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Real-Time Examinations of Lexical Processing in Aphasics

Penny Prather,[1] Lewis Shapiro,[2] Edgar Zurif,[3] and David Swinney[4]

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We argue that the lesion localizing value of disruptions to modular information processing systems emerges most clearly from on-line analyses of processing. In this respect we seek to show that left anterior (but not left posterior) damage causes slowed information access and we discuss the manner in which this slowing might yield some of the specific syntactic limitations charted in Broca's aphasia. The general possibility we raise is that the cortical area implicated in Broca's aphasia is not necessarily the locus of syntactic representations, but rather sustains particular time-based operating characteristics that in turn sustain normal real-time parsing.

Encapsulated modules are argued to rely on a fixed, localizable neurological architecture (see Fodor, 1983; Garfield, 1987). Most existing support for this claim, in fact the support marshalled by Fodor (1983), is based on the gross anatomical correlates of clinically observed deficits, data far removed from the millisecond speeds of modular input system operations. We try to bridge this gap in the present paper; we describe some research with aphasic subjects that examines more directly the

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[1] Address all correspondence to Penny Prather, Ph.D., Aphasia Research Center, Boston V.A. Medical Center, 116B, 150 South Huntington, Boston, Massachusetts 02130.
[2] Florida Atlantic University.
[3] Brandeis University, Waltham, Massachusetts, and Aphasia Research Center, Boston University School of Medicine, Boston, Massachusetts.
[4] The Graduate Center, City University of New York, New York, New York.

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neurological realization of processing modules. In some instances, we have data to present; in other instances, the research is as yet incomplete and we have only promissory notes to offer.

Before describing these research efforts, we provide a very brief historical overview of some issues in the conceptualization and investigation of brain-behavior relationships in aphasia, issues that are important in understanding directions taken in current aphasia research.

DIFFERENT APPROACHES TO THE STUDY OF NEUROLOGICAL REPRESENTATION

The classical classification scheme for aphasia, dating back at least to Broca's paper (Broca, 1861), is based on an association between observable language deficits and specific lesion sites. Broca's aphasia is characterized by nonfluent speech production that is telegraphic in nature and by relatively good verbal comprehension at the level of conversation; this pattern of spared and impaired functioning is associated with lesions to the left anterior cortex. Wernicke's aphasia, in contrast, is characterized by fluent but empty production, marked by the use of vague filler words (e.g., *thing*), and poor verbal comprehension; this pattern is associated with damage to the posterior region of the left temporal lobe.

In the 1960s and 1970s, there was a shift from classification based on the distinction between the activities of speaking and listening, to one based on linguistic information types. The goal was to determine whether or not abstract representational formats had discrete neural representations. Current research directions can be traced to this development and to the different views held by investigators regarding what counts as "discrete neural representations."

One view is concerned only with demonstrating the *isolability* of linguistic components. Essentially, if a linguistic constituent is set in relief by the pattern of sparing and loss following focal brain damage, then it is isolable. In effect, what is sought is a theory of language representation that is "breakdown-compatible." Nothing else is asked of neural representations in this work; in particular, there is no interest in localizing or mapping the neural components and circuitry that classical theory has proposed are crucial to language. This approach is a common sense reaction to existing circumstances. After all, why should the brain areas implicated in classical theory, which takes its data from the unanalyzed activities of speaking and listening, also be relevant to linguistic structural types? So, in this first approach, classical theory is

essentially abandoned, and, most particularly, there is abandonment of the lesion sites that classical theory has proposed are crucial to language (see Caramazza, 1986; Caramazza & Badecker, 1989). That is not to say that proponents of this approach are in principle opposed to lesion localizing information, but for purposes of their investigations, those data tend to be ignored. or at most presented for the record; the expectation is that if indeed there is a correspondence between linguistic components and specific neural structures, then a pattern will emerge across individual case studies that ultimately will allow that inference. It is not, however, a central concern.

There is, however, a second approach that is more forceful on the matter of localization. Moreover, by continuing to focus particularly on Broca's aphasia and by seeking also a contrast with Wernicke's aphasia, researchers taking this approach seem stubbornly impelled to implicate the same brain sites as those proposed in classical theory. More specifically, these researchers seek to determine whether or not the brain region implicated in nonfluent aphasia is also crucial for sustaining various information-bearing processes of relevance to comprehension. The assumption here is that the syndrome of Broca's aphasia exists apart from what is made of it. So, although once mined for evidence of relevance to the neurological basis of production, it is now being mined for evidence bearing on the neurological basis of comprehension devices.

The work we report here embodies the second approach. In this work, we argue that the lesion localizing value of disruptions to discrete information-bearing systems seems to emerge most clearly in on-line analyses of processing.

LEXICAL ACCESS IN APHASIA: SLOW RISE TIME

The starting point for the research we present here is the following generalization: Broca's aphasics have problems with the automatic access of lexical information; Wernicke's do not. This pattern applies both to the access of individual lexical items (e.g., Blumstein, Milberg, & Shrier, 1982; Katz,. 1986; Milberg, Blumstein & Dworetzky, 1987) and to the access of words during the course of sentence comprehension (Swinney, Zurif & Nicol, 1989).

This last-mentioned claim, that Broca's aphasics show impaired lexical access during on-line sentence comprehension, is based on a study that used a cross-model lexical priming (CMLP) task to examine the processing of polysemous words in biasing sentence contexts (Swinney

et al., 1989). As has been shown repeatedly, the normal (neurologically intact) listener, upon hearing a polysemous word in a sentence, accesses all of the word's meanings, not just the single meaning relevant to the sentence. context. Only after a time delay of approximately 1 s does context exert its effect; at that delay, only the contextually relevant meaning continues to be available. The central claim from these studies is that lexical access is not an interactive process. Context has an effect only following normal, exhaustive access.

In line with this form of inquiry, the study of aphasia carried out by Swinney et al. (1989) found that fluent Wernicke's aphasics showed the normal exhaustive access pattern but that nonfluent agrammatic Broca's aphasics had a module-specific disruption to lexical access that could reasonably be implicated in their real-time comprehension problems. These subjects did not, however, appear to lose the modular properties of lexical access. They did not, that is, access only contextually relevant word meanings. Rather, their disruption seemed to preserve the fundamental modular property of cognitive architecture, but to render the internal operations of the access module itself less efficient. Specifically, only the most frequent meaning of the ambiguity was initially accessed, independently of the contextual bias.

This result arose in the context of good comprehension of the test sentences. This is to be expected since only structurally simple sentences were used-sentences of the type that nonfluent, agrammatic Broca's aphasics are known to comprehend such that, clinically, they show "relatively intact" comprehension.

To reconcile the nonfluent, agrammatic Broca's subjects' aberrant lexical access pattern with the strong likelihood that they understood each sentence, Swinney et al. (1989) speculated that the subjects were slower at-but not disbarred from-activating relevant word meanings. Specifically, they speculated that the lexical access component operates with a slower-than-normal rise time; the normal frequency ordered activation of access (Simpson & Burgess, 1985) is protracted such that it is not completed within the temporal window afforded by the CMLP paradigm, i.e., when a probe appears *immediately* after that polysemous item. In effect, Swinney et al. speculated that, although the subjects eventually retrieve the word meanings relevant for comprehension, they are, nonetheless, unable to provide the normal lexically based information to other components of the language processing divide (e.g., the syntactic parser) at the correct (necessary) temporal point in the comprehension sequence.

Examination of this speculation of "slowed rise time" requires parametric examination of priming at different delays between prime and target for control relative to aphasic subjects. Neither the sentence nor pair paradigms used to study priming in aphasics previously is well suited to parametric variations in the delay between prime and target words. Pair paradigms are more practical as a method for sampling different interword delays, but are not ideal for studying rise and fall of *automatic* priming. Presenting words as isolated pairs arguably invites looking for relations between two words that clearly are set apart together (see Prather & Swinney, 1988). As Neely (1977) demonstrated using a pair paradigm, when interword delays are short, subjects cannot anticipate relations and therefore priming effects reflect automatic processes; as delays are longer, however, subjects can look for such relations and to the extent that the paradigm allows noticing relations among words, intentional rather than automatic effects account for facilitation effects at long interword delays.

Accordingly, Prather and colleagues adapted a list priming paradigm to examine the notion of slowed rise time in Broca's aphasics (see Prather & Swinney, 1988). The list paradigm was specifically designed to minimize such strategies as intentionally looking for or anticipating relations between words. In this paradigm, subjects made continuous lexical decisions on words that were presented at varying interword delays; occasionally associatively related words were presented sequentially (e.g., *jump--lemp--frame--SPIDER--WEB--brlok--sun,* etc.). The ratio of sequentially related wbrds in the list was kept quite low (e.g., 1:12.5 in Stern, Prather, Swinney & Zurif, in press), and there was no way to anticipate when sequentially related words would appear. The goal in developing this paradigm was to have a paradigm in which, as for sentences, subjects are processing information continuously, but unlike sentences, timing parameters (interword delays) can be controlled systematically and precisely.

Using the list paradigm, Stern et al. (in press) examined lexical access at delays as short as 300 ms and as long as 1500 ms, and determined that both college-age and neurologically intact elderly subjects show a very similar pattern of automatic lexical access. Neither elderly nor college-age subjects showed priming at the 300-ms delay, both groups showed priming at the 500-ms delay, and for both groups priming had diminished to a nonsignificant effect by the 1100-ms delay (see Fig. 1). These data are interpreted, first, as evidence that lexical access is rapid and does not slow with age, and second, that the list-priming paradigm captures automatic and minimizes strategic facilitation effects. This last claim arises from the fact that the effects *diminish* at longer interword intervals, rather than increase as would be expected if subjects were using intentional strategies (see, e.g., Neely, 1977).

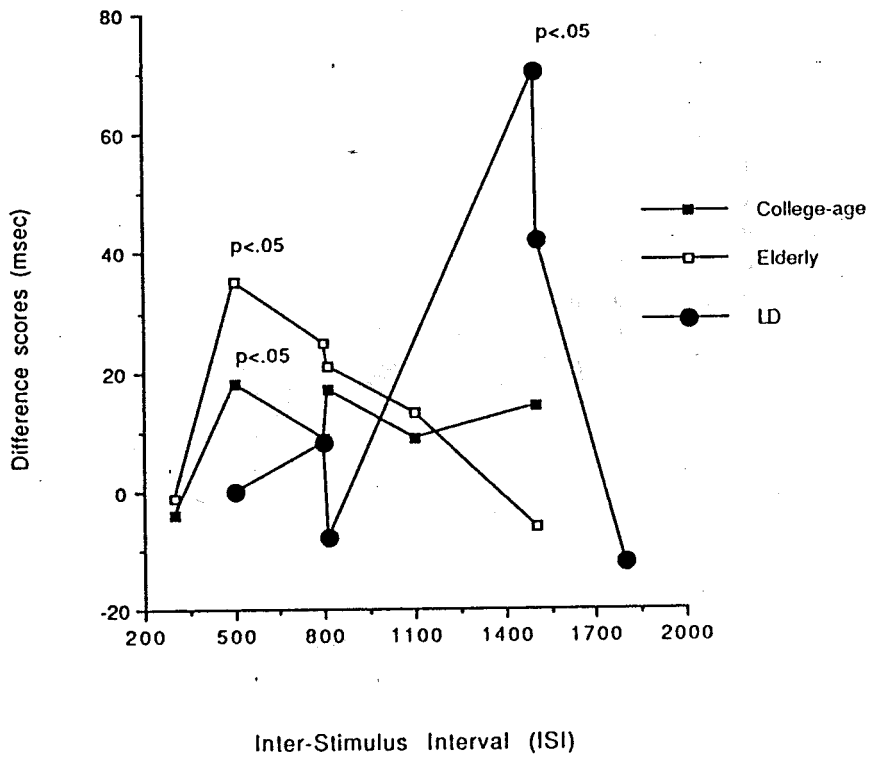

Fig. 1. Difference scores (difference between mean reaction times to control vs. related) as a function of interstimulus interval (ISI), presented separately for College-age subjects, Elderly subjects, and LD (aphasia case study). Note that priming is defined as faster reaction times for related than for control pairs; consequently, a positive difference score indicates priming.

To examine the time course of lexical access following a left anterior lesion, the procedure used by Stern et al. (in press) was adapted for use with aphasics. One case study has been completed to this point, and with results that support-the hypothesis of protracted rise time following left anterior lesion. The subject for this study was LD, a 59-year-old, right-handed male college graduate seen 10 years post onset of a left-hemisphere CVA. Neuroradiological data showed a left anterior lesion primarily in the region of Broca's area (see Prather, Zurif, Stern, & Rosen, 1991). Neuropsychological and speech and language evaluations showed nonfluent and impoverished output, with comprehension better than production, i.e., they pointed to Broca's aphasia.

The materials and procedure used to examine LD's rate of lexical access were exactly the same as those reported in Stern et al. (in press), with the exceptions that, first, rather than running 12 subjects once each, LD was seen 12 times in a completely within-subject design; second, the interstimulus interval (ISI) range examined was longer (500 to 1800 ms rather than 300 to 1500 ms).

The results obtained clearly support an inference of delayed rise time (see Fig. 1). Priming did not obtain at 500 or 800 ms, as it had for the group of normal elderly subjects. Rather, priming effects were reliable only at 1500 ms. Importantly, those effects diminished rapidly, a pattern of results consistent with an inference that automatic rather than strategic facilitation effects have been captured.

Our finding that lexical access can literally be slowed down without disrupting either intentional semantic judgments (e.g., Goodglass & Baker, 1976; Whitehouse, Caramazza, & Zurif, 1978; Zurif, Caramazza, Myerson & Galvin, 1974) or the comprehension of syntactically simple sentences raises, in turn, a number of questions. If rapid processing, one of the presumed major criteria for modularity, is disrupted, does modularity of the affected system dissipate? In particular, is encapsulation as inherent, wired-in characteristic of modules-should they be conceptualized literally as, impenetrable "boxes"-or rather is impenetrability an emergent feature of rapid processing, suggesting a conceptualization of lexical access as a variable process rather than fixed box (see also Prather & Swinney, 1988). From Swinney et al. (1988), we know that nonfluent aphasics show access to primary meanings of ambiguous words independently of context; it may be, however, that the slower access to secondary meanings *is* influenced by context. If so, that would force, a different conceptualization of modules than many at least in the neurosciences-have held. That is, although encapsulation-the momentary impenetrability of the lexical access operation to contextual considerations-is an experimental fact, it may be that it emerges only because the time parameters of contextual integration disallow immediate interaction. It so, the slowing of lexical access in Broca's aphasia may allow information penetration. Such a conceptualization does *not* seem to argue for "hard-wired" modules, but rather for hard-wiring that favors conditions necessary for the emergence of modularity. We are currently examining that hypothesis by essentially replicating the Swinney et al: (1989) cross-modal study, with the added condition of testing downstream from the ambiguous words.

The Prather et al. (unpubl. data, 1991) data also raise tile-question of the domain specificity of lesion effects. "Slowing" is not inherently

domain-specific. It may be that *all*, not just language, modules are affected by slowed processing following a left anterior lesion. To test this possibility, we are also now examining the time course of activation of visual information, specifically ambiguous figures. Preliminary work with college-age students (Hickock, Swinney, Zurif & Prather, 1991) indicates that, as with ambiguous words, both versions of ambiguous figures are elaborated immediately following the presentation of those figures. We arb currently examining whether or not similar full elaboration occurs, and at what rate, for both anterior and posterior aphasics. [5]

[5] There is one apparent exception to the abnormal lexical access pattern observed for Broca's aphasics. It has to do with the access of argument structure information that forms part of the lexical representation of verbs. Briefly, we note that neurologically intact subjects appear to access *momentarily* all of the argument structure information Within a verb's lexical entry, not just the particular argument structure inherent in the sentence being processed. This is the case even when the sentence context preceding the verb indicates the likelihood of a particular argument structure configuration. More to the present point, as with neurologically intact subjects, Broca's aphasics *also* seem to show the typical pattern of exhaustive access of all possible argument structures (Shapiro & Levine, 1990).

One possible explanation for this surprising finding is that fundamentally different processing requirements are implicated for the access of multiple noun meanings, on the one hand, and argument structure, on the other. Consider first the matter of exhaustively accessing a polysemous noun's meanings. Once acoustic/phonetic information is mapped onto the polysemous noun's form stored in the mental lexicon, it is assumed that, as measured by priming, the activation of this element is passed on to the other nodes in the network with which it is semantically and associatively related. Thus, either through a search or through spreading activation-both directed by frequency considerations-the various meanings associated-with a polysemous noun arc accessed (unconstrained by prior contextual information). This is a *time-dependent* operation.

For the exhaustive access of argument structure configurations, however, we entertain a contrasting hypothesis: These structural configurations are not accessed by searching through a network or by the spreading of activation, but rather once the acoustic/phonetic information is mapped onto a verb's entry, the argument. structure possibilities. are all *simultaneously* available. Therefore, rather than being a time-dependent function, verb complexity is associated only with the "effort" required to access indivisible chunks of various sizes. More pointedly on this view, the putative slower-than-normal rise time of lexical activation in Broca's aphasia is an irrelevant consideration in the modeling of argument structure access. Such sensitivity: as the subjects show for Predicate Argument Structure (PAS) has nothing to do with a time-based activation of linked information units as it does for referential information associated with nouns. Rather, it reflects only the capacity to process a *simultaneous* display of information.

EFFECTS OF SLOWED LEXICAL ACCESS ON SENTENCE PROCESSING IN APHASIA: SOME SPECULATIONS

In the preceding section, we raised the possibility that the comprehension deficit after left anterior brain damage, but not after left posterior damage, can be traced to a slowing in the access of lexical information and to a corresponding failure to provide information at the right time in the processing chain of comprehension. We now raise some more detailed suggestions concerning this possibility.

One development of relevance here is Grodzinsky's (1986) descriptive tive generalization that Broca's aphasics have difficulty understanding any sentence in which a transformation has been applied to move a phrasal constituent from a nonagentive position. Rooted in government-binding theory (e.g., Chomsky, 1981), Grodzinsky's argument is that aphasic subjects cannot represent traces and therefore cannot use grammatical rules to assign thematic roles to moved constituents (Grodzinsky, 1986; see also Schwartz, Linebarger, Saffran & Pate, 1987). Faced.with a thematically unassigned NP (as with the first Noun Phrase (NP) encountered in a passive), the nonfluent aphasic applies an "agent-first" strategy, i.e., a nongrammatical strategy, based on the likelihood that, in English, the clause-initial position is usually filled by an agent role (Bever, 1970). When a constituent is moved from the subject position, this strategy works; when the movement is from the object position, however, the strategy yields two NPs for the same sentence. One is assigned by the normal grammatically based procedure in which assignment is given in terms of the sentence's overall hierarchical configuration; the other, as mentioned, is incorrectly assigned by a nongrammatical strategy sensitive only to linear (nonhierarchical) positions. Faced with two agents, the nonfluent aphasic is forced into a guessing situation that leads to random performance.

The requirempent of linking antecedents and traces seems to us to be an operation that is implemented under strict time constraints, stricter than those involved in integrating and representing the gist of an utterance. In real-time terms, the limitation that Grodzinsky (1986, 1990) argues for can be viewed as an inability to reactivate the lexical semantic information of the moved noun or noun phrase at the normal time in the processing sequence-in time, that is, to fill the gap left by the moved constituent and indexed by the "trace." This possibility follows directly from the argument that Broca's aphasics have a slow rise time in lexical access. In this view, the cortical area implicated in Broca's aphasia is not necessarily the locus of syntactic representations, but rather is cru-

cially involved in sustaining fast-acting access systems that are, in turn, involved in building such representations in real time.

We are currently addressing this possibility in Broca's aphasics by exploring the temporal characteristics of the gap-filling operation (the reactivation of antecedent lexical information) in sentence parsing. Specifically, using the CMLP paradigm, we are studying gap filling-in subject- and object-relative constructions (see Nicol & Swinney, 1989, for details of the types of experimental manipulations involved). Assuming, as Prather et al.'s (1991) initial research has suggested, that nonfluent aphasics with anterior lesions are unable to access lexical information within a normal time frame, then they should also be slower to reactivate lexical information at trace positions. Consequently, during real-time sentence processing, they should fail to satisfy very specific syntactic constraints. In short, a slower-than-normal reactivation process should yield the problems specified in Grodzinsky's (1986, 1990) theory, the failure to coindex traces with their antecedents at the necessary structural location.

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