus on the notion of an overarching agrammatism, an agrammatism that implicates the same structures in speaking and listening. Another reason is the fact that the ingredients from the production side of the equation are not in place. In the realm of syntax, models of the production system are far less detailed than those worked out for comprehension (Bock, 1991). For example, whereas levels of representation specified in modern generative grammars seem in certain respects to constitute exactly the targets that real-time comprehension processes compute (Swinney & Fodor, 1989), this kind of relation cannot yet even be gauged for the production system; the data are not available. And this asymmetry is nowhere more apparent than in aphasia research, where characterizations of linguistic and processing features of the comprehension problem are far more theoretically focused than are descriptions of production patterns in aphasia.

Yet, even if for these reasons the question concerning parallelism of linguistic deficits in production and comprehension remains open, Broca's aphasia and Wernicke's aphasia continue to serve research. In effect, these syndromes exist apart from what we make of them; they continue to be mined for answers to other aspects of brain-language relations. Currently, this focuses on evidence bearing on the neurological organization of the comprehension system alone.

In what follows, our discussion of recent research in comprehension treats descriptive generalizations concerning representational limitations and analyses of real-time processing disruptions separately. But we seek to account for the former in terms of the latter.

V. CURRENT ISSUES: REPRESENTATIONAL LIMITATIONS IN APHASIC COMPREHENSION

One view of the representational limitation as it applies to agrammatic comprehension is that, for whatever reason, the patients are virtually incapable of constructing any aspect of a syntactic representation. This view, a legacy of research of the 1970s and of work detailed by Caplan in his "lexical" hypothesis (1983), holds that agrammatic Broca's patients retain no syntactic capacities other than the ability to identify syntactic categories at the word level. In this view, in the absence of any semantic and/or pragmatic constraints, the patients rely solely on the nongrammatical strategy of assigning thematic roles to linear

strings of noun-verb sequences. Most importantly, they rely on the strategy of assigning AGENCY to the first encountered noun (Bever, 1970).

Unfortunately, this claim does not appear to comport well with the data. Setting aside the few uncashed checks-the few cases that show agrammatic production and normal comprehension-the pertinent fact is that for noncanonical structures (e.g., the passive, in which the first noun is the patient, not the agent, of the action) the Broca's patients perform roughly at chance levels (Ansell & Flowers, 1982; Caplan & Futter, 1986; Caramazza & Zurif, 1976; Grodzinsky, 1986, 1989; Grodzinsky, Finkelstein, Nicol, & Zurif, 1988; Wulfeck, 1988). Caplan's lexical hypothesis founders on this fact. Although it correctly predicts good interpretation for active-voice sentences (wherein first nouns are agents), it predicts not random performance for passives, but performance that is, at the least, significantly below chance. That is, on Caplan's account, the Broca's patients should show a systematic inversion of thematic role assignment, always incorrectly interpreting the first noun as agent in the passive.

Grodzinsky (1986; 1990) has provided a generalization that is somewhat more compatible with the performance levels that are actually observed. Before turning to his account, however, we note that the active-passive contrast is part of a larger pattern. Specifically, although Broca's patients show uncertain comprehension for semantically reversible object-relative sentences (e.g., *The girl whom the boy is pushing* is *tall)*- that is, they are not sure who is doing the pushing-they perform well with corresponding subject-relatives (e.g., *The boy who is pushing the girl* is *tall) (e.g.,* Caramazza & Zurif, 1976). And again, even as they have difficulty assigning thematic roles when faced with object-cleft sentences (e.g., *It is the girl whom the boy is pushing),* they have little difficulty when faced with subject-clefts (e.g., *It is the boy who is pushing the girl*) (Caplan & Futter, 1986). As with the contrast between passives and actives, the first-mentioned construction of each pair yields chance performance, the second yields performance significantly above chance.

Grodzinsky's account of this pattern is that Broca's aphasic patients have a problem understanding any sentence in which a transformation has been applied to move a phrasal constituent from a nonagentive position. This account is grounded in government-binding theory (GB; Chomsky, 1981). According to this (and other transformational) theory(s), movement of a constituent leaves a trace (an abstract, phonologically unrealized marker) in the vacated position in S(urface)-structure. Traces are held to be crucial for maintaining interpretative ¡dentity between D(eep) and transformed S(urface) structures. They are involved, among other things, in the assignment of thematic roles in a sentence. If a thematic position is filled with a lexical noun phrase, then it receives its thematic role directly; but if a thematic position contains a trace, then the trace is assigned the thematic role and the moved constituent that left the trace (e.g., the first noun phrase in a passive) gets its role only indirectly, by being coindexed to the trace.

Attendant on this theoretical feature, Grodzinsky's characterization of the comprehension limitation in Broca's aphasia is that, although patients of this type appreciate hierarchical syntactic organization, they cannot represent traces and, therefore, cannot gramatically assign thematic roles to moved constituents. Faced with a thematically unassigned noun phrase, the Broca's patient applies

an agent-first strategy-the same strategy outlined in Bever (1970) and in Caplan's (1983) lexical hypothesis. But in contrast to Caplan's account, the strategy is claimed to apply in the context of an otherwise elaborated syntactic representation. Thus, when a constituent is moved from object position, the strategy yields two agent noun phrases for the same sentence. One is assigned grammatically (via the by-phrase), the other is incorrectly assigned by the nongrammatical strategy. Faced with two agents (on a sentence-picture matching task), the patient is forced into a guessing situation, which leads to random performance.

This explanation accounts for the data, both the failures and the successes. The constructions that yield chance performance-passives, object-relatives, and object-clefts-contain S-structure traces in object position, whereas the constructions that yield good performance-actives, subject-relatives, and subject-clefts-either do not have a trace in their S-structure representation (as in the active) or if there is a trace, it appears in the subject position. And in these latter instances, the agent-first strategy works-were grammatical capacity normal, it would yield the same solution.[4]

Grodzinsky's account has not gone unchallenged. Consider in this respect, two recent reports, one by Martin, Wetzel, Blossom-Stach, and Feher (1989) and one by Badecker, Nathan, & Caramazza (1991).

Martin et al. (1989) examined comprehension for full and truncated passives (respectively, *The boy was pushed by the girl* and *The boy was pushed).* On the basis of Grodzinsky's theory, one should predict that for the latter sentence type, agrammatic patients should not show random performance but systematic inversion of thematic role assignment: They should assign agency to the initial noun phrase, and in the absence of a countervailing force provided by a by-phrase, thereby consistently misassign the thematic role. But this is not what Martin et al. observed. Contrary to Grodzinsky's formulation, they found that for both types of passives, the truncated as well as the full, their patients assigned thematic roles at chance level.

However, as pointed out in a response by Grodzinsky (1991), there are some problematic aspects to Martin et al.'s challenge. On the production task used initially to assign patients to the agrammatic Broca's category, only one of the three patients tested fit within the investigators' own definition of agrammatism. The other two patients performed virtually normally on all the morphological indices in the task and in addition showed much greater articulatory agility than is usually observed in Broca's aphasia. These patients were aphasic, but it is not at all clear that they were Broca's aphasics. (A fourth patient, who

[4] Grodzinsky has not relied uncritically on GB theory (Chomsky, 1981). He has also tested the "neurological adequacy" of competing linguistic theories (Grodzinksy & Pierce, 1987). To state his findings very briefly, he has observed that although Broca's patients have problems interpreting verbal passives (e.g., *Tom was pushed by Marv,* and see text above), they perform significantly above chance with adjectival passives (e.g., *Tom was interested in Mary).* This distinction is statable within GB theory (Chomsky, 1981), but not within lexical functional grammar (Bresnan, 1982). In the former, verbal passives are transformationally derived in the manner described in the text above, whereas adjectival passives are derived by lexical rule. By contrast, in lexical functional grammar, all passives are lexical. From the standpoint of breakdown compatibility on this set of data alone, therefore, GB theory is perhaps to be preferred; of course this only holds if one believes that the entire issue is one of competence and not performance, and that the current state of these competence theories is immutable.

could not be tested on the standard production test used for classification but was tested on a picture description test, also yielded some morphological data that approximated normal levels.) Similarly, the particular use of the comprehension task may have confounded the interpretation of the results. In all, it is not at all clear that this work has refuted the theory.

Badecker et al.'s (1991) empirical challenge, in the form of data from a single agrammatic patient, is even more difficulty to evaluate. Quite simply, the patient's performance was inconsistent. With respect to his comprehension of active and passive sentences, the only pattern that is at all discernible is that the task seemed to make a difference: he performed mostly at chance for both the active and passive constructions in a sentence-picture matching situation, but tended to show above chance performance for both constructions when the task was one of figure manipulation. And with respect to the cleft sentences, he performed at chance on subject-clefts and above chance on object-clefts-the reverse pattern of all previous findings reported for these constructions. Given that the authors make no effort to reconcile their data with those of others, nor even to account for the mysterious patterns within their own experiment (chance on sentence-picture matching, improvement on the figure manipulation task for the same patient and for the same sentence types), it is not clear how or whether these data bear on the hypothesis at stake.

There have been other examinations of Grodzinsky's generalization that have sought to broaden the descriptive adequacy of Grodzinsky's account (Cornell, Fromkin, & Mauner, 1989; Hickok, 1992; Mauner, Cornell, & Fromkin, 1990). The fact is that Broca's aphasic patients have problems, not only with intrasentence dependency relations involving traces, but also with dependency relations involving overt anaphors, in particular, pronouns (Caplan & Hildebrandt, 1988; Grodzinsky, 1990; Grodzinsky, Wexler, Chien, Marakovitz, & Solomon, 1992). So, for example, given sentences of the sort *John bandaged him*, patients perform at chance level, often taking *him* to refer to *John.* And while Grodzinsky's formulation adequately accounts for the Broca's patients' comprehension pattern observed for active, passive, relative, and cleft constructions, it does not cover the Broca's problem with overt pronoun anaphors.

An analysis formulated by Hickok (1992) does, however, provide a unified account for dependency relations involving both traces and overt anaphors. Hickok has revised Grodzinsky's trace-deletion notion to incorporate a recent aspect of syntactic theory termed the verb phrase-internal subject hypothesis (Burton & Grimshaw, 1992; Kitagawa, 1986; Koopman & Sportiche, 1988). The suggestion here is that the grammatical subject (even in simple active sentences) does not receive its thematic role directly from the verb. Rather, the subject noun phrase originates within the verb phrase and occupies its surface position only by undergoing movement and leaving a trace behind. The assignment of a thematic role to the moved subject noun phrase is, therefore, mediated by the trace. Only unmoved object noun phrases are directly assigned thematic roles. On the basis of this hypothesis, Hickok proposes that Broca's patients never assign thematic roles to subject noun phrases in normal grammatical fashion, but instead resort to a nongrammatical strategy. The latter is not the agent-first strategy that figures in Grodzinsky's account, but a fill-in strategy-a strategy whereby in a sentence-picture situation, the moved subject noun phrase is given the thematic role that has not yet been grammatically assigned

and that makes sense in terms of the depiction. This fill-in strategy works for active constructions, subject-relatives, and subject-clefts for which only one noun phrase is available for interpretation as a given unsatisfied argument-that is, remains to be filled in. But the strategy does not work for passive, object-relative, and object-cleft constructions for which, according to the verb phrase-internal subject hypothesis, no argument is directly assigned.

To illustrate, consider some examples provided in Hickok's analysis. These are representations for subject-cleft and object-cleft constructions as specified by the verb phrase-internal subject hypothesis: Respectively, *It was the boy; that* [VP(t)$_i$ *kissed the girl]* and *It was the boy*$_i$ [*that the girl*$_j$ [VP(t)$_j$ *kissed* (t)$_i$]]. For the subject-cleft construction, the internal argument *the girl* is in object position; it has not undergone movement and therefore receives its thematic role (as the person being kissed) directly from the verb. Accordingly, the thematic role for the noun phrase *the boy* (which has been moved from subject position) can be filled in-it can be assigned the one remaining role that fits in with a depiction of the sentence. By contrast, for the object-cleft sentence, both the noun phrases have undergone movement. The noun phrase *the boy* has been moved from object position (as indicated by subscript;), and the noun phrase *the girl,* this time being in subject position, has also been moved (as indicated by subscript). Both thematic role assignments must thus be mediated by traces. And since Broca's patients cannot capture antecedent-trace links for the purpose of comprehension, they cannot narrow down their options-they cannot fill in. So they guess.

Although Hickok's account clearly makes use of the defining characteristic of Grodzinsky's trace-deletion hypothesis-namely, that traces are deleted in S-structure-it also offers an important contrast. In Grodzinsky's view, Broca's patients are capable of grammatically assigning thematic roles to subject noun phrases. In Hickok's revision, chance performance results from completely unspecified thematic assignment-the patients make no thematic assignments whatsoever for passives, object-relatives, and object-clefts. Hickok's variation also accounts for the Broca's comprehension of pronoun anaphors. The verb phrase-internal subject hypothesis holds that the governing category of a pronoun is the verb phrase which entails that it is within this category that the pronoun must be free (Kitagawa, 1986).[5] In this respect, consider the example *John bandaged him*. Its representation under the verb phrase-internal hypothesis is *John* [VP(t) *bandaged him]-again,* the subject noun phrase has undergone movement, leaving a trace. Since the trace of *John* is inside the verb phrase and since the verb phrase is hypothesized to be the governing category, the pronoun *him* cannot refer to John; it must be free. But Broca's aphasic patients cannot link antecedents and traces; they cannot, therefore, apply the binding principle to block co-reference of *him* and *John.* That is, without the trace, nothing in their representation of the sentence specifies what the pronoun *him* refers to-or, more to the point, cannot refer to-and so they guess.

Our account of Grodzinsky's trace-deletion hypothesis and Hickok's reworking of the trace-deletion hypothesis has glossed over a number of clever and

[5] All versions of GB theory (Chomsky, 1981) consider pronouns to be free within their governing category. What is at issue is the identity of the category, the new formulation shifting it from the inflectional phrase (essentially, the sentence level) to the verb phrase.

interesting details of these representational accounts of language dysfunction in aphasia. Still, even from our partial description, it should be apparent that both investigators agree on what is particularly problematic for Broca's patients: namely, their inability to represent intrasentence dependency relations involving traces. Indeed, in Hickok's formulation, the Broca's problem with traces is invoked even to account for their poor performance with dependencies involving overt anaphors.

A final point: The accounts we have covered-Grodzinsky's, Hickok's, and Caplan's before them-all constitute an attempt to describe what can and cannot be syntactically represented. What they do not address is the source of the representational limitations: in particular, the source of the Broca's problem with intrasentence dependency relations.

It is to this issue that we now turn. And, as we show in the next section, the evidence points not to a competence limitation (i.e., not to a partial loss of knowledge that somehow erases traces or the like) but to a disruption to the processes that IMPLEMENT syntactic knowledge in real time.

VI. CURRENT ISSUES: PROCESSING DISRUPTIONS IN APHASIC COMPREHENSION

There are, basically, two competing ideas concerning the nature of the processing disruption that underlies the sentence comprehension limitation in Broca's aphasia-that yield the problems described above. One idea is that there is a failure of mapping between syntactic representations and thematic roles. The other is that there is a disruption in the initial construction of the syntactic representation, a disruption that can be traced to the non-normal operation of lexical access mechanisms.

A. A Mapping Failure

This hypothesis is rooted to data from experimental tasks involving grammaticality judgments. Specifically, Linebarger, Schwartz, and Saffran (1983) observed that agrammatic Broca's aphasics who showed noticeable syntactic limitations in comprehension were, nonetheless, able to detect a wide variety of grammatical deformations in a grammaticality judgment task, including those that required an awareness of syntactic dependencies involving traces. What emerges from this is a picture of agrammatic aphasic patients in which they can be seen to carry out quite complex syntactic judgments yet lack the ability to exploit this sensitivity for comprehension.

As pointed out by Sproat (1986), these judgment data indicate that the failure to specify empty categories, or traces, makes little sense except in processing terms. Sproat's reasoning turns on the fact that in GB theory, the presence of a trace follows directly from the projection principle. This principle states that representations at each syntactic level are projected from the lexicon, each level thereby observing the allowable syntactic environments of lexical items. This means, in effect, that by not representing traces, agrammatic Broca's patients build syntactic structures that violate a core grammatical principle. And if this deficit is one of competence-if the projection principle is no longer

a part of retained knowledge-then the patients ought to have been insensitive to the syntactic deformations provided by Linebarger et al. But since the patients WERE sensitive to these deformations, it follows that their inability to represent traces must be due to some defect in the system that converts the input stream into an interpreted structure. So again the data gained by Linebarger et al. argue for a processing explanation of agrammatic comprehension. But of what sort?

Linebarger et al. (1983) opt for a mapping explanation. In the words of Saffron and Schwartz (1988), the problem arises "not from a failure to parse sentences for their grammatical functions, but rather from a difficulty in assigning those functions the appropriate thematic roles" (p. 390).

Several points about this hypothesis warrant consideration. The first is that it is not clear that the Linebarger et al. data compel any sort of mapping hypothesis. The task of making grammaticality judgments about a sentence need not depend on the normal construction of a coherent syntactic representation. We do not suggest under this view that there need to be different analyzers for comprehension and for grammaticality judgment. Rather, it is simply that it is one thing to notice the absence of anempty position in a deformed "sentence" and make a "non-normal" judgment to it, and quite another matter to fill that position in a nondeformed sentence with the correct antecedent during the strict time constraints of the initial structure-building process. Sensitivity in the first instance will yield good performance on a grammaticality judgment task, but only the latter capacity will yield a normally complete syntactic representation that can support subsequent thematic mapping (Wulfeck, 1988; Zurif & Grodzinsky, 1983).

Further, however, it is not inconceivable to suggest that grammaticality judgments may actually be made by a processing device that is not normally involved in ongoing sentence comprehension. Baynes and Gazzaniga (1987; Gazzaniga, 1989) report that the right hemisphere of split-brain patients can support correct grammaticality judgments, but that this same hemisphere "is severely limited in its capacity to use syntactic information in comprehension," such that the patients have "difficulty understanding semantically reversible active and passive sentences." An interesting possibility is that, although the processing of sentences is left hemispheric, the right hemisphere in aphasic patients may be called into play for grammaticality judgment tasks but is unable to aid normal comprehension.

In addition, it should be noted that if there were to be a mapping problem, it is clearly not an undifferentiated one-one that arises for all syntactic types. Schwartz and her colleagues acknowledge this by pointing to what they term a THEMATIC TRANSPARENCY EFFECT, that agrammatic Broca's patients have noticeably more difficulty in mapping moved noun phrases than in mapping noun phrases directly in thematic positions (Schwartz, Saffran, Linebarger, & Pate, 1987). In effect, they restate in mapping terms the distinction that is at the heart of the various versions of the trace-deletion hypothesis (Cornell et al., 1989; Grodzinsky, 1986, 1990; Hickok, 1992; Mauner et al., 1990).

As the current experimental basis for their theory may have alternative explanations rooted in processes that are independent from the comprehension data they are intended to illuminate, the theory itself needs further empirical definition. And finally, we note that by failing to provide either an independent

theory of parsing or any evidence for the selective disruption of processing modules in terms of their real-time operating characteristics, Linebarger et al. have little basis for distinguishing mapping failures from prior parsing (structural processing) failures. Indeed, as we show below, when real-time processing properties are revealed through the application of on-line analysis, parsing is observed not to be normally intact in Broca's aphasia.

B. Disruptions of Structure Building

The notion that the parser itself is the weak link in Broca's aphasia arises from a recently completed analysis of the ability of aphasic patients to establish intrasentence dependency relations in real time (Zurif, Swinney, Prather, Solomon, & Bushell, in preparation). The analysis is based on observations of early-stage lexical activation characteristics.

Some background: Over the past 11 years, researchers have consistently observed that Wernicke's aphasics have normal lexical access functions and that Broca's do not. The data supporting this generalization come from studies of lexical priming (Blumstein, Milberg, & Shrier, 1982; Katz, 1986; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetsky, 1987; Prather, Shapiro, Zurif, & Swinney, 1991; Swinney, Zurif, & Nicol, 1989). Priming in this case refers to the finding that processing a lexical item (e.g., deciding whether or not a string of letters forms a word) is faster for target words when these are immediately preceded by semantically related words than when preceded by unrelated words. This pattern of results is taken to indicate that the meaning of the preceding related prime has been present to aid the recognition of the subsequent word (Meyer, Schavenveldt & Ruddy, 1975). So, to state the matter directly in terms of the relevant data, Wernicke's patients but not Broca's patients show the normal pattern of faster word recognition in semantically facilitating contexts (priming).

That noted, we hasten to emphasize that Broca's patients are not completely insensitive to prime-target relations-they are not, after all, disbarred from activating lexical meanings. Rather, for Broca's, priming seems to be temporally protracted, or more to the point, lexical contact and activation, as revealed by priming, seems to have a slower than normal time course (Prather et al., 1991; Swinney et al., 1989).

The effects of this form of aberrant lexical access may reasonably be supposed to ramify throughout the comprehension system. Consider just one of its likely effects-that concerning syntactic processing in the case involving the linking of antecedents and traces. Crucially, traces have real-time processing consequences. We refer here to what has come to be known as gap-filling, the demonstration based on priming patterns that in normal subjects, antecedents and traces are actually linked during the course of ongoing comprehension, and that the antecedents actually fill the gap left by their movement at the point when that gap is encountered by the listener. (See Swinney and Fodor, 1989, and Swinney and Osterhout, 1990, for reviews of this work.) This is an operation that is implemented under strict time constraints. And this being so, the inability of Broca's aphasic patients to represent antecedent-trace relations can be viewed in real-time terms as the inability to reactivate the moved constituent

at the normal time in the processing sequence-in time, that is, to fill the gap left by its movement (and indexed by the trace).

We have lately tested the possibility of this scenario by assessing gap-filling in Broca's patients, Wernicke's patients, and elderly neurologically intact subjects (Zurif et al., in preparation). We used subject-relative constructions of the sort *The gymnast loved the professor*$_i$ *from the northwestern city who* (t)$_i$ *complained about the bad coffee*. As shown by this example, movement from subject position is hypothesized.

We chose this construction because it offered the possibility of revealing whether the brain areas implicated in Broca's and Wernicke's aphasia are distinguishable in terms of their functional commitments to sentence processing. The relevant point in this respect is that Broca's and Wernicke's differ not only in terms of lexical access characteristics, but also in their ability to understand the subject-relative construction. Broca's patients, as already indicated, show relatively normal comprehension for this construction. But Wernicke's patients are unpredictable, more often than not showing chance comprehension (Grodzinsky, 1984; Shankweiler, personal communication, February, 1992). So, do Broca's,patients show normal parsing, as Linebarger et al. (1983) would have it? Or does their slower than normal lexical access pattern disallow normal gap-filling, requiring, in consequence, an abnormal reliance on one or another nongrammatical heuristic for thematic assignment? And to consider a reverse scenario, do Wernicke's aphasics show normal gap-filling even though they often fail ultimately to achieve a normal level of comprehension for this sentence type?

Our assessment of gap-filling and the range of possibilities just outlined turned on the use of an on-line task termed cross-modal lexical priming (CMLP) (Swinney, Onifer, Prather, & Hirshkowitz, 1979). Some particulars are warranted here, both about what we mean by on-line and about the nature of the task itself.

By an on-line analysis we mean an analysis that reveals aspects of processes that operate during the course of comprehension. Such an analysis is intended to reveal something of the fixed operating characteristics of these processes, and/or the nature of their real-time interaction, and/or their dependence on processing resources such as memory capacity. And the use of reaction time measures alone does not guarantee this perspective (cf. Berndt, 1990). Several recent incorporations of reaction time measures in grammaticality judgment tasks impel us to emphasize this last point. Either these studies have served to confirm what is known from off-line tasks [e.g., Baum's (1989) demonstration that Broca's patients are relatively insensitive to violations involving gaps] or, at best, they bear only upon very general architectural features [e.g., Shankweiler et al.'s (1989) demonstration that Broca's patients, like normals, reduce their structural options as more of the input is made available]. And again, the finding that a patient notices a structural error in a deformed sentence, even if he does so quickly, does not necessarily indicate that the patient has incorporated all the lexical items into a fully specified structure. In particular, and to return to the present concern, the patient's ability to notice the absence of a gap where one should exist is not necessarily based on the ability to fill that gap with the structurally correct antecedent on-line.

Our use of a CMLP task did, however, reveal whether gaps were filled at the appropriate (normal) time. The features of the task were these: subjects listened to a sentence over earphones (delivered uninterruptedly and at a normal speaking rate) and at one point, while listening to the sentence, were required to make a lexical decision for a visually presented letter string flashed on a screen in front of them.

What we sought to discover was whether a letter-string probe forming a word related to the moved constituent (the antecedent) was primed at the gap. Such priming would indicate that the moved constituent was reactivated, or filled, at the gap (thus providing the prime). So, for each of our experimental sentences we recorded lexical decision times either for antecedent-related probes or for letter string probes that were semantically unrelated control words. For the example given earlier, *The gymnast loved the professor*$_i$ *from the northwestern city*^{*1} *who*^{*2} (t)$_i$ *complained about the bad coffee,* the probes were *teacher* (the probe for the antecedent, *professor*) and *address* (the control probe).

As indicated by the superscripts *1 and *2, priming wasexamined at two points, at the gap indexed by the trace (superscript *2) and at a pre-gap position (superscript * 1). The latter served as a measure of any residual activation from the earlier appearance of the antecedent (*professor*); that is, it allowed an examination of any nonsyntactic priming effects. Of course, in each instance priming was determined by comparing the lexical decision time for the related probe to that for the unrelated probe.

The data that we gained are straightforward. The elderly normal subjects and the Wernicke's patients showed gap-filling; the Broca's patients did not. Specifically, the neurologically intact and the Wernicke's aphasic subjects showed priming (that is, relative facilitation in lexical decisions) for antecedents at gap sites but not at pre-gap sites. The Broca's patients did not show priming at either position.

The finding that Wernicke's patients show gap-filling for sentences that they have problems understanding suggests that the syntactic (parsing) operation that links a trace to its antecedent constituent is separable from the operation of thematic assignment to that constituent. Indeed, the finding that Wernicke's patients are not sensitive to the availability of argument structure entries for a verb in real time (Shapiro & Levine, 1990) strengthens this separation. These findings suggest that gap-filling is syntactically driven, not thematically driven. [See also Hickok (1991) and Fodor (1989) for the same conclusion based on studies of normal parsing.] And they suggest that left posterior cortex-the cortical region implicated in Wernicke's aphasia-is not critically involved in this syntactic process.

Left anterior cortex-the cortical region usually implicated in Broca's aphasia-does seem to be involved in the operation of gap-filling, however. Contrary to Linebarger et al.'s (1983) speculations on the matter, Broca's aphasic patients do have a parsing problem-a problem that explains structural limitations statable in the abstract terms of GB theory and that can itself by explained in a way that allows us to approach the basic resources from which the syntactic system is constructed-that is, in terms of a fairly elementary lexical access system. In this view, left anterior cortex is not the locus of syntactic representa-

tions per se, but rather seems to sustain fast-acting access systems that are, in turn, necessary for building such representations in real time.

VII. CONCLUDING REMARKS

The differences between Broca's aphasia and Wernicke's aphasia serve research as much now as they did over 100 years ago. This said, we do not claim yet to understand the significance of all of the individual features constituting the syndromes, nor to understand the significance of feature variability, nor to understand the significance of anomalous cases within the nonfluent, agrammatic Broca's group. For that matter, it is our hope that models that are currently being developed will eventually do away with the need even to grapple with the clinical signs of these aphasias-that they will allow us to form groups directly on the basis of lesion site. But for the present, however much our classification of Broca's aphasia and Wernicke's aphasia depends on a curious mix of production and comprehension factors and lesion localization considerations, the fact remains that such classification is possible and helpful for theoretical work.

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