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Comprehension in Aphasia: A Cross-Linguistic Study

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Broca's aphasics and normal controls were tested to determine relative sparing and impairment of word order, grammatical morphology, and semantic information in a sentence interpretation task. Patients were native speakers of English, German, or Italian, languages that vary drastically in the "cue validity" or information value of these three sources of information. Word order was selectively spared while grammatical morphology was selectively impaired in all three languages. Nevertheless, language-specific patterns of sentence interpretation remained in Broca's aphasics, even within the impaired morphological component, supporting an interpretation in terms of "accessing" rather than a "loss." Testing with Wernicke's aphasics, anomics, and some additional age-matched controls suggested that the selective vulnerability of morphology is not specific to agrammatic patients, at least in this paradigm. © 1987 Academic Press, Inc.

Until recently, many investigators were convinced that grammatical abilities could be selectively impaired as a result of focal brain damage, across all performance modalities. This "agrammatic" syndrome was believed to occur primarily in nonfluent aphasias, with damage to a specific region in the anterior portion of the left hemisphere called Broca's

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area. Indeed, the terms "Broca's aphasia" and "agrammatism" have often been treated as synonyms (cf. Caramazza & Zurif, 1976; Caramazza & Berndt, 1978; Caplan, 1981; Zurif, 1980)

More recently, the concept of agrammatism has come under considerable fire (e.g., Badecker & Caramazza, 1985; Goodglass & Menn, 1985). Several reformulations of the syndrome have been offered in the process (e.g., papers in Kean, 1985), but these theories have remarkably little in common. Grammatical impairments have been attributed to phonological factors (Kean, 1977), semantic factors (Goodglass & Menn, 1985), memory constraints of several kinds (e.g., Ostrin & Schwartz, 1985), specific aspects of lexical access (Stemberger, 1984), components of on-line sentence processing (Tyler, 1985), dissociations between automatic and controlled aspects of lexical and/or grammatical processing (Friederici, 1982; Grodzinsky, Swinney, & Zurif, 1985; Blumstein, Milberg & Dworetsky, 1984), differential adaptations to disruptions in the timing of language processing (Kolk & van Grunsven, 1985), and a variety of disparate disconnections within the grammar that make sense only within some relatively recent version of government and binding theory (e.g., Rizzi, 1985; Grodzinsky, 1985, 1986; Lapointe, 1985). All these proposals could be at least partially right. The point is that aphasiologists seem to be further from a consensus than at any other point in modern history.

Some investigators have reacted to the fall of agrammatism by decrying any assignment of patients to syndromes, calling for a return to single case studies with no presuppositions about the relationship that one patient might bear to another (Caramazza, 1986). In the midst of this conflict, we would like to suggest instead that inquiries into grammatical impairment in aphasia be broadened further than ever before—across patients with different diagnoses, and across patients from language groups that differ markedly in their basic structure. By considering the full range of variation that is possible in language breakdown, we stand a better chance of characterizing the underlying mechanisms that are dissociated as a result of focal brain damage. This is one way of addressing an issue that is fundamental in any area of biology: the question of plasticity. How many forms can the language processor take under a range of normal and abnormal conditions?

As one part of this comparative enterprise, we have carried out a study of sentence comprehension by aphasic patients from three different languages: English, Italian, and German. These are all Indo-European languages, with a basic or pragmatically neutral Subject–Verb–Object order; but they vary markedly in the richness of their morphological systems, and in the extent to which basic word order can be varied for pragmatic purposes. Our prior research with normal adults suggests that there are dramatic differences among these three languages in the way that listeners "monitor" the input for cues to sentence meaning (MacWhinney, Bates,

& Kliegl, 1984). These differences may be reflected in the pattern of breakdown observed in aphasic patients, if these patients are still influenced by the structural and statistical properties of their native language.

One goal of this study is to provide a strong cross-linguistic test of *the closed class theory of agrammatism* (Bradley, Garrett, & Zurif, 1980; Zurif & Grodzinsky, 1983; Bates, Hamby, & Zurif, 1983; Friederici & Schoenle, 1980; Kean, 1979). This refers to the claim that Broca's aphasia involves a central grammatical deficit, demonstrated in both receptive and expressive processing, with its primary effects on the retrieval and/or interpretation of closed class elements, i.e., free-standing grammatical function words and bound grammatical morphemes. The closed class hypothesis deserves further testing, because of its powerful implications for theories of normal and abnormal language processing. If we can show that grammatical impairments are limited to closed class elements, then we will have markedly reduced the range of alternative explanations for language disorders in aphasia. If patients lose the ability to make use of closed class vocabulary, while retaining their ability to use information about how vocabulary items are ordered in their language, then agrammatism—like anomia—could be viewed as a disorder of *lexical access*. We would still have to explain how different aspects of the lexicon can be dissociated from one another (e.g., content words versus function words, and perhaps nouns vs. verbs). But we could at least begin by working with an array of existing theories of how individual lexical items are recognized and retrieved (Morton, 1970; Marslen-Wilson & Tyler, 1980; McClelland & Rumelhart, 1981; Seidenberg & Tanenhaus, 1986; Swinney, 1979).

We show—we hope conclusively—that the closed class theory does have cross-linguistic validity, although the effect of brain damage on grammatical morphology may differ across task domains. Why is this important? A large number of studies have shown that grammatical morphology is "vulnerable" in both receptive and expressive processing by English-speaking Broca's aphasics. By contrast, word order seems to be relatively resistant to impairment (e.g., Goodglass 1968; Nespoulous et al., 1984; Bates, Friederici, Wulfeck, & Juarez, in press). However, because the English language stresses word order principles at the expense of grammatical morphology, these findings for aphasia might reflect nothing more than a break in the "weak link in the chain." We show that morphology breaks down in sentence interpretation by aphasic patients, while sensitivity to canonical word order information is maintained—even in languages where morphology provides the primary cues to sentence interpretation. This suggests that the "special vulnerability of morphology" is a fact about language breakdown, and not just a fact about English.

We then go on to another strong test of the closed class theory: a comparison across patient groups, in languages where morphological cues

are crucial for sentence comprehension. We show that grammatical morphology is selectively vulnerable in receptive language processing, not only in Broca's aphasics but also in Wernicke's aphasia, simple anomia, and in control populations who are experiencing some kind of serious stress. We conclude that morphological breakdowns occur for different reasons in receptive and expressive language processing.

Before we proceed, we will first consider some reasons why the concept of agrammatism (including the closed class hypothesis) has come under fire in recent years. This section necessarily includes a defense of our decision to perform group studies in the first place, and to test patients from a variety of diagnostic categories.

Then we will summarize some differences among the English, Italian, and German that are particularly relevant to the present study. These are discussed with reference to *the competition model,* a model developed to account for both quantitative and qualitative differences in grammatical processing across structurally distinct language types. We are forced to engage in some defensive arguments here as well, to explain why we have chosen this performance model over the formal linguistic framework preferred by many of our colleagues in the field of aphasiology.

THE CASE AGAINST AGRAMMATISM

The original arguments in favor of a central agrammatic deficit rested on certain parallels between the expressive and receptive language skills of nonfluent Broca's aphasics. (Zurif & Caramazza, 1976; Heilman & Scholes, 1976; von Stockert & Bader, 1976; Caramazza & Berndt, 1978). At a clinical level, comprehension seems to be relatively intact in these patients. This fact led earlier investigators to view Broca's aphasia as a motor deficit, i.e., "motor aphasia" (see Lesser, 1978, for a review). This interpretation made good neuroanatomical sense, in view of the fact that Broca's area lies next to the motor strip. However, a host of studies in the 1970s suggested that nonfluent patients have difficulty interpreting sentences if they are required to rely entirely on morphosyntactic cues—precisely the same elements that are missing or impaired in their expressive language. A few studies also suggested that this "central" grammatical problem may involve word order as well as grammatical function words (Saffran, Schwartz, & Marin, 1980; Schwartz, Saffran, & Marin, 1980; Tissot, Mounon, & Lhermitte, 1973). From this point of view, Broca's aphasia could be interpreted as a selective impairment at every level of the grammar.

The idea that grammar constitutes a "mental organ," with a separate neural architecture, is quite compatible with claims from linguistics and psycholinguistics concerning the modularity of species-specific systems—in particular, the modular structure of language (Fodor, 1983). However,

despite high hopes, recent studies have failed to support the belief that grammar can be selectively isolated in toto from the rest of cognition.

First, many investigators have questioned the idea that agrammatism involves an "across-the-board" impairment of word order and morphology. Several studies have shown that word order is reasonably well preserved in both fluent and nonfluent aphasia (Goodglass, 1968; Ansell & Flowers, 1982; Bates et al., 1983, in press; Kolk & van Grunsven, 1985; Menn & Obler, 1985, in press). The principles for ordering closed or open class elements in simple phrase and sentence frames may be compromised in some patients (e.g., the patients studied by Saffran et al.—but see discussions by Caplan, 1983, Kolk & van Grunsven, 1985, Bates et al., in press). These exceptions do need to be accounted for in any complete theory of grammatical impairment in aphasia. Nevertheless, if there is such a thing as a central grammatical deficit, it does at least seem to have a selectively *greater* effect on inflections and grammatical function words (i.e., the "closed class").

This kind of result has led several investigators to propose some version of the *closed class theory of agrammatism* (Bradley et al., 1980; Friederici & Schoenle, 1980; Friederici, 1986; Grodzinsky, 1982; Kean, 1979; Zurif & Grodzinsky, 1983). There are now several versions of the closed class hypothesis. For example, Zurif and Grodzinksky explain the impairment of closed class elements in *grammatical* terms, based on a dissociation between "positional frames" (which are presumably not lost, if word order is as well preserved as some researchers claim), and a special vocabulary of morphological elements that are used to fill slots in those frames (cf. Friederici, 1985). By contrast, Kean offers a *phonological explanation,* based on the status of inflections and function words as "clitics," i.e., one- or at most two-syllable elements that cannot receive stress under normal conditions. Goodglass and Menn (1985) have suggested instead that closed class morphemes are difficult for aphasic patients because they have little or no *semantic content.* All of these explanations are plausible—and indeed may all contribute to the tendency for Broca's aphasics to omit closed class elements in their speech, and to fail on receptive processing tasks that revolve around the same morphemes. The main point seems to be that the breakdown of language in Broca's aphasia revolves primarily around grammatical morphology, and not around grammar as a whole.

A different set of criticisms have been leveled against the centrality of grammatical deficits—whether or not they are restricted to the closed class. As stated succinctly by Caramazza, Berndt, Basili, and Koller (1981, p. 348),

> Although it is possible that Broca patients may suffer from deficits in addition to this syntactic processing deficit, it should be the case that all patients classified

as Broca's aphasics will produce evidence of a syntactic impairment in all language modalities.

But there is counterevidence for this prediction as well. There are several case studies of patients who show agrammatic symptoms in production, but not in comprehension (Naeser, Haas, Auerbach, Helm-Estabrooks, & Levine, 1984; Miceli, Mazzucchi, Menn, & Goodglass, 1983; Kolk, van Grunsven, & Guper, 1982). There are even more reports of patients who show agrammatic symptoms in comprehension despite fluent production (Caramazza, Basili, Koller, & Berndt, 1981; Caplan, 1985; Smith & Bates, 1987; Bates, Friederici, & Wulfeck, in press).

For example, Caramazza et al. (1981) have shown that *both* conduction aphasia and Broca's aphasia can lead to receptive agrammatism. Some related findings are offered by Smith and his colleagues, using the same paradigm adopted in the present study. Smith and Mimica (1984) had reported that Serbo-Croatian Broca's aphasics are particularly impaired in their ability to use case inflections on nouns as a guide to sentence meaning. By contrast, their ability to use word order and/or semantic information was at or near normal levels. Smith and Bates (1987) extended the paradigm to include fluent anomics. These patients did not make morphological errors in their expressive language, and they performed in the normal range on standardized tests of language comprehension. On our own comprehension test, their use of word order and lexical/semantic information was unimpaired. Nevertheless, the anomic patients performed significantly worse than age-matched normal controls on one aspect of sentence comprehension: the use of case and gender morphology as cues to sentence meaning. This finding suggests that morphology may be a particularly vulnerable aspect of sentence processing, for fluent and nonfluent patients alike.

Finally, patients who are agrammatic in both comprehension and production have proven to retain a surprising degree of sensitivity to violations of grammaticality (Linebarger, Schwartz, & Saffran, 1983; Wulfeck, in press; Crain, Shankweiler, & Tuller, 1984). In view of findings like these, Badecker and Caramazza (1985) have recently suggested that "agrammatism is not a natural kind", i.e., there is no such thing as a unitary syndrome of grammatical impairment.

These are very serious criticisms, enough to suggest that patients should not be grouped together under the assumption that they all share the "same" grammatical deficit. But we do not believe that the failure of agrammatism (at least in its simplest form) leads inevitably to the conclusion that group studies are wrongheaded from the start (cf. Caramazza, 1986). Neurologists and speech pathologists have worked for well over a century with the useful distinction between fluent and nonfluent aphasia. This contrast is real, and occurs in every language studied to

date. Furthermore, both syndromes seem to be associated with grammatical impairments of some kind, although the nature and source of these impairments are now in question. To ignore this radical contrast between patient groups simply because the unifying concept of agrammatism has failed seems to constitute a case of throwing the baby out with the bathwater.

This strikes us as an excellent time in the history of aphasia research to "go back to the drawing board," examining the full range of grammatical impairments that can occur across natural languages and across patients with different aphasic symptoms. Single case studies are a valuable tool in such research. But group studies are also indispensable, if we want to understand (1) the range of individual patterns that are possible within and across languages, and (2) the relative probability of particular symptom patterns and their possible etiology.

In this paper, we compare and contrast patterns of sentence comprehension in Broca's aphasia in three different languages, under controlled conditions. In the two richly inflected languages, we also look at receptive processing in Wernicke's aphasia and in several other control populations. As outlined in more detail below, we define key patient groups in neurobehavioral terms that are familiar to neurologists and speech pathologists in many language communities. The definitions look similar in the abstract, although they will, of course, be realized in different ways from one language to another.

1. *Broca's aphasia* is defined by nonfluent and dysprosodic speech, with reduced utterance length and sentence complexity, together with more omission of function words and/or grammatical inflections than we would expect in a normal speaker of that language. Patients should demonstrate relatively normal comprehension, at the level of clinical interviews and reports from the family about the patient's functioning in everyday life.

2. *Wernicke's aphasia* is defined by fluent or even hyperfluent speech, with superficially normal melodic line, in patients who nevertheless demonstrate moderate to severe problems in the comprehension of everyday language. These patients also demonstrate problems in word finding, accompanied by frequent or occasional paraphasias.

These definitions are quite uncontroversial in clinical practice, in all of the communities that participate in our cross-linguistic project. Our strategy has been to apply conservative definitions independently within each language community, and then compare the patterns that emerge when we take a cross-linguistic view. In other words, we treat language differences as an empirical question; they do not go into our definition of the patient populations.

TABLE 1
LANGUAGE DIFFERENCES

	English	Italian	German
Singular			
1st pers (I)	buy	compro	kaufe
2nd pers (you)	buy	compri	kaufst
2nd pers formal	—	compra	kaufen
3rd pers (he/she/it)	buys	compra	kauft
Plural			
1st pers (we)	buy	compriamo	kaufen
2nd pers (you)	buy	comprate	kauft
2nd pers formal	—	comprano	—
3rd pers (they)	buy	comprano	kaufen

LANGUAGE DIFFERENCES AND THE COMPETITION MODEL

English is quite unusual among the world's languages for its heavy reliance on word order principles, in particular a rigid preservation of the order Subject–Verb–Object (SVO) in most sentence types. This contrasts with a weak system of grammatical morphology that provides very little information about sentence meaning. For example, unlike Latin or German (which are closely related to English), there are no case inflections on the noun phrase to tell the listener "who did what to whom" (except for some remnants of case in the pronoun system, e.g., *we* versus *us*). We also have a very weak system of verb morphology. Table 1 illustrates some contrasts among English, Italian, and German in the degree to which information about the subject of the sentence is incorporated into the verb (from MacWhinney et al., 1984). Except for a few contrasts like the third person singular *s*, English subject–verb agreement is usually ambiguous and hence not a particularly useful cue to sentence meaning. By contrast, the Italian verb system is very richly marked, and usually provides enough information to assign sentence roles with complete disregard for word order. The German verb system is somewhat more ambiguous, but still provides considerably more information than the corresponding cues in English.

Through some combination of noun and verb morphology, most of the world's languages can convey enough information about sentence meaning to permit variations in word order for other purposes, i.e., to topicalize or focus on different pieces of information. In the service of this kind of pragmatic function, Italian permits all possible orderings of Subject, Verb, and Object, albeit with a slight bias toward the pragmatically neutral SVO. The German system of word order variation is slightly more constrained. The most neutral word order is SVO, but SOV and

VS are very common, and other constructions are possible. As a result, Italian and German listeners cannot rely on word order alone as a cue to sentence meaning. In fact, the "habit" of word order variation has apparently induced speakers to use noncanonical orders even when morphology is ambiguous. Italians do say things like "The lasagna ate Giovanni," forcing their listeners to rely on some combination of semantic-pragmatic-situational cues instead of word order.

Our basic point is this: given such differences in the way that languages distribute syntactic, morphological, and semantic information, the language processor must be "tuned" to use the best available cues to sentence meaning. The *competition model* is a general theory of grammatical processing developed by Bates and MacWhinney to account for both qualitative and quantitative differences in sentence processing across natural languages (Bates & MacWhinney, 1982; MacWhinney et al., 1984; MacWhinney, Pleh, & Bates, 1985; Bates & MacWhinney, 1987; MacWhinney & Bates, in press). The concept of *cue validity* plays a major role in this model, referring to the information value of a given grammatical, phonological, or lexical cue to sentence meaning. In a language like English, word order is a highly informative or valid cue to thematic roles, helping the listener to figure out "who did what to whom." In languages like Italian or German, word order is relatively low in cue validity, while morphological and/or lexical semantic cues are high. In a series of cross-linguistic studies with normal children and adults, MacWhinney and Bates have shown that cue validity has dramatic effects on the way that adults behave in sentence processing studies, and on the order in which these aspects of grammar are acquired by children. In languages that are oriented toward word order, canonical sentence orders are learned very early and play a major role in sentence interpretation throughout life. In languages that are oriented toward morphology, grammatical morphemes are acquired much earlier by children and emphasized much more heavily in adult sentence comprehension.

The competition model captures such qualitative and quantitative differences among languages through a set of probabilistic "weightings" in the connections between form and meaning. These correlational relations comprise a significant part of what we "know" about grammatical structure, but from the point of view of performance (i.e., knowledge about what to do) rather than competence (i.e., knowledge of abstract relations).

Many formal linguistic theories have also focused on structural differences across natural languages. Why invoke a psycholinguistic performance model, when much more detailed formal alternatives are available? The reason is that formal models do not offer enough information about variations in performance. In particular, most linguistic theories treat rules as discrete and categorical; a rule is either present in the language,

or it is not. This makes it difficult to account for results that fall somewhere in between (Kolk & van Grunsven, 1985).

This is especially clear in some recent claims by Grodzinsky (1985, 1986) concerning predicted patterns of grammatical deficit in aphasia. In particular, Grodzinsky argues that Broca's aphasics should show either random performance, or near-normal performance, on several distinct structures—depending on their hypothesized access or lack of access to separate grammatical rules and constraints. There are no principles in his model to account for performance that is considerably worse than normal, but considerably better than chance (e.g., 75–80% correct). Such results are ascribed to unspecified performance factors and/or nonlinguistic strategies.

The competition model makes very different predictions. The difference between rules and probabilistic tendencies is viewed as a matter of degree. The "same" rule may have very different strengths from one language to another (e.g., the relative "strength" of SVO word order in English, compared with the relative "strength" of subject–verb agreement in Italian). In our studies of normal listeners, application of rules or structural constraints is a clear reflection of the statistical hierarchies predicted by the model—particularly in receptive language processing. For example, given a simple string like "The horse kicks the cow," English listeners apply an SVO strategy in almost every instance; Italian listeners seem to place less "trust" in SVO interpretations, choosing an OVS interpretation around 15% of the time (Bates, McNew, MacWhinney, Devescovi, & Smith, 1982).

The statistical characterization that we have given to adult performance has important implications for both first- and second-language acquisition, offering us a principled way to account for the various "in between" stages in development. One can think of these outcomes in terms of *competitions* among form-function mappings (or rules, if one prefers that term) that vary in their relative strength—where strength is in turn based on relative frequency, informativeness, and processing costs (see especially Bates & MacWhinney, 1987; MacWhinney et al., 1985). This property of the model also permits us to make explicit predictions about aspects of a given language that are "protected" or "at risk" in brain damaged patients.

Such predictions about performance cannot be made on the basis of categorial theories of linguistic competence. In order for formal models like government and binding theory to account for our findings, a separate performance component has to be invoked. Grodzinsky (1985) acknowledges this point, and stresses the importance of studying aphasia on two fronts: "The aphasic deficit should be studied from both the structural and the processing points of view independently, without ruling out the possibility of reducing one account to another at some future point."

He also admits that proposals based on modern linguistic theory have not yet developed a principled account of performance facts: "An independent processing account, that could be compatible with the present proposal, is not available. Nevertheless, the fact that the present account is formulated in a fashion that does not *preclude* this connection is already promising." Insofar as no principled model of performance has been offered to date to complement extant competence theories, we choose instead to ground our studies of aphasia in a detailed psycholinguistic theory of sentence processing, supported by more than 12 years of cross-linguistic research on normals, in 14 different natural languages (MacWhinney & Bates, in press). We have argued elsewhere that this particular performance model has more in common with competence theories that emphasis the role of the lexicon as a repository for grammatical knowledge (e.g., lexical-functional grammar—see MacWhinney, 1987, for a discussion). These models are more compatible with our claims about the inherent similarities of lexical and grammatical processing, compared with theories that handle lexical, morphological, and syntactic facts in separate modules. Nevertheless, we agree with Grodzinsky that performance and competence issues can be pursued independently, at least for a time.

Note, however, that the competition model leads to predictions for aphasia that conflict directly with performance claims based on the closed class theory of agrammatism. In English, we would expect aphasic patients of any diagnostic category to rely primarily on word order. Morphology should be selectively impaired in aphasia, simply because morphological elements are low in cue validity. Weak elements should be the first to break down when the language processing system is under stress—any form of stress. However, in languages like Italian and German we would expect the opposite to occur: because word order is a weak cue to meaning while morphology is relatively strong, word order cues should be the first elements lost when the processing system is damaged. Hence we are proposing a direct comparison of the competition model (which predicts performance based on statistical differences among languages) and the closed class theory of agrammatism (which predicts performance based on selective damage to morphology regardless of the patient's premorbid language). As we shall see, the results require changes in both theories.

We test sentence comprehension with an enactment procedure that has been used successfully across languages with normal adults and children, and with aphasic patients (Smith & Mimica, 1984; Smith & Bates, 1987). Subjects are asked to act out a series of simple sentences consisting of two concrete nouns and a transitive action verb. These sentences represent orthogonal combinations of lexical, syntactic and

morphological cues to meaning. The items are structured to test three principles of the competition model (Bates & MacWhinney, 1982).

1. *Competition* occurs when two cues lead to opposite interpretations, e.g., the competition between word order and semantic plausibility in a sentence like "The rock is kicking the horse." In these cases, the competition model predicts that the strongest cue (i.e., the one with highest cue validity) will win the competition. However, the size of the victory will be probabilistic in nature, varying in size from one language to another.

2. *Convergence* refers to items in which two or more cues point to the same interpretation, as in the convergence of word order, semantics, and morphology in "The horse is kicking the rocks." As convergence increases, performance should move closer to 100%, depending on the relative strength of the cues involved for a particular language.

3. *Conspiracy* refers to a situation in which two or more weak cues compete together against a strong or dominant cue. An example in English would be the semigrammatical sentence "The rock are kicking the horses," where the weak cues of lexical semantics and subject–verb agreement "gang up" against the dominant cue of SVO word order. On these items the dominant cue usually "wins," but the margin of victory may be very small.

By pitting cues against one another in this fashion, we are able to assess the strength of semantic, syntactic, and morphological sources of information in aphasic patients, relative to normal speakers of each language. This permits us to determine not only *whether* a given component of sentence processing is damaged, but the *degree* of impairment that occurs in each one. Despite its advantages, this method does present some special problems that need to be addressed. We have separated and orthogonalized sources of linguistic information (word order, agreement, and animacy) in order to assess their relative contributions to sentence processing in aphasia. This is the only way to completely unconfound factors that are correlated in normal discourse. In the process, however, we also create a number of bizarre or semigrammatical linguistic stimuli (e.g., the horse are hitting the lambs).

The situation is in some ways analogous to the study of Gestalt organizational principles in visual perception. Under normal circumstances, all the Gestalt principles converge to determine the way that we parse objects against a spatiotemporal background. Researchers in the field of vision have frequently made use of perceptual illusions and various "impossible" events in order to separate the effects of different perceptual principles. They hope that their discoveries are relevant to normal processing, but this assumption can only be defended indirectly, to the extent

that the "odd" laboratory experiments yield coherent findings and enable the theorist to explain and predict behavior in normal circumstances.

The sentence comprehension technique described below has now been used in many different languages, with normal adults and children, monolinguals and bilinguals (for reviews, see Bates & MacWhinney, 1987; MacWhinney & Bates, in press). In every case, results are consistent with known facts about the structure of the respective target languages under more normal circumstances. This proves, at the very least, that subjects make use of strategies in this experiment that draw on detailed structural information about their native language. But we have worried about the possibility that the mere *presence* of ungrammatical stimuli, mixed together with grammatical sentences, could trigger the application of strategies that are entirely unrelated to normal processing (i.e., the same problem that worried critics of Gestalt psychology in their reliance on visual illusions). There are several experiments that mitigate this concern, although one can never make it disappear completely.

In our earlier work we investigated the problem of "unnatural" strategies by varying stimulus presentation in different blocked designs and by varying instructions to subjects (Bates et al., 1982). Results were very similar across manipulations, suggesting that the strategies adopted by adult listeners are quite robust and relatively impervious to task demands.

Another kind of answer comes from the cumulative result of studies across many languages. For examples, in languages like Serbo-Croatian or German, morphologically ambiguous and unambiguous sentences are both grammatical and ecologically valid (depending on certain combinations of case and gender). By contrast, in languages like Hungarian, sentences without a morphological contrast are almost always ungrammatical. Hence, we can compare the results of competition/convergence experiments in languages with grammatical stimuli only, versus languages with a mixture of acceptable and unacceptable forms. Simply stated, our comparisons to date suggest that there are no qualitative differences in reaction times, or in the behavior patterns that subjects show to competition and convergence items, as a function of the relative mix of grammatical and ungrammatical forms.

This was made particularly clear in a recent study of Hungarian reported by MacWhinney, et al., 1985. Experiment 1 presented all possible combinations of word order (NVN, NNV, VNN), presence/absence of case, and presence/absence of an animacy contrast, using concrete nouns and transitive action verbs (e.g., The horse kicks the cow). In this design, one-third of the items were ungrammatical (i.e., the items without a case contrast). Experiment 2 exploited a particular corner of Hungarian where case can be ambiguous, i.e., possessive nominals (e.g., Yours kicked mine; mine kicked yours). The design was identical to Experiment 1, except that none of the stimuli was ungrammatical. Results of the two

experiments were identical in every relevant respect, suggesting that the presence or absence of ungrammatical stimuli does not result in any detectable change in the strategies that listeners use to interpret simple sentences. In both kinds of situations, subjects apparently respond to stimuli by implicitly adding up good sources of information, weighing strong versus weak sources in a competition, and treating "very good" versus "less good" forms according to their relative similarity to prototypic sentences in the language.

In the present study, we are varying orthogonal combinations of word order, subject–verb agreement, and animacy. In English, many of these stimuli are odd or completely ungrammatical (e.g., The horse are kicking the lambs; the cat the pencil is pushing). In German, all the resulting stimuli are grammatical in the strict sense, although some are certainly odd or unlikely. In Italian, all the stimuli are grammatical as well (at least in formal speech), but many are unlikely to occur in isolated sentences—a situation similar to multitudinous studies of English in which listeners are presented with passives or clefts outside of their usual discourse context. In this respect, the German and Italian components of the present study are more similar to Smith's studies of sentence comprehension in Serbo-Croatian aphasics (Smith & Mimica, 1984; Smith & Bates, 1987). But with the inclusion of English, we do have a different mix of "good" and "not so good" stimuli across language groups. We know that many aphasic patients can detect grammatical anomalies (e.g., Linebarger et al., 1983), so we must assume that they can also detect the mix of good and bad sentences in our experimental paradigm. If the patients behave in ways that are drastically different from normals, it is possible that their failure is triggered by the presence of anomalous stimuli—particularly in English. However, if the patients use strategies that appear to be at least superficially like those of normals in their language, it seems fair to conclude that they approach the problem in a similar way—that is, that they interpret converging and competing configurations of linguistic information in accordance with knowledge of the basic structure of their native language. In this respect, the situation is similar to any laboratory study of brain-damaged patients: if the data are interpretable and orderly, we will feel free to generalize from the laboratory situation to real life as it is experienced by these patients.

METHOD

Subjects

Subject selection criteria are always an important aspect of aphasia research, but they are particularly important in a comparative study across patient groups and languages. Suppose, for example, we find a difference between English and Italian Broca's aphasics in the degree to which canonical SVO word order is used in sentence interpretation. We

TABLE 2
SUBJECT DATA

	Comprehension					
	Italian		German		English	
	N	Age range	*N*	Age range	*N*	Age range
Broca's	10	22–77	7	31–59	8	49–66
Wernicke's	9	30–73	6	44–74	—	—
Young controls	10	18–24	10	18–35	12	20–24
Older nonneurological controls	10	40–60		—		—
Older neurological controls	8	32–59	—	—	—	—
Anomics	10	36–44	—	—	—	—

would like to conlude that this difference follows from probabilistic differences in the strength of word order cues in the two languages. But it might also be an artifact of different patient selection criteria at the two respective research sites. Given this problem, we need to explain our approach to subject selection in some detail.

Our goal in this project was to select 5–10 Broca's aphasics in each of the three language groups, compared with 10 normal controls. We also extended the comparison to two categories of fluent aphasia: Wernicke's aphasia (only at the Italian and German sites) and simple anomia without marked comprehension problems (in Italian only). Finally, some additional control groups were added in Italian and German to clarify issues that arose in the first part of the study.

Patients were referred to us for testing by neurologists and speech pathologists at the three respective research sites, with diagnoses of Broca's aphasia, Wernicke's aphasia, or anomia. In support of each diagnosis, we were provided with a summary of the neurological record (including CT scans in many cases), together with the results of standard aphasia batteries that ued, at the respective research sites, the Boston Diagnostic Aphasia Examination in the United States (Goodglass & Kaplan, 1983), the Aachen Aphasia Battery in Berlin (Huber, Poeck, Weniger, & Willmes, 1983), and an Italian version of the Boston exam that is used in Rome. To eliminate the possibility that the patient had changed status since the diagnosis provided at referral, patients were all screened in a biographical interview administered prior to testing. In addition, we elminated all patients with one or more of the following conditions:

1. History of multiple strokes
2. Significant hearing and/or visual disabilities
3. Severe gross motor disabilities
4. Severe motor-speech involvement such that less than 50% of subject's speech attempts were intelligible.
5. Evidence that subject was neurologically or physically unstable and/or less than 3 months post onset).

Table 2 summarizes the final sample of patients and controls in each of the three languages.

How do we know that patients are matched for severity within our comparison groups? The problem of matching across patient groups is an old one in the field: if our instructions are at all complex, then we may end up comparing severe Broca's aphasics (who are nevertheless good at following instructions) with mild Wernicke's aphasics (i.e., the only Wernicke's patients with enough comprehension ability to participate in the experiment).

Fortunately, the enactment procedure used in the present study is relatively simple and straightforward, requiring only a minimum of verbal instructions. It has been used successfully with children as young as 2 years of age, and did not present serious problems to any of the patients who met our other criteria for inclusion. This does *not* mean that we were successful at matching aphasics across categories. It simply means that our procedures were not systematically biased against any of the patient groups—and perhaps less biased than studies of comprehension that require the patient to interpet and compare two or three complex line drawings (e.g., fewer inferences to be drawn and less likelihood that patients with visual field cuts and/or attentional deficits will experience problems in stimulus interpretation).

A second problem dervies from the fact that patients were selected and screened at different research sites, in different countries—where there are invariably different diagnostic procedures and philosophies of patient treatment. Given this situation, one might be tempted to match in a straightforward fashion on the basis of site and extent of lesion. There are several problems with this approach. First, the technical facilities are markedly different from one site to another, making comparisons of radiological findings somewhat precarious. Second, insofar as the focus of our experiment is on linguistic behavior, it is not entirely clear what a match on the basis of lesion would actually achieve. It has been established that degree of behavioral disruption is correlated with size of lesion in posterior aphasias; but correlations between size of lesion and size of deficit are surprisingly small in anterior aphasias (Naeser et al., 1984; see also Damasio, 1981). For these reasons, we decided that a selection based on conservative behavioral criteria would be more appropriate at this time, using neurological evidence to rule out complications that would make the behavioral data difficult to interpret.

The most serious problem in patient matching derives from the very same cross-linguistic contrasts that are the focus of our research. Languages vary drastically in their baseline levels of morphological complexity (and syntactic complexity as well—see MacWhinney & Bates, 1978). So exactly how to we equate patients for severity of impairment when they are coming from different linguistic baselines? This is analogous to a matching problem faced in cross-linguistic research on child language acquisition. Most projects (e.g., the Berkeley project under the direction of Dan Slobin) resort to matching subjects by age rather than linguistic level, because there is no sensible way to equate children across languages for mean length of utterance (MLU). For example, the sentence "Wolves eat sheep" would receive a total morpheme count of four (using Brown's criteria for calculating MLU (Brown, 1973)). The Italian equivalent, "I lupi mangiano le pecore" could receive either a 10 or 12 morpheme count, depending on whether one decides to credit each contrast between unmarked masculine and marked feminine genders as an additional morpheme (see Bates, 1976, for a further discussion of this problem). Using English MLU criteria, Italian children of the same age generally look two to three times as advanced as their American counterparts. If we were to match English and Italian children on the basis of MLU instead of age, we would essentially be comparing normal English-speaking children with language-disordered Italian children. Similarly, if we were to match Italian and English-speaking aphasics on some common metric of mean length of utterance and/or grammatical complexity, we would undoubtedly ensure that are patients are *not* matched in the severity of their underlying impairment.

We chose, then, to define patient groups *within* each language, according to their fit to a prototype used by neurologists and speech pathologists in that community. A prototypic Broca's aphasic would show reduced fluency and phrase length, and a tendency toward omission of functors—*relative to normals in that language*. A prototypic Wernicke's aphasic would display fluent or hyperfluent expressive language, with an apparently normal melodic line; this fluency would be accompanied by marked word-finding difficulties, semantic paraphasias, and perhaps paragrammatisms, together with clinical evidence of an impairment

in language comprehension. Finally, anomics were defined as patients with otherwise normal fluency and melodic line, except for marked word-finding difficulties. This last group of patients did not display serious problems with either word or phrase comprehension in standard aphasia batteries or in clinical interviews. Hence patients are matched across languages only in the sense that they represent degree of deviation from a prototype developed out of observed variation within each language group. This permits us, for example, to compare the "best" patients and the "worst" patients across languages, as well as those who fit the mean. Although we do not agree with Caramazza (in press) that group studies of patients within diagnostic categories are of no use, we do agree that generalizations across groups of aphasics must be accompanied by a careful consideration of within-group variation.

Finally, even though we cannot be assured that patients are matched in degree of severity between languages, it is important to note that our conclusions rest on *profiles* of sparing and impairment within and between groups. We want to know, for example, if morphology is always the most damaged component relative to word order or semantics, within each language and patient type. Hence, even if patients do differ somewhat in overall severity of impairment, the question of qualitative patterning is still relevant.

Materials

The materials used in this study are similar to those described by MacWhinney, Bates, and Kliegl (1984) in a comparison of sentence interpretation by young normal speakers of English, Italian, and German. However, we dropped one factor that was manipulated in their study (i.e., contrastive stress) and reduced the overall number of stimuli from 81 to 54. Each of the 54 sentences contained a concrete action verb in the third person and two concrete animate or inanimate nouns marked by definite articles. The set of nouns and verbs used to generate the stimuli are listed in Table 3. Most of these are straightforward translations across the three languages. However, a few noun substitutions were made in German, because we wanted to restrict ourselves only to a subset of nouns that are ambiguous with respect to case marking. Following MacWhinney et al. (1984), we used the present progressive form of the verb in English (e.g., is/are kicking rather than kicks/kick). This is the most salient form of the English agreement contrast, and the closest match semantically to the way that simple present tense verbs work in German and Italian.

These sentences represent orthogonal variations of word order, semantic reversibility or animacy, and subject–verb agreement. The three levels of word order were the canonical order noun-verb-noun (NVN), and the two noncanonical orders noun-noun-verb (NNV) and verb-noun-noun (VNN). There were also three levels of animacy: semantically reversible sentences where both nouns were animate (AA), and two kinds of nonreversible sentences either with the animate noun first and the inanimate second (AI), or vice versa (IA). Finally, there were three levels of subject–verb agreement involving the singular/plural contrast. On the morphologically ambiguous items (AG0), both nouns agreed with the verb in number. On the morphologically marked items, only one of the two nouns agreed in number with the subject: either the first noun (AG1) or the second noun (AG2). Half of all items had a singular verb and half had a plural verb. These sentences fit a $3 \times 3 \times 3$ repeated-measures design (Order $\times$ Animacy $\times$ Agreement), with two items in each cell. Sample items are also listed in Table 3.

A cursory look at Table 3 shows that some combinations are inherently more plausible than others (e.g., it is more likely for a pencil to hit a cow than to kiss it). To minimize this kind of item-specific effect, three separate sets of stimuli were generated. In each set, lexical items were randomly assigned to sentence types from the appropriate category (i.e., animate noun, inanimate noun, and verb)—with the constraint that the same items never appeared twice in a row. So, for example, an NVN/AI/AG0 item in one set might be "The horses are kicking the pencils," while the corresponding item in another set would

TABLE 3
NOUNS AND VERBS USED IN EXPERIMENTAL SENTENCES

Italian	English	German	Gloss
	Animate nouns		
tartaruga	zebra	das Zebra	
maiale	pig	das Ferkel	
mucca	cow	die Kuh	
orso	bear	die Katze	(cat)
asini	donkey	die Maus	(mouse)
elefanti	elephant	die Ziege	(goat)
	Inanimate nouns		
matita	pencil	die Lampe	
sasso	rock	das Gestein	
dado	block	die Tasse	(cup)
pallone	ball	die Kugel	
	Verbs		
		Infinitive	3rd pers. sing
mangia(no)	eating	essen	isst
acarezza(no)	patting	streicheln	streichelt
bacia(no)	kissing	kussen	küsst
lecca(no)	licking	lechen	leckt
morde(ono)	biting	beissen	bisst
colpisce(ono)	hitting	schlagen	schlägt
spinge(ono)	pushing	stossen	stösst
afferra(no)	grabbing	ergeifen	ergreift
annusa(no)	smelling	riechen	riecht
	Sample sentences		
	The pencil is eating the donkey. La matita mangia l'asino. Die Lampe isst die Maus.		
	Is hitting the rock the elephants. Colpisce il sasso gli elefanti. Schlagt das Gestein die Zeigen		
	The cow the blocks is kissing. La mucca i dadi bacia. Die Kuh die Tassen küsst.		

be "The turtles are hitting the erasers." Within each set, sentence types appeared in the same quasi-random order (again with a constraint against the same item type appearing twice in a row). Patients were randomly assigned one of the three possible item sets.

The objects used for the enactment of sentence stimuli included small plastic animals averaging 1–2 in. in length, and small household objects of a comparable size. Each single object, and each identical object pair for plural items, was glued to a small, light balsa-wood base. This assured that the singular and plural referent objects were equally easy to pick up and manipulate.

Procedure

Patients were all tested individually by an experimenter who is a native speaker of the target language. The patient was told that

> I am going to read a series of sentences to you. Before I read each sentence I will put some objects in front of you. After I read the sentence I would like you to show me the action between the two objects. Now some sentences are not going to make any sense, but I would like you to try and show the action as best you can. Sometimes there are no right or wrong answers. Just make a choice and don't worry about the sentences not sounding right. Do the best you can.

The sentence stimuli were read out loud, one at a time, in a neutral intonation. A minimum of three practice trials were administered before testing began. If the patient did not immediately understand, the experimenter would demonstrate a simple action of moving the most likely agent into or against the most likely object. On these practice trials, all three cues to sentence meaning pointed in the same direction, i.e., NVN/AI/AG1 items like "The horses are hitting the pencil" or "The turtle is kicking the erasers." So the experimenter's demonstration did not bias the patient toward any of the three linguistic contrasts. Once testing began, the experimenter was free to repeat any item once or twice, if the patient did not appear to hear or remember the sentence.

On each trial, the object that the patient picked up was scored as the intended agent, even if he did not carry out a complex enactment of the action verb. If the first noun mentioned was selected, he received a score of 1; if the second noun was selected, he received a score of 0. Failures to respond occasionally occurred, although they were not frequent. On these trials, a score of .5 was assigned (i.e., a score indicating random behavior).

The dependent variable for all analyses was percentage choice of the first noun as agent, where chance performance would be 50%. One hundred percent would indicate choice of the first noun and 0% would indicate choice of the second noun on every item. Note that we do not use the terms "correct" or "incorrect." Even young normal subjects show a considerable amount of variation in these experiments, as we might expect when one valid linguistic cue is pitted against another.

RESULTS AND DISCUSSION

We begin with results comparing Broca's aphasics and young normal controls, within and between languages. Then we proceed to comparisons involving fluent aphasics and other types of control populations in German and Italian.

Broca's versus Normals across Languages

We first conducted a separate analysis of variance for the young normal controls, in a 3 × 3 × 3 × 3 design with Language as a between-subject factor, with Word Order, Agreement, and Animacy treated as repeated measures. The purpose of this analysis was to compare our results in a simplified paradigm with those reported by MacWhinney, et al., (1984) for college students in these three language groups. Since we had less than half as many subjects per cell, our results were somewhat weaker overall, but the pattern of results was similar in almost every respect. (Detailed results are summarized in Table 4.)

TABLE 4
ANOVA SUMMARY FOR YOUNG CONTROLS

Effect	*F* ratio	% Variance
Language (L)	***20.570	10.00
Animacy (AN)	***25.466	4.00
Agreement (AG)	***133.802	43.00
Word order (WO)	***62.734	13.00
L × AN	1.457	00.40
L × AG	***15.822	10.00
L × WO	***35.575	14.00
AN × WO	**4.856	00.50
AN × AG	***11.967	2.00
AG × WO	***6.025	00.50
L × AN × AG	**3.126	1.00
L × AN × WO	0.337	00.06
L × AG × WO	1.183	00.30
AN × AG × WO	1.856	00.30
L × AG × AN × WO	1.269	00.40

** $p < .003$.
*** $p < .000$.

First, there was a significant main effect of word order, with more first-noun choice on the NVN items—exactly what we would expect in three SVO languages. More important, there was a significant interaction of Word Order and Language, illustrated in Fig. 1a–1c. In English, we replicated a pattern that Bates and MacWhinney have reported in several studies: very strong first-noun choice on NVN, accompanied by a tendency toward second-noun choice on the other two orders (reflecting OSV and VOS interpretations). In German, we instead found a consistent bias toward the first noun in all three word orders: SVO, SOV, and VSO. Italians, by contrast, showed a much weaker bias toward SVO, with

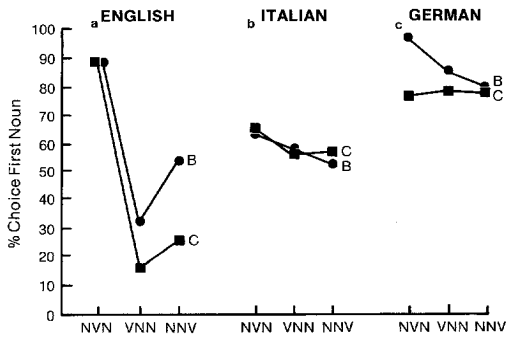

FIG. 1. A–C. Word order × language interaction for Broca and control groups.

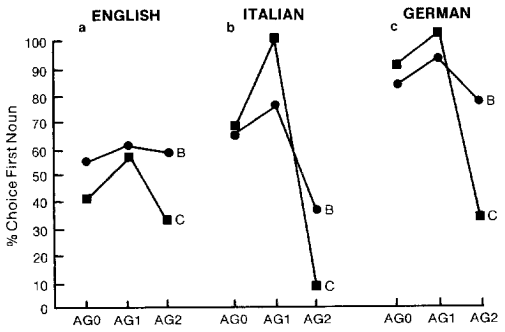

FIG. 2. A–C. Agreement × language interaction for Broca and control groups.

random performance on the other two word order types (reflecting the fact that SOV, OSV, VSO, and VOS are all equally possible in Italian). In short, all three languages show a distinct profile of word order effects, consonant with what we know about the structure of each language.

There was also a significant main effect of subject–verb agreement, in the expected direction: more first-noun choice when the first noun agreed with the verb, less first-noun choice when the second noun agreed with the verb. Like MacWhinney et al., we found a significant interaction between Agreement and Language, illustrated in Fig. 2a–2c. This interaction reflects the fact that agreement is extremely strong in Italian, moderately strong in German, and very weak in English.

There was a main effect of animacy as well, again in the expected direction: more choice of the animate noun as agent, on those items that have an animacy contrast. In this study the Language × Animacy interaction failed to reach significance, in contrast with MacWhinney et al., (1984). They found an interaction reflecting more use of animacy in German, followed by Italian, with least use of animacy in English. The disparity seems to be related to the fact that our northern-German sample made more use of agreement than the Bavarian sample tested by MacWhinney et al. Hence this trade-off between agreement and animacy may be related to dialect differences in the strength of verb morphophonology. In any case, this difference accounts for only a very small proportion of the variance, compared with the effects that replicated between the two samples.

There were also a large number of higher order interactions in our cross-linguistic sample of normals, similar to those reported by MacWhinney et al., (1984) (see Table 4). These interactions reflect the competition, convergence, and conspiracy effects predicted by the competition model. The most consistent choices occur when cues converge; the least consistent choices occur when cues compete. Animacy has its greatest effects when other, stronger cues are absent (e.g., in noncanonical

word orders, or in morphologically ambiguous items). However, these convergence/ competition effects differ from language to language, depending on the *relative weights* of cues in each language. We need not go into all of these higher order interactions, because they are consistent with data reported in considerable detail elsewhere (e.g., MacWhinney et al.; Bates & MacWhinney, 1982; Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984). The point is that we have a consistent processing profile for each language, against which we can compare the relative performance of aphasic patients.

We begin that comparison with a set of 2 × 3 × 3 × 3 analyses within each language, with Patient Group (Broca's vs. normals) as a between-subject factor, and the three linguistic variables (Word Order, Agreement, and Animacy) as repeated measures. Results of these three ANOVAs are summarized in Tables 5A–5C. After considering the effects of aphasia within each language, we can then turn to the full analysis combining Language and Patient Group as factors.

Beginning with English, main effects reached significance for all three linguistic factors: word order, agreement, and animacy. There was also a higher order interaction between animacy and word order, reflecting the fact that animacy effects are greater in noncanonical word orders. More interesting, however, are the effects involving Patient Group. There was, first of all, a main effect of Group: English Broca's chose the first noun significantly more often than English normals. This finding makes

TABLE 5A
ANOVA SUMMARY FOR ENGLISH BROCA'S AND YOUNG CONTROLS

Effect	*F* ratio	% Variance
Group (GP)	**9.662	4.00
Animacy (AN)	***15.333	5.00
Agreement (AG)	***9.636	4.00
Word Order (WO)	***98.403	74.00
GP × AN	1.579	1.00
GP × AG	* 4.172	2.00
GP × WO	* 3.332	3.00
AN × WO	***5.660	2.00
AN × AG	2.167	1.00
AG × WO	1.605	1.00
GP × AN × AG	0.486	00.02
GP × AN × WO	1.486	00.05
GP × AG × WO	1.137	1.00
AN × AG × WO	1.954	1.00
GP × AG × AN × WO	1.713	1.00

* $p < .05$.
** $p <$ 006.
*** $p <$ .000.

TABLE 5B
ANOVA SUMMARY FOR ITALIAN BROCA'S AND YOUNG CONTROLS

Effect	*F* ratio	% Variance
Group (GP)	0.048	00.01
Animacy (AN)	***21.414	11.00
Agreement (AG)	***94.591	65.00
Word Order (WO)	***14.393	3.00
GP × AN	0.331	00.20
GP × AG	***15.377	11.00
GP × WO	0.218	00.04
AN × WO	2.138	1.00
AN × AG	***13.077	6.00
AG × WO	1.228	1.00
GP × AN × AG	1.799	1.00
GP × AN × WO	1.401	00.50
GP × AG × WO	1.770	1.00
AN × AG × WO	0.752	1.00
GP × AG × AN × WO	0.582	00.40

* $p < .05$.
** $p < .005$.
** $p < .001$.

TABLE 5C
ANOVA SUMMARY FOR GERMAN BROCA'S AND YOUNG CONTROLS

Effect	*F* ratio	% Variance
Group (GP)	2.475	4.00
Animacy (AN)	2.491	2.00
Agreement (AG)	***34.636	58.00
Word Order (WO)	2.990	1.00
GP × AN	2.896	2.00
GP × AG	***14.176	24.00
GP × WO	*4.709	2.00
AN × WO	2.168	1.00
AN × AG	*2.926	2.00
AG × WO	1.501	1.00
GP × AN × AG	0.955	1.00
GP × AN × WO	0.074	00.40
GP × AG × WO	2.489	1.00
AN × AG × WO	*2.123	2.00
GP × AG × AN × WO	0.694	1.00

* $p < .05$.
** $p < .005$.
*** $p < .001$.

sense when we consider the significant interaction between Group and Word Order, illustrated in Fig. 1a. There is absolutely no difference between normals and Broca's in the effect of canonical SVO word order. The group differences occur, instead, on the noncanonical word order types: the English second-noun strategies (VOS and OSV) are smaller in the aphasic patients. There was also a significant interaction between Group and Agreement, illustrated in Fig. 2a. Even though the agreement cue is weak to begin with in English, among the aphasic patients it flattens out entirely. Finally, there are no significant interactions involving animacy. In other words, aphasics are not increasing their use of lexical semantics to compensate for a loss of other cues.

Turning to the Italian comparison, there are again significant main effects for all three linguistic variables (word order, agreement, and animacy) in the same directions discussed above for Italian normals. There is also a significant interaction between Agreement and Animacy, showing that animacy cues have their strongest effect when morphology is ambiguous. But again, the most important effects are those involving Patient Group. In Italian, the main effect of Group did not reach significance. There was also no significant interaction between Group and Word Order. Once again, Italian Broca's maintain exactly the same degree of control over canonical word order that we find in the premorbid language. But since noncanonical word order biases are random in Italian normals, they are (not surprisingly) just as random in aphasics. For comparison with English, this nonsignificant Group × Word Order interaction is illustrated in Fig. 1b. We did, however, find a significant interaction between Patient Group and Agreement, displayed in Fig. 2b. This reflects a very marked impairment in the use of verb agreement by Italian patients. Finally, there was no interaction between Group and Animacy. Like their English counterparts, the Italians are not increasing their use of lexical semantics over normal levels to compensate for loss of other cues.

In the analysis for German, the main effects of Word Order and Agreement reached significance; the main effect of Animacy just fell short ($p < .07$). There were three higher order interactions involving Animacy; Animacy × Agreement, Animacy × Word Order, and Animacy × Agreement × Word Order. All three reflect the competition/convergence patterns discussed earlier: animacy has its greatest effects when the two stronger cues are absent, or in competition with one another. In German, like Italian, the main effect of Patient Group did not reach significance. But Group did interact with the linguistic factors. First, there was an interaction between Group and Word Order, illustrated in Fig. 1c. German patients actually make *more* use of canonical SVO word order than their normal controls. The VSO bias is also slightly elevated over that of normals, though the German SOV bias is somewhat smaller in the aphasic patients. The interaction between Group and Agreement is illustrated in

Fig. 2c. This result is also similar to the one reported for Italian: a marked drop in the use of verb agreement by Broca's aphasics. Finally, there was again no interaction between Group and Animacy. Patients are not relying on semantic information more than normal controls.

The picture that emerges across these three analyses seems quite clear. The use of canonical word order is retained by Broca's aphasics, in all three languages, at language-specific levels. The only exception to this is a tendency for German aphasics to make *more* use of SVO word order than German controls. There is some reduction in the use of noncanonical word order strategies, at least in English. But the overall picture is one in which language-specific patterns of word order are retained. Patients are also making completely normal and language-specific use of semantic information. The one clear impairment that is shared by aphasics in all three languages is a loss of access to grammatical morphology.

To validate this comparison across languages, we conducted an analysis of variance across the full design: 3 (Language) × 2 (Patient Group) × 3 (Word Order) × 3 (Agreement) × 3 (Animacy). Our focus in this complex analysis is on the effects involving Language and Group. Although there were a large number of other linguistic main effects and interactions, these are simple reflections of the effects already discussed for normals.

There were main effects of both Group ($F = 6.88$, $p < .02$) and Language ($F = 37.65$, $p < .001$), and a trend toward a Language × Group interaction ($F = 3.00$, $p < .06$). These are accounted for entirely by interactions of these factors with the linguistic variables.

First of all, although there were significant interactions involving Animacy and Language, there were no interactions involving Animacy and Group. In other words, there are language-specific patterns in the use of animacy information, but these patterns held for both Broca's and normals, to exactly the same degree.

By contrast, there were significant interactions involving both Agreement × Language and Agreement × Group, as well as a three-way interaction of Language × Group × Agreement. These confirm the patterns illustrated in Fig. 2a–c. Morphology is markedly impaired across all three groups of Broca's aphasics, although the size of the impairment depends upon the size of the initial agreement effect in the patient's native language. The larger the agreement effect in the premorbid language, the larger the difference between Broca's and normals—in other words, "The bigger they are, the harder they fall."

Finally, there was no interaction between Word Order and Group, but there were significant effects involving Word Order × Language, and Word Order × Language × Group. These reflect the patterns displayed in Fig. 1a–c: English patients differ from normals only on noncanonical word orders, Germans differ only in their overuse of canonical word

order relative to normals, and Italians do not differ from normals in their language at all.

We should point out that main effects and interactions involving the factor Language account for 41% of the experimental variance in this full analysis. Main effects and interactions involving the factor Group account for only 14.6% of the variance. In other words, *we can predict more about an individual's performance in this task if we know his native language than we can by knowing whether or not the individual has suffered focal brain damage.* One further analysis clarifies this point: a 3 (Language) × 3 (Word Order) × 3 (Agreement) × 3 (Animacy) analysis of variance carried out only on the agrammatic aphasics.

There was, first of all, a main effect of Language ($F = 20.96$, $p < .001$). This reflects much more first-noun choice overall by German aphasics, a by-product of the SVO, SOV, and VS biases in that language. Language also interacted significantly with Word Order ($F = 12.83$, $p < .001$), Agreement ($F = 4.04$, $p < .01$), and Animacy ($F = 3.07$, $p < .05$). In each case, the direction of the difference is similar to the corresponding interactions among young normal controls. Since none of the three-way interactions reached significance, it appears that competition and convergence effects are blunted relative to normals. But the important point is that there are statistically reliable differences between languages in the way that patients handle semantic and grammatical information. Broca's aphasics do not look alike across natural languages.

So far we have reported group statistics, treating our small sets of Broca's aphasics like a homogeneous class within languages. As Caramazza (1986) has recently pointed out, this approach can sometimes mask differences among individual patients that would support completely different conclusions. With this possibility in mind, we made it a matter of policy in our cross-linguistic study to examine patterns of behavior for each individual patient and control. Appendix 1 presents main effects for word order, agreement, and animacy for all participants, together with the performance of each individual on items NVN/AG1 items (where canonical word order and agreement converge), and on NVN/AG2 items (where canonical word order and agreement compete). From these statistics, it is possible to determine the hierarchy of importance of cues to meaning for every subject, as well as the relative strength of cues within the hierarchy.

There are indeed individual differences within every group, including college students, as we might expect in a task like this where there are not always right or wrong answers (see Bates et al., 1982, for an extensive treatment of individual strategies within this paradigm). The range of individual variation that is possible in young normals needs to be considered in interpreting patient data.

For example, the group pattern for English suggests that word order

always wins over morphological and/or animacy information. But 2 out of 12 English college controls did choose agreement over word order on competition items; 1 of these 2 also paid more attention to animacy than to word order. Two young normals also failed to show the OSV and VOS strategies for noncanonical sentences that show up in all our group studies of English using this paradigm. Hence there is some "softness" in the English-based strategies evidenced in this experiment. Nevertheless, examination of performance by individual English Broca's aphasics suggests that the range and direction of variation is quite comparable. All eight of the English Broca's aphasics showed a preference for word order over agreement on competition items. Examining the individual patterns for word order collapsed across other variables, Broca's aphasics all preferred the first noun on NVN items, with a range from 78% to 94%; this is well within the 61%–100% range noted within normals. On the VNN items, all of the Broca's aphasics and 10 out of 12 of the normals showed at VOS bias. So it seems fair to conclude that this secondary word order strategy remains in brain-damaged patients. The only noteworthy difference in individual strategies shown by Broca's aphasics pertains to the use of word order strategies for for NNV items: 10 out of 12 of the young normals showed the OSV bias, compared with only 3 of the 8 Broca's. Hence at least one small aspect of word order is diminished in the nonfluent patients, compared with normal controls. Overall, however, patterns of variation in English patients is remarkably similar to performance by English normals.

In the group data for Italian college controls, agreement cues win out overwhelmingly over both word order and animacy. Out of 10 Italian college controls, 1 did fail to show this pattern. More strikingly, however, only 4 of the 10 Italian Broca's preferred agreement over word order on competition items. Hence, on a case-by-case basis, Italian Broca's differ more from baseline patterns in their language than their English counterparts.

More individual variation in strategy showed up among German patients and among German college controls. As discussed by MacWhinney et al. (1984), Germans are prevented from using case contrasts in these sentence materials—their favorite cue to meaning in the real world. The three cues that we varied here (word order, agreement, and animacy) all have roughly similar levels of informativeness and strength in German. Hence, German listeners are faced with a situation in which almost any competition item is a "close call." This leads to more variation among individuals, and less consensus in the group as a whole concerning the "best" cue to meaning in this particular experiment. For example, 7 of the 10 German college students showed a preference for agreement over both word order and animacy in competition items; but only a minority of these subjects showed a 100% preference for morphological contrasts,

compared with 7 of the 10 Italian normals. From this point of view, it is all the more interesting that word order "won out" to such a degree in German Broca's aphasics: all 7 of the German patients chose word order over both morphology and animacy on competition items.

For present purposes, the important point is this: the range of variation seen in aphasic patients still reflects, in case after case, patterns that are peculiar to the patient's native language. English and German patients show more consistent use of word order; Italian patients are more likely to use combinations of animacy and agreement. Some patients are so badly impaired that their performance is close to chance, unless two or more sources of information converge (see also Smith & Bates, 1987). But their performance still shows traces of their premorbid language. The one factor that reliably distinguishes Broca's aphasics from normals is a marked degradation in the use of grammatical morphology as a cue to meaning. In short, the group effects that we have reported here are a faithful representation of individual variance—as we might expect, given the size and reliability of the language effects in the analyses of variance.

This relative preservation of language differences supports the competition model. However, the selective impairment of morphology shown in all three languages provides evidence in favor of the closed class theory of agrammatism. Both theories receive some support from these findings, but both will also have to be constrained. We now turn to a different test of the closed class hypothesis: is the "special vulnerability of morphology" restricted to patients who are agrammatic in their output, or will we find a similar pattern of results in receptive processing by other patient groups?

Comparisons across Patient Groups

In this section, we restrict ourselves to German and Italian, the two languages where enough variance is accounted for by morphology to permit an interesting set of comparisons across patient groups.

First, we extended the paradigm to seven Wernicke's aphasics in Germany and nine Wernicke's aphasics in Italy (see Table 2). The point of this comparison was to determine whether the two classes of aphasia differ significantly with respect to language-specific patterns of sentence interpretation. So controls were excluded, and data were entered into a 2 (Italian vs. German) × 2 (Broca vs. Wernicke) × 3 (Word Order) × 3 (Agreement) × 3 (Animacy) analysis of variance, with Language and Group as between-subject variables and the three linguistic variables as repeated measures. The results of this analysis are summarized in Table 6. We focus here only on the effects involving Patient Group. The other results in Table 6 reflect Language, Word Order, Animacy, and Agreement effects that have already been discussed.

TABLE 6
RESULTS OF BROCA/WERNICKE COMPARISON IN ITALIAN AND GERMAN ANOVA SUMMARY

Effect	*F* ratio	% Variance
Language (L)	***41.668	25.20
Group (G)	*4.351	3.00
Word Order (WO)	***10.347	5.80
Agreement (AG)	***15.26	16.40
Animacy (AN)	***9.944	16.10
L × G	3.076	1.90
L × WO	0.467	0.30
L × AG	*3.819	4.10
L × AN	*3.384	5.50
G × WO	0.586	0.30
G × AG	1.683	1.80
G × AN	0.503	0.80
WO × AG	0.806	0.60
WO × AN	0.955	0.60
AG × AN	**4.352	2.70
L × G × WO	0.146	0.10
L × G × AG	0.507	0.50
L × G × AN	0.415	0.70
L × WO × AG	1.513	1.10
L × WO × AN	0.873	0.60
L × AG × AN	1.897	1.20
G × WO × AG	*3.237	2.40
G × WO × AN	*2.592	1.70
G × AG × AN	0.279	0.20
WO × AG × AN	0.670	1.00
L × G × WO × AG	0.531	0.40
L × G × WO × AN	1.532	1.00
L × G × AG × AN	1.446	0.90
L × WO × AG × AN	0.784	1.10
G × WO × AG × AN	0.983	1.40
L × G × WO × AG × AN	0.559	0.80

* $p < .05$.
** $p < .005$.
*** $p < .001$.

The findings involving Patient Group include a main effect of Group, with greater first-noun choice across the board by Broca's aphasics. A two-way Group × Language interaction just missed significance ($p < .09$). This reflects the fact that the just-cited Group difference is somewhat larger in the German sample—which in turn comes from a greater bias toward subject-initial word orders in that language. There were no two-way interactions between the Group factor and any of the linguistic variables: Word Order, Agreement, or Animacy. Hence, overall, the two patient groups are using linguistic information in similar ways. But there

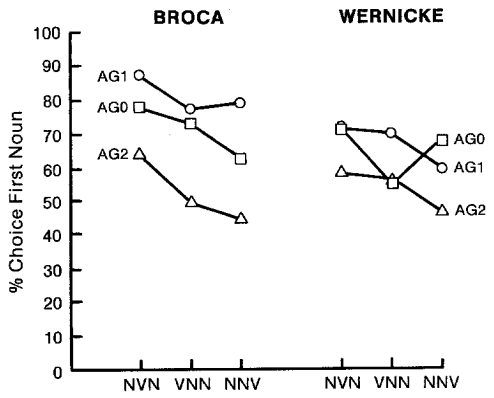

FIG. 3. Group × agreement × word order interaction.

were two interesting higher order interactions that deserve some consideration.

First, there was a Group × Agreement × Word Order interaction ($F = 3.23$, $p < .05$), illustrated in Fig. 3. This result involves a surprising reversal of the fluent/nonfluent difference between Broca's and Wernicke's aphasics. Specifically, the so-called agrammatics are actually *more* attuned to grammatical information than the posterior aphasics. This can be seen above all in the performance of the two respective groups on NVN/AG1 items—the sentences where morphological and syntactic information are maximally redundant. Here Broca's perform close to the normal range, averaging 86% choice of the first noun; on the same items, Wernicke's choose the first noun only 70% of the time. Since this effect is collapsed across contrasts in animacy, it can only mean one thing: Broca's aphasics are able to exploit the convergence between two grammatical cues, using one to "boost" or "retrieve" the other. This finding is entirely consistent with a report by Smith and Bates (1987), that Serbo-Croatian Broca's aphasics perform extremely well when word order, case, and gender agreement all point to the same interpretation. For a long time we have assumed that the apparently normal comprehension of Broca's aphasics in a conversational setting was due to their ability to take advantage of semantic/pragmatic information. However, these findings suggest that Broca's are in fact capitalizing on *many* kinds of redundancy available in naturalistic speech input.

There was also a Group × Animacy × Word Order interaction ($F = 2.59$, $p < .05$), illustrated in Fig. 4. This graph also reverses the expected comparison between Broca's and Wernicke's aphasics. If receptive language paralleled the impairments seen in expressive language by the same patients, then we might expect a relatively greater impairment of *semantic* factors in Wernicke's aphasia, with sparing of grammatical

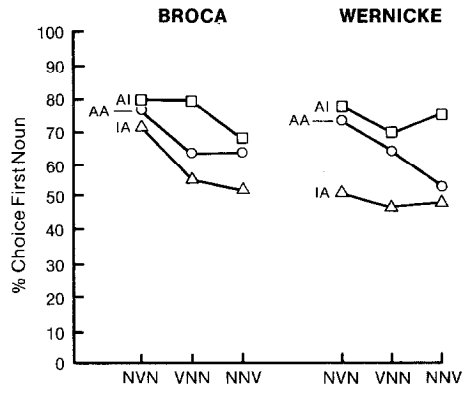

FIG. 4. Group × animacy × word order interaction.

information. And yet, we can see from Fig. 4 that Wernicke's aphasics are actually make relatively *more* use of the semantic contrasts in our stimuli. In particular, on NVN/IA sentences where canonical word order and animacy compete, animacy wins more often for the Wernicke's aphasic than it does for Broca's. On NVN/AI items, where SVO order and animacy converge, both groups perform at similar levels (choosing the first noun around 80% of the time, collapsed across levels of subject–verb agreement).

These group differences are small, compared with the large amount of variance accounted for by Language and by the linguistic trends themselves. But we are forced to conclude that grammatical morphology is at least as vulnerable in Wernicke's aphasia as it is for expressive agrammatics. This result does not follow in any obvious way from peculiarities of the task. In fact, a strategy based entirely on verb agreement would work very well in this experiment. On every item that involves a morphological contrast, the patient is presented with a single animal or object on a little platform, standing by a pair of animals or objects on a similar platform. If morphology were stronger than either word order or semantics in these patients, they could short-circuit other information altogether by simply listening for the verb. They could then perform successfully with the following strategy: "If the verb is singular, move the single object; if the verb is plural, move the object pair." However, the results suggest instead that morphological information is difficult for *both* Broca's and Wernicke's aphasics.

Given this finding, we decided to pursue the generality of the "special vulnerability of morphology," focusing on Italian where morphological effects are strong despite these demonstrated deficits. These analyses are summarized briefly, focusing only on differences (or lack of differences) between patient groups.

First, data were collected from 10 Italian anomics, defined as fluent patients suffering from isolated word-finding deficits, in the presence of clinically normal comprehension. The anomics were compared to Broca's aphasics, in a 2 × 3 × 3 × 3 analysis of variance with Group as a between-subjects factor. There were *no* significant interactions involving the Group factor, and no main effect. In other words, Italian anomics are just as impaired as Broca's aphasics in their use of morphology; but like Broca's aphasics, their use of word order and semantic cues follows the normal Italian profile. There was one nonsignificant trend involving group: a Group × Animacy effect ($F = 3.03$, $p < .07$). This involved a tendency for anomics to make somewhat more use of animacy than agrammatic aphasics—suggesting that the anomics are perhaps *slightly* better organized in their ability to compensate for a morphological deficit by taking more advantage of lexical cues.

This last set of results parallels those reported by Smith and Bates for Serbo-Croatian, where anomics were also selectively impaired in use of case morphology relative to normals. However, their anomics did perform better than Broca's aphasics; ours did not. The difference may be due to nothing more than sampling differences between the two research sites. But it may also mean that the selective vulnerability of morphology is weaker for "local" case marking than it is for "long distance" marking via subject–verb agreement. If so, this would offer an interesting parallel to some related findings for children: case morphology is acquired relatively early as a cue to sentence meaning (Slobin & Bever, 1982; MacWhinney et al., 1985), but subject–verb agreement is acquired perhaps 2 or 3 years later (Kail, 1985; Caselli & Devescovi, 1985; see also Ammon & Slobin, 1979, for a discussion of the contrast between "local" and "global" cues in child language).

At this point, the question of "normal controls" becomes a particularly serious one. Given the uniformity of our findings on morphological deficits across aphasic populations, we must ask whether or not this pattern results from global effects of aging. In Italian, we addressed this by looking at two different samples of controls in the same age and social class range of our aphasic patients.

The first was a group of eight neurological patients without evidence of cortical damage (including cases of poliomyletis, and myasthenia gravis). Some of these patients were taking central nervous system drugs, but none had diagnoses implicating focal lesions of any kind. Like the anomics, they were compared with Broca's in an analysis of variance with Patient Group as a between-subjects factor. Once again, there was no main effect of Group, and no significant interactions. A Group × Animacy trend was found ($F = 3.24$, $p < .06$), reflecting a slightly greater use of animacy by the neurological controls. This is similar to the trend in the Broca/anomic comparison, suggesting that the neurological controls are a little better

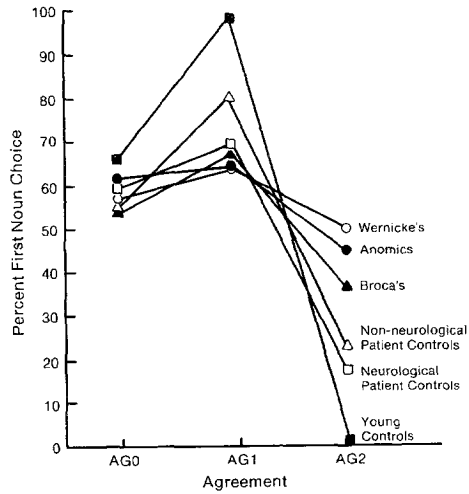

FIG. 5. Group × agreement interaction for Italian speakers.

at compensating for a morphological deficit by paying more attention to semantics.

The second group of 10 patients were drawn from the orthopedic ward; none of these individuals had any diagnosed form of nervous system damage, and none were taking central nervous system drugs. But they were all hospitalized, and all experiencing the stresses associated with that experience. This group was substituted for the neurological controls in a comparison with Broca's aphasics. Once again, we found no significant Group contrast in the use of morphology—although an inspection of cell means showed that as a whole this control group tended to pay more attention to the agreement contrasts. We found exactly the same Group × Animacy trend reported in the other two-way comparisons ($F = 3.04$, $p < .06$), with orthopedic controls making more use of animacy information. In addition, there was a Group × Word Order trend ($F = 2.76$, $p < .07$). But in this case, the comparison favors the Broca's. The aphasics chose the first noun across all NVN items 61% of the time, compared with only 51% for orthopedic controls.

So all of our age-matched patient controls appear to be abnormal, at least when they are considered as a group (see below). This was confirmed in two further analyses. First, we put all the Italian groups together in one large analysis of variance, with six levels of the between-subjects factor Group (Broca's, Wernicke's anomics, neurological controls, orthopedic controls, and college students). The resulting Group × Agreement interaction is illustrated in Fig. 5. Although the older patient control groups do seem to stand in between the aphasics and the college students

(particular on the AG2 items), the group effect is contributed primarily by the young normals.

A second analysis was restricted to the three control groups: neurological, orthopedic, and young college students. Here we found a large Group × Agreement interaction ($F = 7.80$, $p < .01$), markedly favoring the college students. There was also a significant interaction involving Group × Animacy, with (as we have come to expect) more compensatory use of semantic information by the older "normals." In addition, there was a Group × Animacy × Word Order interaction ($F = 2.49$, $p < .05$). This showed that the older controls also favored animacy over word order to a greater degree than college students—the normal pattern for Italian, we should stress, but exaggerated in the older patients.

Is receptive agrammatism nothing more or less than an effect of getting old? It is not quite that simple. First, the effects are overwhelmingly greater for morphology than for word order. Hence the results cannot be accounted for by some general drift toward random performance, failure to attend, or any other across-the-board factors.

Second, not all the orthopedic patients showed this selective vulnerability of morphology. Appendix 1 includes information on the performance of neurological and orthopedic controls, compared with aphasic patients and with young normals. The neurological controls, like the various aphasic groups, tended to vary from close to random on all factors (save the cases where all information converged), to normal on all factors except for a noticeable diminution of morphology. The distribution of performance was, however, quite different among our Italian orthopedic patient controls. Five of these individuals looked entirely like the college students (i.e., close to a deterministic preference for morphology). The other five were indistinguishable from aphasic patients, particularly in the use of morphology. There seems to be some sort of "cliff" that some patients fall over in this task. The difference does not appear to be due to level of education, since some of the most deficient orthopedic patients were college graduates. Nor does it map directly onto age—although the tendency is in that direction. There was a 10-year mean difference between the five patients who performed like college students and the five who performed like aphasics. But the patients with preserved morphology included a 69-year-old man with a grade school education.

Perhaps some metalinguistic factor is in operation, causing some older patients to "distrust" the experimenter (e.g., "Does he think I'm crazy? I know a pencil can't kick a cow"). In Italian, it is hard to answer this question, since the natural tendency in the language is for animacy contrasts to play a major role when agreement is ambiguous (MacWhinney et al., 1984). In other words, a semantically based strategy should not be viewed as "nonlinguistic" for an Italian listener (cf. Caplan, 1983). For this reason, it seemed important to return to German, where word order

effects were extremely strong in both college controls and aphasic patients. If there is some sort of metalinguistic preference for animacy in older controls, a "face-saving" strategy adopted by older individuals, then the same thing should occur in German.

We therefore added a comparison in German, between college students and a group of older, nonneurological controls matched to the aphasic patients in age and range of social class. This analysis again revealed a significant Group × Agreement interaction, favoring the college students ($F = 5.16$, $p < .05$). There was also a Group × Animacy × Agreement interaction ($F = 2.52$, $p < .05$). However, this interaction does *not* mean that older individuals are more influenced by semantic information. In fact, interacting with their difficulty using morphology, older controls are actually making *less* use of animacy. What is happening is basically this: the older controls, like aphasic patients (particularly German Broca's), are much more reliant on the use of word order—which takes the form, in German, of a strong across-the-board preference for the first noun. This tendency is evident in a marginal main effect of Group ($F = 3.76$, $p < .07$), with more first-noun choice overall by older patients. But it shows up in the interaction in several more interesting and systematic ways. First of all, consider the items where morphology is ambiguous (AG0). Here IA sentences (inanimate first, animate second) represent a direct competition between animacy and word order (as in "The pencil is kicking the cow"). On these items, German college students chose the first noun 70% of the time. On the same items, older German controls chose the first noun 90% of the time. Similarly, consider the items where both animacy and agreement compete against word order (AG2/IA sentences). Here college controls chose the first noun only 25% of the time—compared with 58% for the older Germans. In other words, older German controls were making more use of word order than college students. Individual patient data in Appendix 1 shows that a heavy reliance on word order characterizes the performance of almost every older patient in the study.

In short, the vulnerability of morphology across older patients and controls cannot be simply ascribed to a metalinguistic bias toward "common sense." In Italian, older controls tend to use animacy as a substitute for a difficulty in using morphology. But in German, the controls are more likely to turn to word order as compensatory device.

SUMMARY AND CONCLUSION

The main conclusions that can be drawn from these data are the following.

1. *Language differences.* Broca's aphasics retain language-specific patterns in the use of word order, agreement, and animacy information.

These language differences actually account for more variance overall than the difference between patient groups. This pattern confirms predictions of the competition model with regard to a strength-based, probabilistic model of the differences in grammatical processing across natural languages.

2. *Patient group differences: Broca's versus normals.* Nevertheless, the effects of Broca's aphasia seem to be relatively specific. Morphology is consistently and markedly impaired in all three languages, whether or not the patient had to depend on morphological cues in his premorbid state. By contrast, the use of animacy information seems to be intact. There may be some diminution in the use of noncanonical word order strategies, at least in English. But canonical word order seems to be completely spared—and may actually be used more by patients in some languages, to compensate for loss of access to morphology. Taken together, these patterns provide support for some version of the closed class hypothesis.

3. *Patient group differences: Wernicke's, anomics and older controls.* The "special vulnerability of morphology" is apparently not restricted to patients suffering from expressive agrammatism. Instead, morphology seems to be vulnerable across all languages and patient groups—including some nonneurological patient controls, compared with healthy, young normal speakers of the same language. We did find that Broca's aphasics can take advantage of a convergence between grammatical cues (i.e., word order and agreement) better than Wernicke's aphasics, in both German and Italian. But this finding runs directly counter to the once popular interpretation of Broca's aphasia as an agrammatic syndrome.

With regard to the first two points, we have arrived at a compromise between these two competing theoretical positions. The competition model is confirmed in its predictions regarding probabilistic differences in sentence interpretation across structurally distinct language types. But it must be modified to account for the patient's selective problems with morphology—perhaps by invoking separate sources of "cue cost" (e.g., some of the semantic, perceptual, and memory factors discussed below).

The closed class hypothesis has withstood a strong cross-linguistic test. However, it must be qualified to account for language-specific effects in the relative strength of morphology, and for the ability of most patients to combine information from different grammatical sources to achieve near-normal performance.

The real "fly in the ointment" for the closed class theory comes from the second part of the study: consistent evidence that deficits in morphology can occur as a simple result of aging and/or global stress of some unspecified kind (e.g., being a patient in the orthopedic ward). This certainly adds to the general disenchantment with a central syndrome of agrammatism.

We considered the possibility that older patients are simply reacting to a situation of being tested by a young experimenter in a childlike task (e.g., "I'm not crazy enough to think that a pencil can kick a cow"). Indeed, older controls do rely more on animacy in Italian, a finding that could support this kind of metalinguistic interpretation. But older controls are more likely to compensate by an overuse of word order in German—even when word order competes with "common sense" lexical semantic contrasts. We therefore believe that our results have something to do with "real" language processing (at least in the domain of language performance). There are at least four related processing explanations that could account for the vulnerability of morphology across groups.

First, older patients may simply have difficulty *hearing* the series of unstressed verb and noun endings that make up the agreement cues in English, German, and Italian. Our patients were screened to exclude cases of diagnosed hearing deficiency. But subtle forms of hearing loss could still be operating. This possibility could be tested by administering written versions of the task (an option that we are now pursuing with a small set of Italian patients). It might also be useful to carry out an auditory version of the task with young normals, with the stimuli administered through various levels of white noise.

Second, older patients may have selectively greater difficulty in *remembering* the noun and verb suffixes long enough to interpret a sentence. Support for this view hinges on a contrast between our findings and those of Smith and Bates for Serbo-Croatian. Their anomic patients were significantly impaired in the use of case morphology relative to normals, but they were also considerably better at case assignment than Broca's aphasics. This may be due to the fact that case morphology imposes a smaller load on short-term memory.

This last idea is supported by several lines of evidence. As we noted earlier, cross-linguistic studies of normal children support the idea that "local" morphology is acquired earlier than "global" morphology. Local morphology refers to inflections and functors that can be bound quickly to an immediately adjacent element (e.g., a suffix on a noun). For example, case suffixes are so unambiguous in some languages that semantic roles can be assigned as soon as one noun/suffux unit is computed. Global morphology refers to bindings between inflections that occur across discontinuous units in a sentence. For example, to make use of subject–verb agreement in a simple Italian sentence, a listener has to go through the following steps:

1. Bind the person and/or number markings on the first noun and store them together.
2. Bind the person and/or number markings on the verb and store them together.

3. Compare the noun and verb units. If there is a mismatch, discard the noun as a possible subject of the sentence; if there is a match, hold the noun in mind as a possible subject until the other candidates have been checked.

4. Bind the person and/or number markings on the next noun and compare this unit with the verb and with the previous noun; if all three match, morphology is an ambiguous cue and you have essentially wasted your time.

Interestingly, this local/global contrast seems to have its primary influence on receptive language processing. For example, subject–verb agreement is not used as a primary cue to meaning by Italian children until they are between the ages of 5 and 7 years (compared with acquisition of case morphology in a similar comprehension task between the ages of 2 and 3 for Serbo-Croatian and Hungarian children—see Bates & MacWhinney, 1987, for a review). However, subject–verb agreement appears in the spontaneous speech of Italian children between the ages of 2 and 3, co-occurring with expressive control over case in Serbo-Croatian and Hungarian. This comprehension/production disparity strongly suggests that agreement is vulnerable in receptive processing because of the load it places on short term memory.

A third explanation for the selective vulnerability of morphology involves an integration of semantic and memory factors in the processing of closed class elements, compared with ordered strings of content words. As Goodglass and Menn (1985) have pointed out, closed class elements are notably lacking in semantic content and hence in "imageability." This would make them, as a class, more difficult to perceive and remember. In order to use a word order cue to meaning, the listener needs to remember the verb, all the arguments of that verb, and the order in which they occur. In this sense, word order and agreement are both "global cues." However, the elements that have to be kept in mind to compute a word order relationship are usually concrete, imageable, and easy to remember (i.e., content words). The elements that have to be kept in mind to compute morphological agreement are abstract and notably lacking in imagery (i.e., number, person, gender) and very easy to forget. Hence a word order cue that is distributed over content words may be easier to use than an agreement cue that is distributed over several morphological elements.

A fourth possibility, originally proposed by Kean (1977) has to do with the phonological status of grammatical morphemes, in particular their status as unstressed clitic particles. This differs slightly from the literal "hearability" argument raised above, referring more to the internal status of stressed phonological words compared with weaker clitic forms. The various agreement suffixes manipulated in this study are all indeed un-

stressed elements of sentence structure—although the contrast between third person singular and plural verbs in Italian does involve a difference of a full syllable (e.g., *mangia*—is eating; *mangiano*—are eating). There are very few languages in which major morphological contrasts carry full stress. Turkish is one such exception, where the highly regular and semantically transparent case suffixes also carry a strong stressed vowel (Slobin & Bever, 1982). Preliminary research on the comprehension and production of case suffixes in Turkish aphasics does suggest that the Turkish morphemes may be "protected" against brain damage—even in the comprehension paradigm used in the present study (Talay & Slobin, personal communication). However, because those morphemes are also "protected" by other semantic and perceptual factors, the results are not likely to be conclusive for the clitic hypothesis.

Any or all of these factors may be operating to create the "selective vulnerability of morphology" that we have demonstrated in this study. In fact, the impairment of morphology appears to be *overdetermined*—at least in receptive language processing. *This means that patients could lose access to morphological elements for any of several reasons, and perhaps for different reasons in different patient groups.* This is consonant with an argument offered by Caramazza et al. (1981), who report evidence for receptive agrammatism in both conduction and Broca's aphasics. They suggest that the Broca's deficit is due to a central factor that holds across all modalities of grammatical processing; the conduction deficit is due, instead, to factors that are specific to receptive language. In the same vein, Friederici (1985) and Swinney, Zurif, Rosenberg, and Nicol, (1984) have suggested that differences between patient groups are more likely to appear in "on-line" tasks that make it difficult for a patient to apply metalinguistic strategies that obscure his "true" language status. Since our sentence interpretation task is most assuredly "off-line" (with very long reaction times in many instances), we cannot rule out that possibility. A final answer will require a detailed comparison of morphological processing across patient groups, *and* across tasks that tap into different processing constraints.

These arguments pertain to our surprising finding that morphology is vulnerable across many clinical populations. A different kind of challenge to our findings revolves around the amount of preservation of word order (and, to a lesser degree, morphology) evidenced by almost all our aphasic patients. Several investigators have suggested that aphasic patients may use processes that are qualitatively different from normal parsing, even though the result looks quite similar (Saffran et al., 1980; Caplan, 1983; Grodzinsky, 1985, 1986). Could our patients have "mimicked" the language-specific patterns observed in our study?

In a recent study of sentence comprehension in aphasia, Caplan (1985) has presented overwhelming evidence that problems in receptive grammar

occur in every form of brain damage; differences in performance among his large sample of patients were predicted almost exclusively by severity of aphasia, and not by site of lesion or by qualitative differences in speech behavior. Because his stimuli did not systematically unconfound word order and morphology, we cannot know the source of stimulus difficulty—at least not from the point of view of our performance model. Otherwise, however, our findings seem to yield the same conclusion: receptive agrammatism can occur for many reasons. Nevertheless, Caplan still believes in a principled distinction between the parsing mechanisms used by a normal listener (i.e., mechanisms that are informed by linguistic rules) and the grammatical heuristics used by aphasic patients (i.e., strategies that the patient develops to compensate for his loss of normal parsing). In his view, the challenge for the future is to find systematic ways to distinguish rules from heuristics, and to untangle the different "mix" of each used by patients with different etiologies.

In principle, we agree with Caplan that patients may obtain a superficially similar outcome in our sentence comprehension task by means that are qualitatively different from those employed by normals. But we do want to raise some concerns about overextending the notion of "nonlinguistic strategy." The idea that patients could short-circuit parsing in comprehension experiments was first raised in a rather conservative discussion of sentence-picture matching tasks (e.g., Caramazza & Zurif, 1976). The original idea was that patients could attend only to lexical semantic cues (e.g., "boy," "apple," and "eat,") and reconstruct a likely interpretation of the sentence without applying any form of grammatical analysis at all. Later, it was also suggested that patients could develop "pseudolinguistic" strategies that more closely mimic the operation of a parser (Saffran et al., 1980; Caplan, 1983). An example would be a heuristic like "Assume that the first animate noun you hear is the subject of the sentence." Caplan and Futter (1986) have proposed even more detailed heuristics, including the following example (Caplan & Futter, p. 9; cited by Grodzinsky, 1985): "Assign the thematic roles of agent, theme and goal to N1, N2 and N3 in structures of the form N1-V-N2-N3, where N1 does not already bear a thematic role." Unlike an event reconstruction based on lexical cues, this second kind of strategy must have its origins in the patient's knowledge of language-specific word order principles.

In our own study, patients retain control over canonical SVO; many also retain normal or near-normal use of the biases that normal speakers in each language show toward NNV and VNN constructions. They are also able to make use of a convergence between word order and morphological information to achieve quite satisfactory levels of comprehension (see also Smith & Bates, 1987). In our view, the idea of "special" nonlinguistic or pseudolinguistic strategies has to be stretched a little too far to account for such cross-linguistic differences in the use of

morphosyntactic information. Patients certainly could have a rich set of heuristics that mimic the parsing profiles of normal listeners in diverse language groups. However, we would like to find a principled, a priori way of deciding between "true" parsing and heuristic processes.

Much of the history of psycholinguistic research suggests that this distinction will not be easy to find. Whether that normal model is best described in terms of categorial knowledge, or statistical processes, is surely one of the most vexed topics in the field. It can be traced back directly to the original contrast between competence and performance—a contrast that has been repeatedly proposed and then abandoned in the field of psycholinguistics (Fodor, Bever, & Garrett, 1974; Bresnan, 1982). Bever (1970) proposed long ago that *normal* language processing may consist primarily or entirely of a massive set of heuristics and "shortcuts" that bear only a loose relationship to the speaker's idealized knowledge of his native language. We too have felt quite comfortable using the term *strategy* to account for the performance of young normal listeners in the present study, arguing all the while that this probabilistic behavior bears a systematic and meaningful relationship to both structural and statistical facts about the subject's native language. From the point of view of a performance model like ours, there may be no difference between heuristic and algorithmic processes even in normal language processing.

In the absence of a principled way to distinguish between heuristic and "real" parsing, the most parsimonious approach may be to assume that normal looking performance is governed by normal processes. As Grodzinsky (1985) puts it, "A deficit analysis should assume maximal similarity to normal."

We can only underscore the finding that morphology is indeed a particularly vulnerable and hence especially interesting domain for neurolinguistic research, even in languages where morphology is the most important source of information for normal native speakers. By contrast, basic word order patterns are robust and resistant to the effects of aging and/or the effects of specific brain damage. Hence the closed class theory appears to be correct in its broad outlines, pointing us in the direction of a lexicalist or "item-based" approach to the relationship between brain and language.

APPENDIX 1

Subject	NVN	NNV	VNN	Ag0	Ag1	Ag2	AA	AI	IA	NVN vs. Ag1	NVN vs. Ag2
English college controls											
84	89	22	0	33	50	28	39	33	39	100	67
91	94	36	56	50	72	53	64	83	39	100	83
90	100	3	0	33	36	33	36	33	33	100	100
80	89	28	11	39	67	22	44	50	33	100	67
89	100	0	0	33	33	33	33	33	33	100	100
81	61	61	50	61	100	11	50	72	50	100	0
82	78	0	6	33	39	11	22	28	33	100	33
83	100	33	0	39	44	50	44	50	39	100	100
85	100	8	0	39	36	33	42	33	33	100	100
86	100	28	6	44	56	33	50	44	39	100	100
88	78	50	39	67	67	33	56	83	28	100	50
87	78	28	22	33	78	17	56	50	28	100	50
English Broca's											
60	89	50	0	56	39	44	72	94	50	83	100
61	89	56	44	61	67	61	50	72	33	100	100
62	100	44	22	56	61	50	56	67	44	100	100
63	100	72	44	67	78	72	72	94	50	100	100
64	78	39	39	61	56	50	72	33	83	67	
65	78	44	61	44	61	56	56	56	83	67	
66	83	39	33	50	55	50	44	67	50	100	83
75	94	67	17	50	72	56	56	67	56	83	100

Italian college controls											
153	56	56	56	67	100	0	67	67	33	100	0
160	61	50	50	61	100	0	61	61	39	100	0
158	61	61	61	67	100	11	72	72	33	100	17
151	89	56	56	83	94	22	72	72	56	100	67
152	67	56	39	61	100	0	56	56	100	0	
154	61	50	53	64	83	17	58	78	28	100	17
155	56	56	50	61	100	0	61	67	33	100	0
156	61	56	56	72	100	0	67	67	39	100	0
157	67	33	39	39	100	0	44	44	50	100	0
159	61	56	61	78	100	0	67	67	44	100	0
Italian Broca's											
1	78	56	44	61	67	50	50	89	39	67	67
2	67	50	61	61	72	44	78	83	17	83	83
3	67	42	50	61	58	39	56	86	16	67	50
6	61	44	56	50	56	56	61	44	56	67	83
5	56	56	44	67	89	0	61	67	28	100	0
4	39	50	33	33	61	28	44	61	17	67	17
58	56	44	39	56	61	22	44	56	39	83	33
18	72	56	78	72	61	72	67	61	78	67	67
17	83	56	72	89	100	22	78	72	61	100	50
19	61	50	61	67	100	6	61	67	44	100	17
German college controls											
101	72	72	72	89	100	28	72	78	67	100	17
102	78	78	72	94	100	33	89	72	67	100	33
103	56	67	50	61	94	17	67	78	28	100	0

APPENDIX 1—*Continued*

Subject	NVN	NNV	VNN	Ag0	Ag1	Ag2	AA	AI	IA	NVN vs. Ag1	NVN vs. Ag2
German college controls											
104	72	72	72	94	100	22	72	78	67	100	17
105	64	61	72	92	100	6	67	72	58	100	0
106	94	100	94	100	100	89	94	94	100	100	83
107	56	56	61	67	100	6	67	72	33	100	0
108	67	56	67	89	100	0	61	67	61	100	0
109	67	67	72	100	100	6	67	72	67	100	0
100	100	100	100	100	100	100	100	100	100	100	100
German Broca's											
7	83	61	83	67	89	72	89	61	78	83	83
8	83	83	78	94	89	61	72	94	78	83	83
9	100	39	67	61	72	72	72	72	67	100	100
10	89	61	89	72	89	78	61	100	78	100	83
11	100	83	78	100	94	67	83	83	78	100	100
161	94	100	94	94	94	100	89	100	100	100	100
162	100	94	89	94	100	89	94	89	100	100	100
Italian neurological controls											
45	56	44	50	78	17	38	78	28	100	17	
46	61	39	56	50	50	56	56	100	0	67	67
47	56	50	61	56	72	39	72	78	17	83	83

48	50	50	67	56	72	39	67	83	16	50	50
49	89	61	33	56	72	55	78	61	44	83	100
50	56	44	61	72	55	33	50	89	22	50	50
51	33	39	61	50	61	22	50	72	11	67	0
52	67	61	83	100	6	67	72	50	100	0	
Italian orthopedic controls											
171	56	56	56	67	100	0	67	67	33	100	0
172	67	44	61	56	67	50	67	94	11	67	67
173	50	44	61	44	78	33	61	83	11	67	33
174	56	50	50	67	89	0	67	67	22	100	0
175	38	61	44	39	100	6	44	67	33	100	0
176	50	56	56	61	100	0	67	61	33	100	0
177	50	50	61	61	78	22	61	89	11	67	17
178	61	50	44	50	100	6	50	67	39	100	0
179	56	50	44	44	56	50	56	89	6	67	50
180	50	44	56	50	61	39	50	89	11	50	50
Older German controls											
21	83	94	89	89	89	89	94	94	78	83	83
29	100	94	94	100	100	89	100	100	89	100	100
28	100	100	100	100	100	100	100	100	100	100	100
27	100	100	100	100	100	100	100	100	100	100	100
26	78	89	83	78	100	50	78	89	83	100	33
25	78	78	61	100	100	22	83	72	67	100	33
24	78	67	78	100	94	28	67	78	78	83	50
23	83	72	83	89	89	61	100	100	56	83	83
22	72	44	67	72	94	17	78	72	50	100	17
20	100	100	94	100	100	94	100	94	100	100	100

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