The Neurology of Empty Categories: Aphasics' Failure to Detect Ungrammaticality

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Abstract

■ A direct investigation into the grammatical abilities of Broca's and Wernicke's aphasics sought to obtain critical evidence for a revised model of the functional neuroanatomy of language. We examined aphasics' ability to make grammaticality judgments on a set of theoretically selected, highly complex syntactic structures that involve, most prominently, fine violations of constraints on syntactic movement. Although both groups have been thought to possess intact abilities in this domain, we discovered severe deficits: Broca's and Wernicke's aphasics (whose performances differed) exhibited clear, delineated, and grammatically characterizable deficits—they follow from the Trace-Deletion Hypothesis, which is motivated by independent comprehension results. These conclusions have both linguistic and neurological implications: Linguistically, they show that the aphasic deficit interacts with more than one module of the grammar. Namely, it manifests not only when the thematic module is called for in interpretive tasks but also when constraints on syntactic movement are tapped in a study of judgment. Neurologically, the results support a view of receptive grammatical mechanisms in the left cortex, which is functionally more restrictive than currently assumed; neuroanatomically, however, it is more distributed. ■

INTRODUCTION

Current neurological modeling of language perception has syntax located anteriorly in the left cerebral hemisphere, and semantics and the lexicon are posteriorly represented—located temporo-parietally around the Sylvian fissure (Alexander, Naeser, & Palumbo, 1990; Caplan, 1987; Damasio & Damasio, 1989). Results from experiments on aphasic patients with focal lesions in these regions constitute the main evidential basis for this view: It is now recognized that the comprehension deficit in Broca's aphasia (subsequent to damage to Broca's area and its vicinity) implicates receptive mechanisms of grammatical analysis (Damasio, 1992; Goodglass, 1983; Zurif, 1980), whereas Wernicke's aphasia (following a posterior lesion in and around Wernicke's area) involves the lexical and interpretative components of the language faculty (Goodglass & Kaplan, 1983; Damasio & Damasio, 1992; Zurif, 1995).

Upon a more careful examination, however, the experimental evidence becomes less conclusive, at times even appearing contradictory: Wernicke's aphasics have some disturbances in syntactic comprehension (Zurif & Caramazza, 1976; Shapiro, Gordon, Hack, & Killackey, 1993), and Broca's patients fail at certain tasks that probe receptive syntactic abilities (Caramazza & Zurif, 1976) but are successful in others. Taken at face value, these findings cast serious doubts on the model in which Broca's area (but not Wernicke's) supports receptive syntactic mechanisms. Yet, given certain provisos, the neurological model can still be maintained. Wernicke's patients' failures in syntactic comprehension are rather inconsistent and varied (Shapiro et al., 1993; Zurif, 1995; Zurif & Caramazza, 1976) and are by and large ignored. In the case of Broca's aphasia, moves have been made to reconcile empirical contradictions: Syntactic abilities have been broken down into tasks, and it has been claimed that "syntactic comprehension is compromised" (Martin, Wetzel, Blossom-Stach, & Feher, 1989) and that "grammaticality judgment is intact" (Linebarger, Schwartz, & Saffran, 1983).

Common to such analyses is a rather "holistic" approach to the functional deficit, issues of cerebral localization being of more concern than linguistic questions. Gross distinctions between form and meaning seem sufficient, and hence, less attention is paid to more detailed structural properties of linguistic stimuli. These interpretations of results have enabled the neurological model of language to prevail, with further corroboration (albeit limited) from electrophysiological studies (ERP) (Friederici, 1995; Kluender & Kutas, 1993; Münte, Heinze, & Mangun, 1993; Neville, Nicol, Barss, Forster, & Garrett, 1991) and from functional imaging (Bookheimer, Zefiro, Gallard, & Theodore, 1993; Stromswold, Caplan, Alpert, &

Rauch, 1996). The relative difficulty (dictated by technologically imposed constraints) in making fine distinctions among complex linguistic types makes the latter techniques slightly limited. This observation, when coupled with the fact that many lesion analyses lump together complex grammatical systems without necessarily distinguishing among syntactic types that are used in experiments, may account for the apparent inconsistencies in results discussed above. Namely, it is possible that seeming experimental discrepancies can be reconciled upon an examination of the details of the structural properties of experimental stimuli. This move gives rise to a new, alternative interpretation: Broca's (and perhaps Wernicke's) aphasia may become a *selective* deficit to receptive grammatical (i.e., syntactic) mechanisms, affecting only subsystems of the syntax (in addition to overt problems in speech production). In this view, inconsistencies in experimental results are only apparent and disappear once the right linguistic distinctions are made. The data are thus explained, and a more restrictive view of the role the language areas play in language processing emerges (cf. Grodzinsky, 1986, 1990; Fromkin, 1995; and Grodzinsky, 1993, for edited collections championing this approach).

The implications of these conclusions to the neurological study of language cannot be underestimated: Data on a partial syntactic deficit not only lead to a refinement of our view of brain/language relations but also force an experimental linguistic approach, which commends extensive use of large varieties of sentence types as test materials. Given inherent limitations of current imaging and electrophysiological methods regarding fine distinctions among linguistic types, one must rely almost exclusively on investigations of aphasics because aphasia studies are the ones that enable tests of the most fine-grained aspects of language and their neural representation.

We therefore followed the grammatical perspective, adopting, as a descriptive device, the Trace-Deletion Hypothesis (TDH: Grodzinsky, 1986, 1990, 1995). This account, aimed at a precise characterization of the pattern of selective loss and sparing in agrammatic Broca's aphasia, is based on the observed correlation between a syntactic property of a sentence (i.e., its being derived by a grammatical transformation) and a comprehension failure in this syndrome. A syntactic transformation is a complex operation that moves sentential constituents (i.e., it changes their position in the string relative to other constituents). One part of this operation is the creation of a *trace*—an abstract position marker that appears in the representation of a transformationally derived sentence, marking the position from which the moved element had been extracted. Traces bear a complex relationship to their antecedents (the "moved" elements), which the theory specifies precisely in the form of general constraints. Trace-antecedent relations, and constraints thereof, explain a large number of syntactic phenomena observed in natural language. In a modular grammar such as is commonly assumed, traces interact with more than one module. Most notably, they play two roles in syntactic representations: First, they mediate the indirect assignment of thematic (θ-) roles—the (θ-) role of a moved constituent is transmitted to its "new" position by virtue of a link established between this constituent and its trace (in the "old" premovement position); second, they are critically involved in the determination of grammaticality. Licit and illicit movements are expressed in the form of constraints that either ban certain configurational relations between traces and their antecedents or prohibit the presence of traces in certain positions (more on that below).

Regarding agrammatic Broca's aphasia, the TDH claims that traces of syntactic movement of phrasal constituents are deleted from grammatical representations of patients, resulting in a selective syntactic impairment. When a noun phrase is moved, a trace is left behind, yet in agrammatism, according to the TDH, there is no trace, and therefore the syntactic relations it mediates cannot be computed by the linguistic system of the agrammatic. Assignment of thematic (θ)-roles to such moved noun phrases (NPs), which is normally transmitted through the trace, cannot take place, causing an interpretive deficiency. With certain auxiliary assumptions, the comprehension deficit follows. Thus, structures with constituent movement are the locus of the comprehension disorder, whereas traceless structures, or structures with traces of nonphrasal categories (i.e., heads, see below), are intact.

This view is more restrictive than the one standardly held: It maintains that only transformationally derived structures, and nothing else, would cause comprehension problems to agrammatic Broca's aphasics, detectable in timed and untimed receptive language tasks. Empirical evidence to that effect has accumulated (Zurif & Caramazza, 1976; Shapiro et al., 1993; Grodzinsky, 1989; Hickok & Avrutin 1995; Hagiwara, 1995; Swinney, Zurif, & Nicol, 1989; Zurif, Swinney, Prather, Solomon & Bushell, 1993; Lonzi & Luzzatti, 1993; Swinney & Zurif 1995).[1] As for Wernicke's aphasia, no structural hypothesis is available because there is no systematic study of the syntactic deficit in this disorder. As a consequence, little evidence is available on the role the temporal lobe plays in syntactic processing. Our exploration, which focused on judgment of the grammaticality of sentences (rather than comprehension), is thus the culmination of a series of experiments, with results that underscore the value of the neurolinguistic approach for models of language localization.

Our investigation, in fact, goes in yet another direction. Uncovering the aphasic deficit may have implications not only to the neurological theory of language representation but also to the theory of function—linguistic theory. If linguists take their theory to be *about* the human linguistic capacity, it implicitly contains a theory of language loss: Any linguistic theory has certain predictions about the way language may or may not be lost. Our findings, thus, may have implications in both directions—linguistics and neurology. So, the issue we sought to test—whether or not the disruption to traces of transformational movement, implicated in the comprehension deficit, is reflected in the patients' performance on acceptability judgments as well—is important in two respects:

Neurologically, we wanted to demonstrate that, contrary to common belief, the deficit is structure dependent and not task dependent, namely, that the common sweeping claim that grammaticality judgment is intact (whereas comprehension is disrupted) in agrammatism is false. Rather, we sought evidence supporting the claim that the deficit implicates certain syntactic resources that are exploited in *any* language task insofar as the structures involved are of the right kind. Obviously, the most powerful way to demonstrate this point is indeed through grammaticality judgment. Comprehension, so the story goes, requires both syntactic analysis and interpretation. Because grammaticality judgment makes no interpretive demands and taps syntactic abilities in the "purest" form possible, showing structurally selective failures in a judgment experiment should be most compelling.

Linguistically, we wanted to show that the aphasic deficit interacts with more than one module of the grammar. Specifically, the available evidence suggests that only the θ-module is involved because the main experimental findings regarding the agrammatic comprehension deficit come from comprehension studies, which document failures to assign θ-roles to moved constituents. Yet, if the deficit is not restricted to the θ-module, we should expect it to manifest elsewhere, namely, in tasks that require the mobilization of other parts of the grammar. In particular, since traces are also involved in the operation of constraints on syntactic movement, the TDH would predict that violations of grammaticality, in which the trace is crucially involved, would go undetected by agrammatic aphasics. This is because these traces are deleted from the representation and hence cannot participate in the determination of the grammatical status of a string. Such a finding, if obtained, would provide strong evidence to the claim that the deficit manifested in trace-deletion is indeed representational and does not follow from a deficit to a specific grammatical module. This conclusion would follow from a demonstrated multimodular deficit to the grammar in the sense detailed above.

We thus investigated these highly complex issues through a grammaticality judgment task, for which a rather sophisticated choice of experimental materials was necessary. In order to explain our research question, as well as the choice of structures we investigated, we now present a rough typology of syntactic movement operations and certain principles that constrain them. Grammatical transformations, or movement rules, are complex operations that typically involve the copying of an element (a phrasal or lexical category) to a position other than its underlying one and the substitution of this element by a trace in the latter position. This creates objects called *syntactic chains,* which contain the antecedent and its traces (one or more) in the form of an ordered set of syntactic markers that represent the path of the moved element from its underlying position to the position where it is phonetically realized. Movement is constrained—elements cannot move freely within a string. One way of getting this result is by stating prohibitions on certain possible relations within a chain, namely, by formulating constraints on the internal structure of these syntactic objects. To demonstrate all that, we present a typology of syntactic chains and a certain constraint on movement that manifests in each type.

X^0-Chains (Verb Movement)

X^0-chains are objects that are created from movement of a lexical (rather than phrasal) category—a head. Not every movement of a head results in a grammatical string, as can be seen in the case of verb movement in the formation of yes/no questions in English (1):

(1) a. They could have left

b. *Could* they *t have* left?

c. **Have* they *could t* left?

Here the question-forming operation moves a verb to the front of the sentence by copying the verb in the first position and substituting it by a trace in its original position. Importantly, the only modal *could* may move (1b) but not *have* (1c). To account for such facts, the Head Movement Constraint has been proposed (cf. Chomsky, 1986; Pollock, 1989; Travis, 1984), according to which a head that moves cannot skip an intervening head between its base position and its landing site.[2] Consider how this constraint accounts for (1). It claims that (1c) is ungrammatical because movement of *have* would cross an element of the same kind. This, however, is not the case in (1b)—*could* does not cross a like element. The asymmetry in (1b) and (1c) thus follows. Verb movement is restricted, and the Head Movement Constraint is a property of X^0-movement in general: Similar effects are observed in negation, placement of adverbs in certain languages, Subject-Aux-Inversion, Do-support, and the movement of main verbs into second position in Germanic languages (see Haegemann, 1991, for an exposition). As we shall see, other types of syntactic movement will be similarly constrained, although they will differ in many other respects from X^0-movement.

A-chains (NP-movement)

Perhaps the best-known type of movement operation is the one that covers cases that result in chains headed by a phrasal constituent in an A-position. They include passive, unaccusatives (including Raising), and perhaps Psychological predicates (cf. Belletti & Rizzi, 1988; Pesetsky, 1994). Here movement is again constrained by some principle that must block, among other things, cases like (2f):

(2) a. It is likely that [Mary will win]
 b. *Mary* is likely [*t* to win]
 c. It seems that [Mary is foolish]
 d. *Mary* seems [*t* foolish]
 e. *It* seems that *Mary* is likely [*t* to win]
 f. **Mary* seems that *it* is likely [*t* to win]

In a sense, the restriction here resembles the previous one: all the A-movements in (2a through e) are licit, yet once the moved NP *Mary* crosses a like element (*it*), ungrammaticality results. Although chains of different types indeed differ in certain respects, they do not constitute totally distinct formal objects (cf. for instance, Lasnik & Uriagereka, 1988, for expository discussion). Rizzi (1990) proposed to unify the relation between all types of empty categories and their antecedents while preserving certain distinctions among chain types. This is a constraint called Relativized Minimality (RM)—a condition that looks at chains and determines whether or not a particular link within it is a legitimate formal object. RM requires that a trace be governed by the closest (minimally distant) potential antecedent (with government being a well-defined formal notion). In (1c) *could* is a potential antecedent, yet the government relation must hold between *have* and the trace; in (2f) *it* is a potential antecedent, yet the government relation could hold between *Mary* and the trace. The cases are thus similar in that there is illicit crossing of a potential antecedent, yet they differ, among other things, in the identity of this antecedent. The Minimality requirement must therefore be defined relative to antecedent type in each chain type—a potential antecedent is of the same type as the moved one, hence *Relativized* Minimality.[3]

A′-Chains (Wh-Movement)

These are typically chains of wh-movement (including questions, relative clauses, and the like). The antecedent is an element in an A′-position, and RM must, again, block movement that crossed a potential antecedent—a constituent of the same kind as the moved one. A question cannot cross another question. It is easy to see how the asymmetry in grammaticality between multiple question structures (3a) and (3b) follows from RM:

(3) a. *Whom* did John persuade *t* [to visit *whom*]
 b. **Whom* did John persuade *whom* [to visit *t*]

We see, then, that in each of the cases there is an asymmetry between two types of movement operations (4a-b):

(4) a. ...*X*...*t*...*Y*...
 b. *...*X*...*Y*...*t*...

In one (4a), no crossing of an element of the same kind occurs, resulting in grammaticality; whereas in (4b), crossing leads to ungrammaticality. RM covers all these, abstracting away from the identity of the elements involved by requiring that the definition of minimality be relativized to the category of the moved element. So, if the moved category is a head, it cannot cross similar heads; if it is an NP, it is barred from crossing other NPs; if it is a question (wh-)expression, it is likewise prohibited from crossing others, as the linguistic data above demonstrate. Minimality considerations such as RM are central to the current linguistic framework (cf. Chomsky, 1995 and much subsequent literature). Obviously, the presentation here is schematic, dodging over many problems and issues. For present purposes, however, it will suffice.

What happens if traces are deleted from syntactic representations? Can considerations of grammaticality in which traces are involved, such as RM, be executed over a traceless representation? This is an issue raised by the TDH with respect to agrammatism and whatever other syndromes for which deficits consistent with this hypothesis may be found. If traces are indeed deleted from syntactic representations as a consequence of focal brain damage, no computation of ungrammaticality can be carried out properly in constructions where traces are involved. On the other hand, if the deficit implicates only certain functional aspects of traces (for instance, their role in mediating indirect assignment of θ-roles), in spite of the comprehension deficit, the patients will exhibit normal, full-fledged abilities in detecting violations even if the representation of traces is mandatory.

It is for these reasons that we set ourselves to test aphasics' abilities to judge the grammaticality of strings that contain traces along the lines presented in the foregoing discussion. Recall that this test was devised against task-based claims that there is no purely syntactic deficit in Broca's aphasia, hence no judgment problem, and that what appears to be a syntactic disruption is a reflection of a disruption to interpretative stages of language processing. The structural TDH, by contrast, had never been tested from this experimental perspective. We tested the patients on violations of RM in all chain types, we tested them on violations of related grammatical principles in A′-chains, and finally, we tested them on violations that involve no chains at all. Our test (Table 1) was structured as follows: Conditions 1 through 4 involved violations of movement of phrasal categories (*XP*-movement), broken down to Condition 1, which contained cases of NP-movement that create A-chains and violations of RM such as (2) (Superraising); Conditions 2 and 3 contained violations of constraints on movement in A′-chains, other than RM (although they are arguably related—*that-trace* effects and adjunct/complement asymmetries, respectively); and Condition 4 involved violations of RM in A′-chains (Superiority). Importantly, there are comprehension results for such structures, documenting selective deficits along the lines of the TDH and its real-time correlates (Grodzinsky, 1989; Hagiwara, 1995; Hickok & Avrutin, 1995; Swinney & Zurif, 1995; Swinney et al., 1989; Zurif et al., 1993). Conditions 5 through 8 were controls: In 5 and 6 there are violations of grammaticality, but none requires the representation of traces for their detection. Condition 5 contains a violation in which the gap left by a moved constituent is filled, for which knowledge of argument structure is necessary (Linebarger et al., 1983; Shapiro & Levine, 1990; Shapiro et al., 1993), and Condition 6 features systematic violations of lexical requirements. Conditions 7 and 8, on the other hand, tested violations of RM in cases of traces of X^0-movement (which are presumably intact for the patients), namely, that of a lexical (as opposed to phrasal) category (see data in Lonzi & Luzzatti, 1993, and analysis in Grodzinsky, 1995). We tested both Broca's and Wernicke's aphasics because the latter were also expected to do well on our test.

RESULTS

We report three findings:

1. Severe grammaticality judgment deficits in both syndromes.
2. A deficit restricted to a particular set of structures, namely, those involving the movement of phrasal constituents (A- and A′-chains only). All others are intact.
3. A between-groups difference.

Table 1. Examples of the Test Sentences

Condition	*+Grammatical*	*−Grammatical*
1. NP movement	It seems likely that John will win. It seems that John is likely to win. John seems likely to win.	**John seems that it is likely to win.*
2. Wh-movement/that-trace	Which woman did David think John saw? Which woman did David think that John saw? Which woman did David think saw John?	**Which woman did David think that saw John?*
3. Superiority	I don't know who said what.	**I don't know what who saw.*
4. Adjunct/complement	When did John do what?	**What did John do when?*
5. Filled gaps	Who did John see? Who saw John?	**Who did John see Joe?* **Who John saw Joe?*
6. Bad complements	The children threw the football over the fence. The children sang.	**The children sang the football over the fence.* **The children threw.*
7. Place of auxiliary	They could leave town. Could they leave town? They could have left town. Could they have left town? They have left town. Have they left town?	**Have they could leave town?*
8. Negation	John has not left the office. John did not sit.	**John did not have left the office.* **John sat not.*

The Broca's Aphasics

See Table 2. The overall error rate was 26.6% per condition (Misses, 28.1%; False Alarms, 24.8%, collapsing across grammatical types).[4] Performance showed a clear pattern: There was a marked deficit in structures involving *XP* movement, i.e., displacement of phrasal constituents; [Conditions 1 through 4, with 21/32 (65.6%) cells with "high" error rates (>25%), and 12/32 (37.5%) cells with "very high" error rates (>50%)] whereas structures and violations involving lexical requirements (Conditions 5 and 6), and X^0 movement (i.e., displacement of lexical categories; Conditions 7 and 8) were relatively preserved [6/32 (18.7%) cells with "high" error rate; 2/32 (6.7%) cells with "very high" error rate]. The raw data show two types of differences: There are differences in error rates between the "test" Conditions 1 through 4 and the "control" Conditions 5 through 8, and there are individual differences in the Misses to False Alarms ratio. A 2 × 2 within subject analysis of variance (ANOVA) with two factors (condition type, grammaticality) revealed a significant difference between these two types of conditions (1–4 vs. 5–8); ($F(1, 3) = 25.11, p < .05$). No effect of grammaticality (i.e., when the scores on grammatical sentences were compared to those on the ungrammatical ones) was found ($F(1, 3) < 1, p = .83$) and no interaction. Similar results were obtained through an analysis that categorized performance levels into four levels according to percentage of error. An individual subject analysis indicated that the performance of all patients was in the predicted direction. A further subject analysis revealed yet another difference between the two condition types: Every patient had a high error rate in at least one of the two halves (+G, –G) of each of Conditions 1 through 4, but not for Conditions 5 through 8.

The Wernicke's Aphasics

See Table 3. The overall error rate was 26.3% (Misses, 33.8%; False Alarms, 17.8%). When data are categorized, a marked deficit is found in Conditions 1 through 4 [28/56 (50%) cells with "high" error rates (>25%) and 20/56 (35.7%) cells with "very high" error rates (>50%)], whereas Conditions 5 through 8 were less impaired [17/56 (30.3%) cells with "high" error rate; 7/56 (12.5%) cells with "very high" error rate]. On this measure, the difference between condition types is ostensibly smaller than in the Broca's patients. A 2 × 2 ANOVA with the same design as above revealed a significant difference between the two condition types ($F(1, 6) = 18.3, p < .05$), no effect of grammaticality ($F(1, 6) = 2.53, p = .16$), and no interaction. Individual variation in this group was greater than that of the Broca's aphasics. A subject analysis revealed no additional differences. An analysis with the categorized data obtained similar effects.

Between Groups Comparisons

An ANOVA with a 2 × 2 × 2 design with one between subject factor (patient type) and two within subject factors (condition type, grammaticality) revealed no significant main effect for patient type. However, condition × patient interaction approached significance ($F(1, 9) = 3.94, p = .078$). An analysis with the data categorized into four performance levels also revealed an interaction ($F(1, 9) = 4.61, p < .060$), as did a nonparametric test.

Overall, our results indicated that the experiment was well balanced: For both groups, item analyses revealed no effects of order or any specific item. For all subjects of both groups, errors were distributed across the four experimental sessions in a roughly uniform manner.

Table 2. Broca's Aphasics' Scores (% error)

	Patient								
	FC		*RD*		*FA*		*WF*		
Condition	*+G*	*–G*	*+G*	*–G*	*+G*	*–G*	*+G*	*–G*	*X'*
1. NP movement	0	*25*	25	*38*	0	***100***	38	*0*	28.2
2. Wh-movement/that-t	0	***88***	**75**	*25*	0	***100***	33	*38*	44.9
3. Superiority	0	***63***	**63**	*38*	**75**	*0*	**88**	*0*	40.9
4. Adjunct/complement	0	***88***	**88**	*0*	**75**	*25*	**88**	*0*	45.5
5. Filled gaps	0	*0*	19	***69***	0	*13*	6	*13*	15
6. Bad complements	0	*4*	0	*17*	13	*0*	38	*0*	9
7. Place of auxiliary	0	*25*	4	***75***	2	*0*	21	*0*	15.9
8. Negation	0	*13*	6	*25*	0	*19*	38	*6*	13.4

Normal font indicates judgment of grammatical sentences (errors = False Alarms).
Italic indicates judgment of ungrammatical sentences (errors = Misses).
Gray areas mark high error rates (>25%); **Bold** marks very high error rates (>50%).

Table 3. Wernicke's Aphasics' Scores (% error)

	Patient														
	RDe		*WD*		*NLC*		*JB*		*JML*		*WN*		*CC*		
Condition	*+G*	*−G*	*+G*	*−G*	*+G*	*−G*	*+G*	*−G*	*+G*	*−G*	*+G*	*−G*	*+G*	*−G*	*X'*
1. NP movement	4	***50***	0	***75***	0	*6*	25	*25*	4	*38*	0	***100***	0	***50***	*26.9*
2. Wh-movement/that-trace	42	***63***	13	***75***	17	***100***	**92**	*13*	29	***63***	13	***63***	8	***75***	*47.5*
3. Superiority	0	*25*	13	*38*	0	***88***	**50**	*13*	0	*0*	13	***100***	0	*0*	*24.3*
4. Adjunct/complement	0	*0*	**50**	***63***	**50**	*0*	**100**	*13*	38	*0*	13	***75***	**100**	*0*	*35.8*
5. Filled gaps	6	*0*	25	***69***	0	***50***	13	*0*	0	*13*	13	***44***	6	*6*	*17.5*
6. Bad complements	0	*13*	**75**	*4*	25	*0*	0	*13*	0	*13*	0	*21*	0	*4*	*12*
7. Place of auxiliary	17	*0*	2	***63***	0	***75***	15	*0*	4	*38*	0	***100***	6	*13*	*23.8*
8. Negation	0	*31*	44	*25*	0	*6*	44	*0*	13	*38*	19	***50***	6	*44*	*22.8*

Note: Normal font indicates judgment of grammatical sentences (errors = False Alarms).
Italic indicates judgment of ungrammatical sentences (errors = Misses).
Gray area marks high error rates (>25%); **Bold** marks very high error rates (>50%).

Variation

We chose to present the raw data in conjunction with the statistical analysis in order to discuss explicitly the potential significance of variation within subjects and the proper way to treat it. We made this rather unusual move in order to grapple with the nagging problem of intersubject variation, which was, apparently, considerable for both the Broca's and the Wernicke's aphasics. Such apparent variation leads, like always, to two paths: one that focuses on commonalities among the patients; and the other, on differences.

We focused on the dimension that points to similarity between the patients (i.e., the contrasts between conditions) rather than the one along which they varied (i.e., within condition preferences). Our decision to analyze the data in this way was not arbitrary or biased. It stems from the view that the crucial aspect of the data is the selective representational deficit that is common to all patients. Such a deficit defines boundaries for erroneous behavior, within which each patient may operate according to individual choice. Specifically, lack of traces in syntactic representations leads to uncertainty regarding their grammatical status. This uncertainty is the critical aspect of the aphasic deficit. The resulting behavior may be varied, subject to idiosyncratic response bias: A patient, faced with uncertainty due to this grammatical deficit, may overaccept, or overreject, with the response being dictated by personal preference, as well as situational factors. Variation in this case thus reflects, most likely, individual strategies for dealing with uncertainty that is a consequence of the deficit, not its core. Any interpretation of the results must therefore abstract away from this aspect of the data in order to detect the underlying cause of uncertainty, which is uniform. The standardly used signal detection theoretic analysis would thus not be useful in the present case for the establishment of a criterion because individual differences are acknowledged in the analysis, yet are claimed to be irrelevant on conceptual grounds.

DISCUSSION

The demonstration of multiple errors in this task for both syndromes is new (although there are some possible correlates to it in ERP studies, cf. Friederici, 1995; Kluender & Kutas, 1993; Mauner, Fromkin, & Cornell, 1993; Münte, Heinze, & Mangun, 1993; Neville et al., 1991; see also Mikelic et al. 1995, for a related study). Although severe, the disturbance to receptive syntax in Broca's and Wernicke's aphasia is highly restricted, pertaining solely to the representation of dependencies between traces and their antecedents, provided that these antecedents are phrasal, not lexical, categories (*XP*-movement). The orientation of the deficit analysis now changes: Rather than being *task oriented* (i.e., linked to comprehension, and not grammaticality judgment, across grammatical types), the analysis becomes *structure dependent* (i.e., linked to syntactic construction across tasks). Thus the common belief in the field—that judgment is intact even though comprehension is compromised—is unjustified; rather, the picture now becomes more closely tied to grammatical factors: In syntactic constructions that contain traces of *XP*-movement, the patients may fail in *any* task. Moreover, at least as far as our study is concerned, Wernicke's aphasics are also impaired rather severely, again, contrary to what has become common knowledge. Namely, they are grammatically intact but impaired in certain aspects of interpretation. And although a precise characterization of the deficit in this syndrome remains to be worked out, two

Table 4. Patient Information—Broca's Aphasics

Patient	*Sex*	*Hand*	*Age*	*Onset*	*Lesion Site*	*Clinical Signs*	*Speech*
FC	M	R	63	1973	MRI 10/24/94: Very large left dorsolateral frontal lobe lesion involving almost all of the inferior and middle frontal gyri. Lesion includes all Broca's area and the white matter deep to it. Lesion continues superiorly to includes the lower 2/3 of the premotor, motor, and sensory cortex and the WM and PVWM deep to these areas. There is no lesion in the temporal and parietal lobules.	R hemiparesis	Nonfluent Telegraphic Agrammatic Dyspraxic
RD	M	R	79	7/76 & 11/77	CT 1978: 2 left frontal lesions—Broca's area with deep extension across to L frontal horn—lower motor cortex (face and lips). L temporal lobe sparing more than 1/2 of Wernicke's area.	Mild R weakness	Nonfluent Telegraphic Agrammatic
FA	M	R	71	7/5/92	Left CVA—unremarkable CT scan done on date of stroke.		Nonfluent Telegraphic Agrammatic Paraphasias
WF	M	R	60	4/30/94	CT 5/21/94: A large lateral frontal lesion, a large lesion in frontal operculum, and two small lesions, one to motor cortex and the other to caudate putamen (anterior limb of internal capsule).	R hemiparesis	Nonfluent Agrammatic Impaired articulation Long latencies in speech

novel conclusions must be emphasized because they follow directly from our results: (1) There is a syntactic movement-related deficit in posterior (Wernicke's) aphasia, and (2) this deficit is not identical to that found in anterior (Broca's) aphasia.

These observations lead to some general conclusions regarding the neuroanatomy of linguistic functions: (1) Both major language areas are implicated in the representation and processing of complex syntactic dependencies (although they may differ in the exact details of this involvement), (2) many syntactic operations are computed in loci that are still to be discovered, as indicated by the intactness of other syntactic skills in our patients, and (3) given the distinct speech production patterns in the two syndromes, our results argue for a dissociation between processes of language production and reception in the left cortex.

Linguistically, the finding for Broca's aphasia coheres with previous comprehension results and with the TDH: The intactness of X^0-movement (in both judgment and comprehension) rules out a disorder overarching all types of syntactic transformations. Specifically, the deficit cannot be attributed to general constraints on grammatical operations, such as RM, or to any other principle of minimality, because not all operations that fall under such principles are impaired, as we have seen. The apparent intactness of these general principles leads to the conclusion that the deficit is to syntactic *representations,* not principles. That is, the medium for representing syntactic analyses is disrupted, blocking the representation of empty categories, with ramifications to any receptive linguistic activity that presupposes the postulation of such categories, whether comprehension, judgment, or real-time tasks. Moreover, the deficit has now been shown to be multimodular. That is, it is not restricted to the thematic part of the grammar or to that part that governs the distribution of traces. Rather, it *interacts* with the various grammatical modules, and hence, the only locus for impairment is the medium for representation, where various relations are computed and the different constraints are satisfied. This view receives further corroborating evidence: Zurif et al. (1993) and Swinney and Zurif (1995) have shown that agrammatic aphasics are unable to carry out normally processing tasks that involve empty categories. Their findings, together with the current result, point in the same direction: that the deficit is indeed to the representational medium rather than to grammatical (or other) knowledge.

Regarding Wernicke's aphasia, ours is the first study to document a systematic syntactic deficit, opening new venues for the understanding of the mixed picture

Table 5. Patient Information–Wernicke's Aphasics

Patient	*Sex*	*Hand*	*Age*	*Onset*	*Lesion Site*	*Clinical Signs*	*Speech*
JB	M	L	54	9/94	CT 11/30/94: L temporo-parietal lesion involving ~1/2 of Wernicke's area and portions of middle temporal gyrus, extending to anterior middle temporal gyrus. Also: a small superior extension into the posterior supramarginal gyrus; a patchy lesion in area 37.	Mild R visual field cut	Fluent Anomic Paraphasias
CC	M	R	69	6/20/84	CT 7/17/84: L hemisphere lesion involving portion of posterior temporal lobe with superior extension into the supramarginal and angular gyri (surface and deep) and large occipital lobe lesion.	R homonymous hemianopsia	Fluent Anomic
RDe	M	R	55	7/30/85	CT 7/31/85: Low-density area in anterior part of L temporal lobe near the sylvian fissure.	Mild R weakness	Fluent Neologisms Paraphasias
WD	M	R	72	2/24/91	CT: L hemisphere lesion in the posterior part of the inferior section of MCA and 1/4 of Wernicke's area deep to supramarginal gyrus.		Fluent Anomic
NLC	M	R	68	10/12/87	CT 10/13/95: Decreased density in L posterior parietal. Adjacent to the posterior body of L lateral ventricle, lesion does not appear to distort the ventricle. Low-attenuation region in L posterior temporo-parietal region.	No hemi-weakness or sensory deficits	Fluent Naming difficulty Paraphasias Neologisms
JML	M	R	59	1/6/86	CT 1/22/86: Vague patchy lesion involving the L temporal isthmus and posterior superior portion of putamen and insular area. Patchy, superior lesion extension in posterior supramarginal and angular gyri with deep extension across to the border of the body of L lateral ventricle-interrupting pathways of arcuate fasciculus.	R hemiparesis R hemisensory deficit R field cut	Fluent Anomic Paraphasic
WN	M	R	72	12/14/94	MRI 12/15/94: Extensive, diffuse acute cortical infarction involving the distribution of the L MCA extending from the middle to posterior left temporal lobe, inferior parietal lobe and anterior occipital lobe. No hemorrhagic component is identified.		Fluent Paraphasias

drawn by previous results. Some involvement of temporo-parietal areas in syntactic processing has been shown, yet only when additional, solid findings are obtained, can the precise role of these regions be determined. The role of the language areas in reception of syntax is thus more limited than current views maintain—they implement only subsystems of syntax (albeit highly complex ones). The computation of these functions, however, is disrupted as a consequence of more cerebral areas than previously supposed.

METHOD

Subjects

A total of 11 aphasic subjects participated in this experiment, four Broca's and seven Wernicke's aphasics. They were all selected by the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1983), neuroimaging data, and clinical workup (see Tables 4 and 5 for details). The Broca's aphasics were also screened for comprehension: We tested only patients who performed significantly above chance on a selection test requiring the proper comprehension of active and subject-relative sentences and at chance level (guessing performance) on passives, and object-relatives (see Grodzinsky, 1991; Grodzinsky, Pierce, & Marakovitz, 1991; Swinney & Zurif, 1995 and many others for justification of such a selection). Informed consent was obtained from all subjects, in accordance with the current requirements of the institutional review board of Boston University School of Medicine.

The Test

We devised a test containing a carefully selected variety of sentence types, some violating, and others conforming to, the relevant principles of syntax—those that govern traces. We asked our patients to judge the grammaticality of strings of words (some grammatical, others ungrammatical).

There were several technical problems we had to solve before embarking on our study. First, there are many fine judgments that are done best contrastively. That is, certain violations of grammaticality are so fine that they can be detected only when pitted against their grammatical counterparts. Such cases had to be excluded from the test because our patients, being aphasic and suffering from even slight memory limitations, could not be expected to hold one complex sentence in memory and compare it to another.[5] Second, the concept of grammaticality judgment is foreign to most people, and we had to go through detailed explanations to convey to our subjects (aphasic and nonaphasic alike) what exactly we wanted. Many subjects confused grammaticality with norm, and, seeking to impress the experimenter, overrejected. To overcome all these difficulties, we piloted the test with matched normal controls for over a year and changed instructions and test parts gradually until we reduced error rates to the desired minimum. The instructions are very detailed, and the test contains a large set of control structures (see Appendix for instructions).

The experiment presented subjects with sentences of different types, randomized[6] so that no two structures of the same type appeared in succession, and evenly divided into four testing sessions (whose order was varied across subjects), separated into two visits per subject, at least 48 hours apart. Each visit was composed of two sessions, with a 10 to 15-min break in between. Sentences were presented both visually, printed in very large (48-point) font, and auditorily, read aloud twice[7] (or more, if the subject so requested) at the same time, and the patients (seated in front of a three-ring binder containing 124 standard sheets) were asked to decide whether each was grammatical or ungrammatical. Responses were communicated through a response sheet that is standardly used in this type of study (a colored smiling face with "yes" under it and a frowning face with "no"). The experimenter encouraged the subject to point to one of the faces to indicate the response, rather than attempt to say Yes or No because four of our eleven subjects were nonfluent Broca's aphasics. No time limits were imposed because we wished to probe grammatical ability in as "pure" a fashion as possible, and subjects were encouraged to ask for repeated readings upon need and to request breaks if they felt tired. There was a relatively lengthy training session in which detailed instructions were given, explaining and demonstrating the nature of the task. This was necessitated by the extreme subtlety of the judgments required. Ten practice sentences were given (of types unrelated to the experimental material). Feedback and examples of correct and incorrect responses were given only during the training phase. The validity of the instructions and the test materials had been secured through the testing of several neurologically intact, socioeconomically and age-matched control subjects, whose error rates were less than 5%, randomly distributed across conditions. The test itself had a variety of syntactic constructions containing traces of movement, where, crucially, the trace is directly involved in the determination of the grammatical status of the structure. Each violation was accompanied by a set of grammatical controls. We thus presented our patients with eight test conditions (where a condition stands for a grammatical principle). Each sentence type had eight tokens in the experiment. So, given that there were 31 different types, the total number of sentences in this experiment was 31 * 8 = 248.

APPENDIX

Instructions to Subjects

In this study you will be looking at and listening to sentences. You will hear a sentence (I will read each sentence aloud twice), and you will also be able to see the sentence written on a piece of paper. Some of these sentences are good English sentences, but some are bad English sentences. The ones that are bad sentences are bad because they don't make any sense or they sound funny when you hear them spoken.

For example, the sentence "The player hit the baseball lightly" is a good sentence, but the sentence "Lightly hit player the baseball the" is a bad sentence—it doesn't make any sense and it sounds strange. When you hear and see the sentence, it is your job to decide whether it is a good sentence or a bad sentence. If it is good, point to the smiling face, which is the Yes response. If it is a bad sentence, point to the frowning face, which is the No response.

We are interested in what you think about these sentences (i.e., your intuition—which is not always what you learned in grammar school). For example, when you hear the sentence "where are you coming from?," this sounds like a good sentence, right? (Wait for subject to confirm). However, in school they teach you that even though this sentence looks and sounds good to you, it is a bad sentence because it ends in a preposition. But we are interested in *your* intuitions. So, think about the sentence "John was seen Bill Mary." It doesn't end with a preposition and still, you know that this is a bad sentence because it looks and sounds funny.

In other words, when you hear and see the sentence, don't make judgments about the sentence based on rules of grammar that you learned in school—just ask yourself if the sentence looks and sounds good to you and also if it makes sense to you.

Furthermore, if the sentence looks and sounds bad to you, do *not* adjust the sentence in any way so that it becomes a good sentence.

Make a judgment as to whether the sentence is good or bad based on exactly what you see and hear, without any alterations.

For Aphasics Only

It is important to listen carefully and make a decision about each sentence based on *your* own intuition, which is how *you* feel about the sentence. Remember, point to the smiling face when you feel that the sentence is a good one and point to the frowning face when you feel that the sentence is a bad one.

Do you have any questions?

We will do some practice items before we do the actual test. We will discuss each of the practice items together so that you will understand how the experimental items should be completed. During the experiment, we will take a short break and then continue with the test items.

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Notes

1. Some studies have been claimed to have produced results that putatively deviate from this generalization, Martin et al., (1989) for instance. For reanalyses of these studies, their assumptions, methodologies, and findings, see Grodzinsky, 1991; Zurif, Gardner, & Brownell, 1989; Zurif, Swinney, & Fodor, 1991.
2. The HMC also requires that a head move only into head position (cf. Travis, 1984).
3. This presentation is obviously simplified, presenting just the leading ideas of the constraints in question. For precise definitions and detailed discussion, consult Rizzi (1990) and much subsequent literature, most notably Chomsky (1995).
4. The number of sentences contained in each experimental condition was determined by grammatical considerations. Thus the number of sentence types (hence token sentences) was unequal across conditions. This potential problem is obviated in the analysis because the results are expressed in proportions, not absolute numbers.
5. In fact, there have been claims that such comparisons are exactly what the agrammatic aphasics, at least, cannot do, and it is for this reason that they fail on certain tasks that require such comparisons (cf. Grodzinsky & Reinhart, 1993; Grodzinsky, Wexler, Chien, Marakovitz, & Solomon, 1993).
6. Randomization was carried out through use of Psychlab version 1.0 for Macintosh.
7. Reading rate was normal, yet on the slow side. Efforts were made not to give away the grammatical status of a sentence through intonation. These efforts were successful, given that no effect of grammaticality was found in both groups.

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