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Syntactic Processing in Aphasia

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In this report we comment upon subject selection and methodology, and we describe some recent studies of syntactic processing in aphasia. Our data show that, like neurologically intact subjects, Wernicke's patients reactivate moved constituents (instantiate coreference) at the site of their extraction (even for sentences that they do not understand). Broca's patients, by constrast, are shown not to create such syntactically governed links (even for sentences that they do understand). These data isolate the processing bottleneck in Broca's aphasia and more generally suggest that syntactic comprehension limitations can be traced to changes in cortically localizable resources that sustain lexical processing.

METHODOLOGICAL CONSIDERATIONS

Issues of Subject Selection

The focus of the first major book on agrammatism (Kean, 1984) was on the claim of "overarching" agrammatism, that is, on the claim that Broca's patients were as syntactically limited in comprehension as in production. Even then the claim was challenged. Exceptions were noted: not all agrammatic speakers were agrammatic listeners (Goodglass & Menn, 1984; Kolk, van Grunsven, & Keyser, 1984).

Partly because of these exceptions, very few if any researchers still carry out inquiries concerning this "overarching" hypothesis. However, there is also another reason for the current lack of interest in this hypothesis: there is currently no theoretical focus to any such inquiry. The simple notion of a loss of syntactic competence in Broca's aphasia-a loss that is necessarily equally manifest in all activities-is no longer tenable. And, there is no processing perspective to take its place-nothing to guide us concerning a possible *functional* overlap of, production and comprehension systems. Mostly, the ingredients from the production side of the equation are missing. This is especially true at the level of syntax. Whereas aspects of representational formats specified in generative grammar seem to constitute precisely the targets that real-time to be gauged for production (Bock, 1991), the paradigms for doing so have yet to be developed. In the face of all this, Broca's aphasia is currently being mined for answers to different questions. For the most part, it is being examined for information bearing on the comprehension system on its own, occasionally, for information bearing on the production systems alone, but, again, hardly ever for answers concerning parallelism. In effect, Broca's aphasia exists apart from what is made of it at any given time.

Yet, although Broca's aphasia continues to serve research-including the research efforts of the participants at the TENNET symposium which gave rise to this volume-some of these participants appeared rather tentative about accepting clinical categorization. Two examples among several: In her preconference paper circulated among the participants, Marcia Linebarger entered "... the usual disclaimers ... regarding the heterogeneity of agrammatic performance and the assumptions underlying all neuropsychological research," and during the conference, David Caplan questioned whether there was any empirical basis at all for linguistically characterizable syndrome-specific deficits.

We examine some of Caplan's specific criticisms at a later point-in the context of our work. Here we enter only some general considerations: namely that any empirical challenge to a theoretical claim must always be taken seriously and that the existence of exceptional cases-of Broca's patients who do not show interpretable comprehension problems or even any comprehension problems at all justifies gingerness concerning classification. However, disagreeable data are not unique to psychology (see Zurif, Swinney, & Fodor (1991) on this matter); also the exceptions have to be put in perspective. Several of the most highly touted ones (Miceli, Mazzucchi, Menn, & Goodglass, 1983; Kolk et al., 1984) are likely not even Broca's patients to begin with: one of Micelli et al.'s (1983) cases was able to repeat and read aloud without any agrammatic limitation and, like Kolk et al.'s (1984) patient, another showed normal fluency and normal phrase length. The risks that we take in seeking generalizations based on analyses of the agrammatism associated with Broca's aphasia are worrisome enough without incorporating patients that do not belong in the category. After all, however variable output is in Broca's aphasia, the patients all share a recognizable nonfluency-one of the important feat

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tures upon which identification rests in the first instance. Moreover. even given the vagaries of clinical judgment, the Broca's patients who do show comprehension breakdowns far outnumber those Broca's who do not. Were this not the case, there would have been no basis for the TENNET Conference.

Off-Line and On-Line Measurements

Our second methodological concern is with a distinction that has rightly become quite important in the evaluation of theoretical claims: the off-line-on-line distinction.

By off-line measurements we refer to those that reveal aspects of the aphasic limitation measured after comprehension and expressed as a final product-as an inability to comprehend a particular construction or to judge its grammaticality. Typical off-line techniques are sentence enactment, sentence-picture matching, truth-value judgment, and grammaticality judgment. Their worth in helping us think about representational limitations is indisputable. However, they have not been overly valuable in helping us explain these limitations in processing terms.

Linebarger, Schwartz, and Saffran's (1983) interpretation of their grammatical-judgment data illustrates this last point. Their finding is that Broca's patients carry out quite complex syntactic judgments, showing in this respect a sensitivity to structure and to grammatical categories (e.g., empty categories) that they are unable to exploit for comprehension. Linebarger et al. (1983) take this to indicate that the Broca's comprehension problem is not at the level of syntactic processing, but at a later processing stage-at the stage of thematic role assignment or mapping. However, these off-line grammatical judgment data do not compellingly support this interpretation. It is one thing to notice the absence of an empty (trace) position in a deformed sentence and quite another to link the trace with its antecedent in real-time-to fill the gap indexed by the trace during the strict time constraints imposed on the structure-building process. It is entirely possible that sensitivity in the first (off-line) instance is based on a local "checking" procedure-a post-sentence problem solving process in which locally available antecedents are checked, against any open (unfilled) verb arguments. "This kind of top-down, strategic intervention is likely to be far removed from gap-filling-from the normal reflexive linking of an antecedent and its trace. Thus, although the off-line judgments charted by Linebarger et al. (1983) indicate the Broca's patient's sensitivity to empty categories, the data do not help us fill in details from a real-time processing perspective. In particular, they do not help us distinguish processing at the syntactic level from processing at a later stage.

To isolate such stages we need to apply on-line techniques-techniques

that can be brought to bear on ongoing processes at any time. In what follows we describe how we've already used such techniques to study sentence processing in aphasia. First, however, we provide the context for their application.

REPRESENTATIONAL LIMITATIONS AND PROCESSING DISRUPTIONS

As can be seen elsewhere in this issue (e.g., Grodzinsky, Hickok & Avrutin), efforts to characterize Broca's comprehension limitations at the sentence level turn, for the most part, on the notion of trace-deletion or, for current purposes, on the extensionally equivalentnotion of chain disruption and a resultant failure of thematic role transmission. Details aside, there remains a relatively uncontroversial observation driving these claims: namely, that Broca's patients have noticeable problems understanding movement-derived structures. It is to this limitation-and the implied failure to form syntactically licensed dependency relations-that processing accounts have been directed.

Syntactic Processing vs. Mapping: A First Pass

As already alluded to in our discussion of grammatical judgments, two options concerning the processing bottleneck have been suggested. One option is that it occurs during the construction of a syntactic representation-the system is unable to establish dependency relations in real time (Zurif, Swinney, Prather, Solomon, & Bushell,* 1993). The second option is that the problem is at a later stage-at the stage of thematic mapping (Linebarger et al., 1993; Linebarger, this issue).

As stated here, the two options are evenly matched. In the literature, however, the playing field is invariably less level. Those who support mapping (e.g., Linebarger, this issue)-even some who do not (Kolk & Weijts, this issue)-generally pit their work against the trace-deletion hypothesis (e.g., Grodzinsky, 1986, 1990) or its progeny (e.g., Hickok, Zurif, & Canseco-Gonzalez, 1993; Mauner, Fromkin, & Cornell, 1993) as if these "trace-based" hypotheses were claims about processing. However, they are not about processing. They try to capture the Broca's limitation along structural lines; they do not try to account for the source of the limitation along processing lines. It is immaterial to the trace-deletion notion (in any of its manifestations) whether traces are absent from a syntactic representation or (as the mapping hypothesis *has* it) present but unusable.

The point here is that the source of the comprehension limitation has to be investigated on independent grounds. Without data to isolate a . processing level in terms of its unique operating characteristics, there is no basis for distinguishing one intermediate processing stage from an-

other. More directly to the current concern, without such data the mapping hypothesis remains an unsupported stipulation. As it happens, with such data the hypothesis will be seen to fail.

Lexical Activation in Aphasia

The on-line analyses presented in this section are based on measures of lexical activation in particular syntactic environments. They widen the focus to include Wernicke's aphasic patients as well as Broca's patients, and they build -upon earlier observations-data from lexical priming experiments-that Wernicke's patients, but not Broca's patients, show roughly normal lexical activation characteristics in circumstances that support automatic processing (e.g., Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetsky, 1987; Prather, Zurif, & Love, 1992; Prather, Zurif, Stern, & Rosen, 1992; Swinney, Zurif, & Nicol, 1989). Priming in this case refers to the finding that processing a lexical item (for example, deciding whether a string of letters forms a word) is faster for target words when these are immediately preceded by semantically associated words than when preceded by unrelated words (e.g., Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1977). In effect, activation of the first, or prime, word aids recognition of the target. Thus, to state the matter directly in terms of the data, Wernicke's patients, but not Broca's, show the normal pattern of faster word recognition (lexical decision) in semantically facilitating contexts.

That noted, we hasten to add that the Wernicke's patients are not likely to be entirely normal in accessing word meaning. To be sure, the priming data for this group ought to be interpreted as reflecting lexical activation (the point of interest here), but these data do not rule out "coarse-coding" and, therefore, ultimate imprecision with the semantic network. Contrariwise, the abnormal priming pattern for Broca's patients should . not be taken to indicate that these patients are disbarred from activating word meanings. In fact, they are not completely insensitive to prime-target relations. Rather, for the Broca's patients, automatic priming seems to be only temporally protracted: automatic lexical activation seems still to be present, but to operate under a slower-than-normal time course (Friederici & Kilborn, 1989; Prather et al., 1992a,b; Swinney et al., 1989).

Not all investigators agree with this last assessment of lexical activation in Broca's aphasia. In particular, Ostrin and Tyler (1993) and Hagoort, Brown, and Swaab (1994) claim that Brocas' patients can carry out lexical access in a normally rapid automatic manner. In Hagoort et al.'s (1994) words, automatic activation in Brocas' aphasia is ". . . just fine."

Evaluation of the relative merit of these opposing claims requires an analysis of the on-line paradigms to which the evidence is rooted. In this

respect, the most direct evidence of slowing in Broca's patients stems from the two Prather et al. studies (Prather et al., 1992a,b). In these two studies the patients were presented with words in the form of continuous lists. This roughly mimics the unbroken succession of words in sentences, but more than this, this list technique has been independently shown to yield automatic (as opposed to strategy-driven) activation in neurologically intact subjects (Shelton & Martin, 1992). The same cannot be said for the techniques used by Ostrin and Tyler (1993) and by Hagoort et al. (1994). Both used a word-pair paradigm that incorporated neither a distraction manipulation nor relatedness variations. Without the former they most likely elicited controlled or strategy-driven processing and without the latter, they had no way of checking this possibility. Setting words together in pairs (or in triplets) seems to suggest to subjects that the words somehow belong together, and it thereby fosters both expectations of relatedness and a postlexical checking strategy (e.g., Shelton & Martin, 1992). Neither is likely to be relevant to sentence processing. So at least for the present, it remains a reasonable bet that initial lexical activation is not normally rapid in Broca's aphasia. Indeed, as we show below, the payoff on this bet has already had considerable heuristic value.

Gap-Filling in Aphasia

Empty categories have processing consequences. We refer here to gap-filling, the demonstration (based on priming) that antecedents and traces are linked during the course of comprehension. (See Swinney & Fodor (1989) and Swinney & Osterhout (1990) for reviews of this work.) This is an operation that is implemented under strict time constraints and one that is unlikely to accommodate slower-than-normal lexical activation. This being so, it seemed reasonable to hypothesize a connection between the Broca's slowed lexical processing and their syntactic limitation. Specifically, it seemed reasonable to view the Broca's inability to interpret antecedent-trace relations as a failure to reactivate moved lexical items at the normal time in the processing sequence-in time, that is, to fill gaps left by their movement.

We have examined this suggestion by assessing gap-filling in Broca's patients and Wernicke's patients in two experiments (Zurif et al., 1993; Swinney, Zurif, Prather, & Love, 1993).[1]

In the first experiment (Zurif et al., 1993) we used subject-relative con. structions of the sort, "The man liked the tailor, with the British accent

[1] We have also assessed gap-filling in age-matched neurologically intact subjects. In fact, the normal subjects were used to pretest the different sentence types for the two experiments.

who $(t)_i$ claimed to know the queen." As shown in this example by co-indexation, movement from subject position is hypothesized.[2]

We chose this construction because of the perspective it offered both within and across aphasic groups. As described elsewhere in this issue (e.g., Grodzinsky), Broca's patients show relatively normal comprehension for this construction. However, Wernicke's patients are unpredictable, more often than not showing chance comprehension. (Grodzinsky, 1984; Shankweiler, personal communication, February, 1992). Thus, for Broca's patients these sentences provided the strongest test of our suggestion that they could not carry out normal syntactic analysis in real time: We could determine if slower-than-normal lexical activation disallowed normal gap-filling even for sentences correctly comprehended, and we could determine if even in such circumstances Broca's were abnormally reliant on nongrammatical strategies. As for Wernicke's patients, it allowed us to determine the possibility of a reverse scenario: viz. whether, given their normal initial contact with lexical entries, they could fill gaps even for sentences which they often fail ultimately to understand.

Our assessment of gap-filling and the range of possibilities just outlined, turned on a cross-modal lexical priming (CMLP) paradigm (Swinney, Onifer, Prather, & Hirshkowitz, 1979). 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. (To accommodate the right-side weakness of Broca's patients, all subjects "button-pressed" with their left hand when making their decisions.)

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 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 unassociated control words. For the example given earlier, "The man liked the tailor_i with the British accent^{*1} who^{*2} $(t)_i$ claimed to know the queen," the probes were "clothes" (the probe for the antecedent, "tailor") and "weight" (the control probe).

As indicated by the superscripts ^{*1} and ^{*2}, priming was examined 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 baseline; it allowed us to distinguish structurally governed reactivation at the gap site

[2] Technically, it is the Wh-element ("who") that is hypothesized to have been moved from the subject position of the relative clause. However, since "who" and "tailor" co-refer, "who" inherits the semantics of "tailor."

TABLE I
Amount of Priming (msec)

Position	Pregap	Gap
Wernicke's patients	44	125*
Broca's patients	-20	-68

Note. Reaction time to control probes minus reaction time to related probes.
*Signficant priming ($p < .03$).

from any residual activation due simply to the earlier appearance of the antecedent ("tailor"). Of course, in each instance, priming was determined by comparing the lexical decision time for the related probe to that for the unrelated probe.

It should be apparent from our description of the task that the lexical decision itself does not require that the subject consciously seek a relation between the visual probe and anything in the orally presented sentence (as is the case, for example, in probe-latency tasks). Rather, at least until the visual letter string is presented, the subject is simply listening and trying to understand the sentence. (We encourage this by randomly asking comprehension questions between trials.) Once the visual probe is presented, all such normalcy ends, of course. But this happens only after the point of theoretical interest concerning sentence processing has passed.

The findings for the aphasic patients on this task are presented in Table 1. As can be seen, the Wernicke's patients reliably filled gaps immediately (as did our neurologically intact subjects who were used to pretest the sentences-see Footnote 1). The Broca's patients did not fill the gaps immediately.[3] It appears, therefore, that the brain areas respectively implicated in Broca's and Wernicke's aphasia have different functional commitments-the former is crucial for the real-time construction of intrasentence dependency relations in a way that the latter is not.

As mentioned earlier, we also carried out a second study (Swinney et al., 1993). This time we used object-relative sentences. Given the Broca's failure to fill gaps for subject-relatives (sentences that they understand), we had little expectation that they would show gap-filling for object-relatives (sentences that they fail to interpret). However, our interest in using object-relatives had to do mostly with Wernicke's patients (who also show less-than-normal comprehension for such sentences). We wanted to broaden the base of our observations of this group's gap-filling

[3] We emphasize that the Broca's patients' failure to show gap-filling cannot be construed as some global failure to prime. In other nonscntence circumstances, when some of the patients were presented with word lists, they did show priming, even if in a temporally protracted manner.

TABLE 2
Amount of Priming (msec)

Position	Pregap	Gap
Wernicke's patients	3	108*
Broca's patients	122	-9

Note. Reaction time to control probes minus reaction time to related probes.
*Signficant priming ($p < .02$).

capacity, particularly because reactivation in subject-relatives might have been affected by the relativizer "who" in that construction and also because movement within subject-relatives has the special property of being "string-vacuous" (e.g., Clements, McCloskey, Maling, & Zaenen, 1983): such movement does not reorder any of the elements of the sequence.

Accordingly, our second study featured object-relative sentences of the type:

"The priest enjoyed the drink$_i$ that the caterer was^{*1} serving^{*2} (t)$_i$ to the guests."

We used the same CMLP task as in the first experiment, and again, we checked for priming both at the gap (superscript *2) and at a baseline, pre-gap position (superscript *1). For the example given, "wine" was the probe for "drink" and "boat," the control probe.

As can be seen in Table 2, the Broca's patients again did not show significant priming at either probe site. Still, even though not significant, they did show some advantage for related probes (relative to control probes) at the pre-gap position. In effect, for this group there was no sign of structurally determined reactivation of the antecedent, only a sign of some residual activation-the consequence, likely, of having processed the earlier appearance of the constituent in a slowed-down fashion. As for the Wernicke's patients, they once more showed priming at the gap and only at the gap, and again, this pattern corresponded to that shown by the neurologically intact subjects with whom we pretested the material.

Caplan, in his discussion at the TENNET Conference, questioned the basis of our Broca's-Wernicke's difference in gap-filling. He claimed that the Wernicke's patients we tested had off-line comprehension scores that were superior to those for the Broca's patients, and he suggested that the patient's ability to fill gaps might, therefore, have more to do with their comprehension level than with their syndrome identification. Granting the claim, the argument is sound. However, we do not grant his claim. On our off-line comprehension assessment accompanying each of our gap-filling experiments, neither the Broca's nor the Wernicke's patients showed normal performance for noncanonicial (object-gap) structures. In fact, in the second gap-filling experiment, the patients comprising the Wernicke's group performed at a lower level on the off-line

test than did the Broca's. Notwithstanding Caplan's speculation on the matter, our gap-filling data can be interpreted only in terms of a Broca's-Wernicke's contrast.[4]

Syntactic Processing vs. Mapping: A Second Pass

It was earlier forecast that on-line data would show the processing bottleneck in Broca's aphasia to be at the syntactic level and not at a later stage of processing as suggested by the mapping hypothesis. We now return to this topic.

Consider first the data obtained for the subject-relative sentences. Broca's patients show good understanding for subject-relative sentences. In this circumstance, the mapping hypothesis (e.g., Linebarger et al., 1983) stipulates normal syntactic analysis (normal mapping, too). By contrast, as we have framed it, the syntactic hypothesis [in line with various

[4] Mauner (this issue) has also raised some questions about our data, and these, too, are empirically unfounded concerns. In particular, she assumes that Broca's patients have slower absolute reaction times than do Wernicke's patients, and in consequence, expresses the concern that our screening procedure (a two-standard deviation cutoff) would be more likely to exclude data from Broca's than from Wernicke's patients. However, as we have pointed out elsewhere (Zurif et al., 1993), our two-standard deviation screen was uniquely determined from each subject's distribution of reaction times and therefore did not disproportionately exclude Broca's responses. For that matter, contrary to Mauner's suppositions, the Broca's response times were not even systematically greater than those for Wernicke's patients. In the experiment employing subject-relative sentences, the average reaction times for the Broca's patients (for all probes in all locations) and for the Wernicke's patients were, respectively, 1113 and 1041 ms, but, with object-relative sentences, the Broca's patients' mean was only 1248 ms, while that for the Wernicke's was 1472 ms. At any rate, what is critical here is the difference between absolute reaction time and relative reaction time. The absolute reaction time numbers that we have just entered-those that concern Mauner-likely reflect psychomotor slowing and are of no direct relevance to our study. What is relevant are the relative reaction times that have allowed us to factor out this effect. It is these relative times based on experimental-control probe differences that have allowed us to chart lexical activation. When we suggest that there is a slowing of lexical activation in Broca's aphasia, what we are referring to is the failure to find a significant priming effect-a significant experimental-control probe difference-under particular temporal constraints as defined by the probe positions in the sentence; absolute response times have no relevance to this issue. Mauner enters other concerns, these being the amount of data excluded by our screening procedures and the frailty of the gap-filling effect even for neurologically intact subjects. With respect to the latter, she cites the work of McKoon, Ratcliff, and Ward (1994). In this connection we urge the reader to consult the paper by Nicol, Fodor, and Swinney (1994) wherein the McKoon et al. claims are very definitely empirically blunted (in all relevant cases there were shown to be methodological problems inherent in the manner in which McKoon et al. attempted to examine the issues). As for the amount of data we excluded, we note that we also collected more for each subject than is usual when testing college students. Still, in the general spirit of Mauner's cautionary note, we, too, emphasize how much there remains to be understood concerning the gap-filling effect (and; indeed, all on-line effects). However, such cautionary notes fail to explain or blunt the relevance of the differences we report.

representational accounts (e.g., Grodzinsky. 1986; Hickok et al., 1993)] predicts a failure of gap-filling and an abnormal reliance on nongrammatical strategies in Broca's aphasia, whatever the construction and however good their understanding is. Clearly, therefore, our subject-relative data are accountable by the syntactic processing hypothesis, and not by the mapping hypothesis.

We think that our data for object-relative sentences also require an explanation along syntactic lines. To make this argument, however, we need-first to fix the processing stage at which gap-filling occurs. Some help in this respect is provided by Shapiro and his colleagues (Shapiro, Zurif, & Grimshaw, 1987, 1989; Shapiro & Levine, 1990; Shapiro, Gordon, Hack, & Killackey, 1993). They have shown that. Wernicke's patients are insensitive in real-time to the argument-taking properties of verbs. Unlike neurologically intact subjects, the patients are unable to access momentarily all of the possible argument structure configurations within a verb's entry. They are unable, that is, to generate a fully elaborated thematic grid in the normal manner. Accordingly, it seems reasonable to view gap-filling as being syntactically, not thematically, driven-as reflecting processing at a stage prior to the full availability of a verb's argument structure and to thematic mapping. Indeed, the fact that the Wernicke's patients filled gaps in sentences for which they show uncertain comprehension strengthens this possibility. In light of these data, then, the Broca's patients' inability to fill gaps is to be viewed as a syntactic processing failure, and not a mapping failure.[5]

We emphasize, however, that in respect to judging the relative merits of the syntactic and mapping hypotheses, the critical data remain those provided in our first (subject-relative construction) study. For as we have shown in this study, even though the Broca's patients successfully comprehend subject-relatives, their comprehension is still shakily based on an impoverished (abnormal) syntactic analysis.

FUNCTIONAL LOCALIZATION

Most of the papers in this issue-and most aphasia studies generally-are concerned only with evaluating cognitive theory. The goal is usually to determine if distinctions within a linguistic theory are neurologically defensible-if they correspond to deficit patterns following brain damage.

[5] Linebarger avoids this possibility in her preconference paper by claiming that Shapiro's data bear on subcategorization rather than on thematic information. Her cItim, however, fails on two counts: (1) She invokes the internal structure of a complement rather than the simple fact of its presence or absence; that is, she has the wrong grain size, and (2) she fails to account for an important finding concerning alternating vs. nonalternating datives-constructions that differ with respect to subcategorization, but not with respect to thematic options.

By contrast, our gap-filling work permits not only a connection to linguistic theory but also to functional neuroanatomy.

Our connection to functional neuroanatomy turns on the fact that the syndromes we have examined here-Broca's aphasia and Wernicke's aphasia-are distinguishable both clinically and also roughly with respect to lesion site. To be sure, the brain area associated with Broca's aphasia now seems to have greater extent than initially proposed: Broca's area in the foot of the third frontal convolution is no longer considered to be singularly important, and adjacent and deeper areas have also been implicated (Alexander, Naeser, & Palumbo, 1990; Naeser, Palumbo, Helm-Estabrooks, Stiassny-Eder, & Albert, 1989). Still, the fact remains that the modal lesion site for Broca's area is distinguishable from that for Wernicke's aphasia. For the latter, the greatest involvement is still typically considered to be in the superior temporal gyrus (Wernicke's area). We note also that approximately 80% of Broca's and Wernicke's aphasias appear accountable by the areas defined by these modal sites (M. Albert & H. Goodglass, personal communication, June, 1994). In this sense, then, the real-time processing differences shown for Broca's and Wernicke's patients appear to index different functional commitments for the areas respectively associated with each syndrome.

Wernicke's Aphasia and Functional Localization

Obviously we are only just beginning to characterize the role of the area associated with Wernicke's aphasia. Our data-alongside those reported by Shapiro and his colleagues (e.g., Shapiro et al., 1993)-suggest that with respect to language capacity, this area broadly sustains semantic processes and not those involved in initial parsing and in the formation of dependency relations. However, crucial data are missing even for this rough formulation. In particular, we have yet to determine if Wernicke's patients reactivate only structurally appropriate constituents at gaps. At present, then, we can tentatively conclude only that the brain area implicated in Wernicke's aphasia is not crucially involved in the syntactic business of recognizing and filling gaps immediately in real-time.

Broca's Aphasia and Functional Localization

By contrast, the brain region usually associated with Broca's aphasia does appear to be necessary for the operation of gap-filling. The data reviewed here show that Broca's patients are unable to form dependency relations-whether for object-relative constructions that they have difficulty understanding or even for subject-relative constructions that do not pose difficulty for them.

The consequences of the problem seem relatively straightforward. Since they do not have the processing resources to establish dependency

relations normally-to fill the gap at exactly the right time in the processing sequence-they cannot provide the syntactic information necessary for thematic assignment to moved constituents. Presumably, therefore, the Broca's patients rely abnormally on some nongrammatical strategy to achieve thematic mapping for moved constituents (e.g., Grodzinsky, 1986; Hickok, 1992).

We think it reasonable to link these structural limitations in Broca's aphasia to disruptions of automatic lexical activation. We thereby begin to see that the brain region implicated in Broca's aphasia need not be the locus of syntactic representations per se, but rather might be necessary for providing the resources that sustain lexical activation and its syntactic ramifications.

We have proposed in this paper that these resources sustain the normal speed or rate of activation. But in line with Hagoort et al. (1994) and Ostrin and Tyler (1993), the Broca's failure to integrate a moved constituent might well suggest other possibilities concerning the functional commitment of its associated region. For example, several investigators have suggested that it accommodates the memory storage demands that arise during comprehension (e.g., Ostrin & Schwartz, 1986). And certainly, a prima facie case can be made that long distance dependency relations of the sort described here are especially reliant upon some form of working memory capacity. (See Kolk and Weijts in this issue for a discussion on this matter.)

Another possibility is that the broad cortical area implicated in Broca's aphasia sustains multiple functions, including both speed of activation and memory. Yet another possibility is that memory capacity is diminished only because of the increased cost of slower-than-normal activation.

All are variations on the same theme, namely, that syntactic limitations might be. rooted to changes in cortically localizable processing resources.

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