

Semantic Operations in Aphasic Comprehension: Implications for the Cortical Organization of Language

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We provide data on the neurological basis of two semantic operations at the sentence level: aspectual coercion and complement coercion. These operations are characterized by being purely semantic in nature; that is, they lack morphosyntactic reflections. Yet, the operations are mandatory (i.e., they are indispensable for the semantic well formedness of a sentence). Results indicate that, whereas Broca's patients have little or no trouble understanding sentences requiring these operations (performance was above chance for all conditions), Wernicke's patients performed at normal-like levels only for sentences that did not require these operations. These findings suggest that sentence-level semantic operations rely very specifically on the integrity of the cortical area associated with Wernicke's aphasia, but not on the region corresponding to Broca's aphasia. In the context of other findings from lesion and imaging studies, this evidence allows a view of the cortical distribution of language capacity that is drawn along a linguistic line, one which distinguishes syntactic from semantic operations.

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INTRODUCTION

We are concerned here with the neuroanatomical basis of the capacity to carry out semantic composition. Two components are involved in this process: the semantic and the syntactic components. The semantic component involves information about such entities as conceptualized objects, events, properties, times, and quantities. The syntactic component is the system where word order, subject–verb agreement marking, and case marking are determined and whose units are nouns, verbs, adjectives, and the like.

In many instances semantic composition is dictated solely by the syntactic arrangement of the words in a sentence—but not always. There are instances where the

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construction of sentence meaning also requires the insertion of “syntax-free” semantic content (i.e., content that has no morphosyntactic reflections) which is determined by the internal arrangement of lexical conceptual structures within the given sentence and/or the sentence’s contextual setting. In this article, we show that composition utilizing these “syntax-free” semantic properties depends on the integrity of a cortical region different from the region underlying syntactic composition.

THE NEUROANATOMICAL DISTRIBUTION OF SENTENCE COMPREHENSION PROCESSES

Our connection to neuroanatomy turns on the lesion-localizing value of the classic syndromes of Broca’s and Wernicke’s aphasia. Broca’s aphasic patients are identified by their nonfluent output and relatively intact comprehension. In contrast, Wernicke’s aphasic patients are characterized by fluent but not particularly informative speech and poor auditory comprehension.

Broca’s aphasia is associated with variable anterior left hemisphere lesion sites, often including but certainly not limited to Brodmann areas 44 and 45 (Broca’s area). Therefore, functional localization based on Broca’s aphasia can only be considered inexact. Nonetheless, this large anterior region is clearly distinguishable from the posterior region associated with Wernicke’s aphasia. For the latter, the greatest involvement appears to be inferior to the sylvian fissure, implicating especially the auditory association cortex in the posterior portion of the superior temporal gyrus (for details see, e.g., Alexander et al., 1990; Benson, 1985; Goodglass, 1993; Naeser et al., 1989; Tonkonogy, 1986; Vignolo, 1988).

Investigation of sentence comprehension in Broca’s patients reveals a statistically well-defined pattern: above-chance comprehension of agentive canonical structures (structures in which the noun phrase preceding the verb is interpreted as the *agent*, as in active-voice constructions with agentive verbs: *The girl chased the boy*) and at-chance comprehension of noncanonical structures (those in which the noun phrase preceding the verb is interpreted, not as the agent of the action, but as the entity acted upon or undergoing the action, e.g., agentive passives: *The boy was chased by the girl*) (Grodzinsky, Piñango, Zurif, & Draí, 1999; Zurif & Piñango, 1999; Draí & Grodzinsky, 1999). This pattern appears to reflect the Broca’s patients failure to construct syntactic dependencies.¹ So, however apparent its role in production, the left anterior brain region associated with Broca’s aphasia appears also to be implicated in syntactic analysis for the purpose of comprehension.

As mentioned, these syntactic comprehension operations can only be ascribed to an imprecisely bounded anterior region. Nevertheless, it is not clear if we should even expect to find a more specific focus for syntax than that suggested by aphasia research. In this respect we note that, whereas functional imaging analyses generally

¹ A dependency relation can be conceived as a connection between the position where a constituent (a noun phrase) is heard in a sentence and the position where it is interpreted. So, in the sentence: *This is the cat, that Tom, still in his pajamas, chased (the cat), last night*, the noun phrase *the cat* is heard at the beginning of the sentence, but its interpretation, that is, its *thematic* role as “chasee,” is only obtained further down the sentence, where the verb *chased* is realized. The place where *the cat* is putatively interpreted by recopying *the cat* is signaled with italics. (This is done with the understanding that this copy is a hypothetical construct; *the cat* is only heard once.) We call the relation between the noun phrase *the cat* and the position following the verb (i.e., the gap) a dependency relation because of the necessary connection that must exist between this gap position (where interpretation takes place) and the noun phrase (also called the “antecedent”) for the sentence to be interpretable at all.

implicate left inferior frontal cortex in the syntactic processing of noncanonical sentences, no single Brodmann area within this region has yet to be activated reliably. Different studies have variously implicated BA44, BA45, BA47, and, indeed, all three together (cf. Caplan et al., 1998; Dapretto & Bookheimer, 1999; Cooke et al., 1999; Ni et al., 2000). Moreover, it would appear that fine-grained localization on the basis of neuroimaging may be problematic even in principle since the sulcal contours defining BA44 and BA45 are not reliable landmarks of cytoarchitectonic borders (Amunts et al., 1999; Roland & Zilles, 1998; Zilles et al., 1997).

Given these localization issues, it appears that the Broca's/Wernicke's contrast is still a reliable window to the cortical distribution of language; one that has important functional consequences at the sentence level. Two facts are relevant here: First, although in off-line tasks Wernicke's patients reveal problems comprehending noncanonical structures, the canonical/noncanonical difference is less sharp in Wernicke's patients than in Broca's patients. Second, if there is a similarity, it turns out to be superficial: From a real-time perspective the underlying causes for the structural limitation are seen to be very different in the two types of aphasia (e.g., Zurif et al., 1993; Swinney et al., 1996). From this perspective, only the anterior site associated with Broca's aphasia is involved in the reflexive construction of syntactically governed relations as described in footnote 1. Still, Wernicke's patients have sentence comprehension problems. These problems do not seem directly accountable by syntactic factors—or by reference to single word meanings (e.g., Caramazza & Zurif, 1976). In what follows, we investigate the hypothesis that such comprehension problems are caused by an inability to carry out certain aspects of semantic composition.

To this end, we study Wernicke's and Broca's aphasic comprehension in terms of two semantic operations at the sentence level: complement and aspectual coercion. These operations are of interest because both lack syntactic reflections yet, just like syntactic dependency relations, they are indispensable for sentential well formedness. Given the above evidence, we expect Wernicke's but not Broca's patients to be especially vulnerable in their comprehension of sentences requiring these operations.

Directly below, we present the linguistic properties of these two operations including experimental evidence that supports their semantic nature.

COMPLEMENT AND ASPECTUAL COERCION

Complement and aspectual coercion are two operations that are purely semantic in nature. Their purpose is to make elements within a verb phrase agree in their intrinsic selectional or temporal constraints, respectively (Moens & Steedman, 1987; Pustejovsky, 1991, 1995; Briscoe, Copestake, & Bougarev, 1990; Jackendoff, 1997).

Complement Coercion

Consider the following contrast:

- (1a) The boy began reading/writing the book.
- (1b) The boy began the book.

The interpretation of sentence (1a) is obtained straightforwardly via simple syntactic composition. The noun phrase *The boy* is initiating an activity reading/writing with the object-noun phrase *the book*. In this case it is said that semantic composition is syntactically transparent: The meaning of the sentence comes directly from the

meaning of the lexical items put together by syntactic composition. The verb *begin* selects for an activity, and it is the activity *writing/reading* that semantically licenses its object-NP, *the book*.

Consider now sentence (1b). The meaning we obtain from this sentence is that the boy began *doing* something with the book—e.g., reading, writing, or making it. This sentence contrasts with (1a) because whatever the boy is actually *doing* with the book is not overtly represented in the sentence. Nevertheless, such an interpretation cannot be avoided. That is, there is no possible well-formed interpretation of (1b) where an activity associated with the object-NP is not necessarily entailed.

This situation occurs because verbs like *begin*, *enjoy*, and *try* semantically select for an activity as their complement (e.g., whatever activity is *begun*, *enjoyed*, or *tried*). Therefore, when they co-occur in syntactic representation with a direct object-NP that is not an activity, an incompatibility arises. Such an incompatibility is resolved by the insertion of extrasemantic content which, crucially for our purposes, has no syntactic reflections. For sentence (1b) this extrasemantic content takes the form of *reading*, *writing*, and so on, which is added to the semantic representation of the verb phrase so that the verb phrase refers not to the verb *begin*, but to an activity that takes as its object the NP *the book* (Briscoe et al., 1990; Pustejovsky, 1991; Jackendoff, 1997).

Within his generative lexical framework, Pustejovsky (1991, 1995) proposes that in the absence of contextual information to the contrary, the inserted material is selected out of the lexical properties associated with the NP occupying the direct object position; that is, one must use information from the meaning of the object-NP in order to fill in the proper predicate in the semantics. Pustejovsky (1995) argues that such lexical properties are encoded as part of the lexical entry of the noun in what he calls its *qualia* structure. The *qualia* structure thus furnishes a default reading in cases where an otherwise biasing context (e.g., biasing discourse) is not provided. It includes, among other things, the object's appearance, how it comes into being, and how it is used. This suggests that only the general kind of function (here an activity) is determined by the verb itself (Jackendoff, 1997).

To summarize, complement coercion is a semantic operation triggered by a semantic incompatibility between an event-taking verb and a nonevent object. In this circumstance, an extra piece of content (i.e., an activity selected from the *qualia* structure of the NP naming the object complement) is pasted in, thereby solving the selectional incompatibility. We use the term "enriched semantic composition" to refer to the set of semantic compositional operations that has this sort of pasting-in property (e.g., Jackendoff, 1997). Sentence (1b) is thus a case of enriched composition.

Aspectual Coercion

Consider the following contrast:

- (2a) The girl slept until dawn.
- (2b) The girl jumped until dawn.

The interpretation of sentence (2a) is obtained straightforwardly via simple syntactic composition. The girl is performing an activity, *sleep*, for the period of time indicated by the time phrase *until dawn*. It represents a case of syntactically transparent semantic composition: The meaning of the sentence comes directly from the meaning of the lexical items put together by syntactic processes. Notice that *sleep* as a temporally unbounded activity is aspectually compatible with *until dawn*, a prepositional

phrase inside the verb phrase that places a temporal boundary on the activity expressed by the verb.^{2,3}

Consider now sentence (2b). The interpretation we retrieve from this sentence is that the girl jumped *repeatedly* until dawn. Moreover, the meaning of repetition does not come from *jumped* or from *until dawn*, nor is it signaled by any morphosyntactic means. Nevertheless it cannot be avoided.

Notice that *jump* is a point-action activity. That is, it is an activity with an intrinsic beginning and an end which is, by definition, not compatible with the imposition of any kind of additional temporal boundary. This incompatibility should in principle yield an ungrammatical sentence. So as with (1b) above, the fact that sentence (2b) is fully grammatical and easily interpreted demands an explanation. And as with complement coercion, one way to explain well formedness in this circumstance is to posit an operation that pastes in a piece of content in the semantic representation of the verb phrase—the added content changing the point-action activity to a repeated activity. So in sentence (2b) this piece of information, which we term the “repetition function,” is introduced to achieve compatibility between the head of the verb phrase *jumped* and its aspectual modifier, the prepositional phrase *until dawn* (also inside of the VP) (see Talmy, 1978; Pustejovsky, 1991). We note that the change from a point-action activity to a repeated activity can also be viewed as an instance of “type shifting” (a lexical process where the meaning of the verb is changed from a noniterative/telic sense to an iterative sense) thus attributing a derived status to the iterative version of the verb (e.g., Partee & Rooth, 1983; Chierchia, 1984; Klein & Sag, 1985). Importantly, however, both generalizations assume an on-line (productive) operation that is nonsyntactic and both, therefore, are coextensive for the distinction we draw here between syntactically transparent and syntactically nontransparent interpretations.

For the purpose of this article, then, aspectual coercion is defined as an operation whereby a repetition function is introduced—either as a generative operation in the semantic component or as type shifting in the lexicon—to achieve aspectual compatibility between the verbal head and its temporal modifier. Like (1b), sentence (2b) is a case where enriched semantic composition takes place.

² Regarding aspectual coercion, “aspect” refers to “situation” aspect, i.e., Aktionsarten (Pustejovsky, 1995; Vendler, 1967; Verkuyl, 1972, 1993). Situation aspect captures the temporal characteristics of a verb or a verb and its complement(s). This can be observed in the contrast:

(3a) Jane drew a circle. (temporally bound, only one circle was drawn)

(3b) Jane drew circles. (temporally unbounded, there is no limit to the number of circles that were drawn)

Situation aspect stands in contrast to viewpoint aspect, which refers to the different perspectives a speaker can take with respect to the temporal course of development of an event or state. There are two types of viewpoint aspect, perfective (2a) and imperfective (2b):

(4a) She drew a circle yesterday. (speaker looks at the event as a whole)

(4b) She was drawing a circle yesterday. (speaker is looking at the event from the inside)

As noted, when we refer to aspectual coercion, the “aspectual” part of it is restricted to situational aspect.

³ The notion of “temporal boundedness” we refer to here is that piece of content indicating a durational boundary that is found in the meaning of the verb itself. For instance, the verb *sleep* can be interpreted as having a limit only in the context of an activity performed by living organisms. From a commonsense point of view we know that anyone who falls asleep must wake up sometime. Nevertheless, from the point of view of the lexical-semantics of the verb itself, nothing indicates such an end. That is, nothing in the meaning of *sleep* (also: *walk*, *run*, *swim*, *float*, and other activity verbs) indicates that it must end at some point. Contrast *sleep* with *dive*. In the latter we must include the beginning and the end of the action in order to preserve its lexico-semantic integrity. That is, we cannot conceive of the action *dive* without admitting that it has a beginning (e.g., jumping off the board) and an end (e.g., hitting the water). It is this class of verbs which we term “temporally bound” or “telic.”

There are a number of important properties of this semantic operation that warrant mention here. First, as with complement coercion, aspectual coercion is mandatory. That is, there is no alternative interpretation of the sentence where the operation is allowed not to take place. There is no ambiguity in the semantic interpretation of the sentence. For example, one cannot interpret sentence (2b) to mean that the girl makes such a big jump that it lasts until dawn, which is what the sentence would mean if the interpretation of the sentence were to be derived from simple syntactic composition alone. This shows that for the sentence to be interpretable at all, the nonsyntactic operation must also occur.⁴

Second, the application of the aspectual coercion operation is constrained by the nature of the verb and—if applicable—its complement. Thus, the verb must refer to a bounded activity for coercion to take place. One cannot mean by *The man walked for an hour* that necessarily during the hour the man repeatedly started and stopped walking. The reason this reading is not available is that *walked* is intrinsically temporally unbounded (see footnotes 3 and 4), so no extraneous temporal boundary can bring out what does not exist in the verb's meaning.

Third, the operation requires that the verb must be “iteratable.” That is, the action the verb conveys must be repeatable by the same agent of the action onto the same recipient of the action (the latter when applicable) as follows:

(5a) *The man died until dawn.

(5b) *The man killed the chicken until dawn.

In sentences (5a) and (5b) the verbs *died* and *killed* respectively are both point-action activities. Nevertheless, both sentences are ungrammatical with the bounding phrase *until dawn* because they both violate the “iterability” constraint. In sentence (5a) the function is prevented from being interpolated because the meaning of *died* does not allow for iteration (an individual can only undergo one death). Similarly, in sentence (5b) the function cannot be interpolated because, although the man can certainly kill many times, the chicken can only be killed once. Not all iteration means coercion, however. In the sentence *The man killed (the) chickens for an hour* the only possible interpretation is “one man has killed several chickens one at a time” (i.e., the killings occurred in a distributed manner). This interpretation, it must be noted, does not come from coercion but from simple syntactic composition. The iterative reading is expected given the plural marking on the object-NP *chickens*.

Our last point here has to do with an experimental finding: Testing neurologically intact subjects in a dual-task interference paradigm, we have observed a computational cost for the enriched composition operation required for aspectual coercion. In effect, we have isolated a nonsyntactic compositional process—an operation whereby the sense of “repetition” is pasted in while comprehension develops in real-time (Piñango, Zurif, & Jackendoff, 1999). We interpret this finding as reflective of the nonsyntactic nature of this operation.

EXPERIMENTS: GENERAL CONSIDERATIONS

Given our claims regarding the nature of the deficit underlying Broca's and Wernicke's aphasia we have a straightforward prediction: Wernicke's aphasic patients

⁴ Note that this constraint can be violable if a special context is provided. For instance, if in the context of the sentence *The girl jumped for an hour* we have previously established that, say, the forces of gravity no longer hold (e.g., situations in *Alice in Wonderland*), then we have made it possible, via such

should have difficulty carrying out the semantic operations of complement coercion and aspectual coercion. Broca's patients, in contrast, should perform at normal levels on sentences requiring these operations because the nature of their problem is syntactic, not semantic.

Two experiments were carried out. Each contained two conditions: *transparent* and *enriched*. The transparent condition consisted of sentences whose semantic interpretation arose out of lexical items put together only via syntactic composition. The enriched condition was composed of sentences whose semantic interpretation, in addition to syntactic composition, required the interpolation of the coercion function to achieve semantic well formedness.

In both experiments we tested patients who had been diagnosed as either Broca's or Wernicke's aphasics. Diagnosis was based on the application of The Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1972) and converging clinical opinion. The Broca's patients for whom we had neuroradiological data all had left-sided perrolandic lesions, although, as is common, the damage was not restricted to this region. By contrast, the Wernicke's patients all had only posterior lesions, these involving mostly Wernicke's area. These neuroradiological patterns broadly conform to current views of lesion localization concerning the classic syndromes (Benson, 1985; Goodglass, 1993; Naeser et al., 1989; Tonkonogy, 1986; Vignolo, 1988.).

EXPERIMENT 1: COMPLEMENT COERCION

Methods

Subjects. Eight subjects participated in this study: three patients clinically diagnosed with Broca's aphasia: (HB, RD, and JB), two patients clinically diagnosed with Wernicke's aphasia (WN and CC), and three education- and age-matched controls. A description of the lesion site for each of these patients is included in Table 1. The Broca's patients ranged in age from 59 to 77 years and all had at least a high school education. The Wernicke's patients ranged from 57 to 69 years and all had at least a high school education.

Materials. Twenty-five pairs of experimental sentences (ranging from 8 to 11 words) were constructed. Each pair contained one transparent sentence and its enriched counterpart. As an example, the syntactically transparent member of one pair was *The boy began reading the book*. Its enriched counterpart was *The boy began the book*—a sentence that, because of the putative complement coercion operation, we also understand as involving an activity such as reading. For each experimental pair, a picture was constructed depicting what the sentence expressed—the same picture, of course, serving both members of the pair.

In addition to the 25 experimental pairs, 50 semantic foil sentences along with their corresponding pictures were also constructed. This allowed a sentence–picture matching task in which the experimental picture would always have a 50% probability of being the correct choice. Returning to the above example, for *The boy began reading the book*, the correct depiction was of a boy reading a book, and the foil showed a boy exchanging money for a book. At another point in the test, the foil sentence *The boy is buying a book* was presented with the same two pictures. In this case, the correct picture was the latter.

By creating 50 foil sentences, we ensured that no sentence was paired twice with the same picture. So just as the same picture (a boy reading a book in our example) served for both the transparent and enriched members of each pair, so, too, the picture of a boy exchanging money for a book was paired once with the foil sentence described above, *The boy is buying a book*, and once with a synonymous foil sentence, *The boy is purchasing a book*.

a context, to override the default interpretation (the one requiring iteration) in favor of one where the jump actually took an hour. That this interpretation is possible *only* when a biasing context has been provided constitutes an argument for the notion that coercion is a necessary element of the rules of the interface between syntax and semantics rather than an extrasentential process.

TABLE 1
Patients Descriptions

Name	Diagnosis (BDAE & clinical consensus)	Lesion site information
WN	Wernicke's	WM is a male who suffered a stroke in 1994. An MRI scan taken that year shows an extensive and diffuse cortical infarction involving the distribution of the left middle cerebral artery extending from the middle to the posterior of the left temporal lobe, and including also inferior parietal lobe and anterior occipital lobe.
JM	Wernicke's	JM is a male who suffered a left CVA in 1986. A CT taken later that year shows a vague patchy lesion involving the temporal isthmus, which has been interpreted as interrupting the auditory fibers from the medial geniculate nucleus before reaching Heschl's gyrus and Wernicke's area. The patchy lesion extends superiorly into the posterior supramarginal and angular gyrus areas with a deep extension to the border of the left lateral ventricle.
CC	Wernicke's	CC is a male who suffered a stroke in 1984. A CT scan taken later that year reveals two left hemisphere lesions, one involving a portion of the posterior temporal lobe, including the posterior half of Wernicke's area, with superior extension into supramarginal and angular gyrus areas, and a second in the occipital lobe.
JC	Broca's	JC is a female who suffered a stroke in 1995. A CT scan taken that year indicates a large left fronto-parietal lesion.
RD	Broca's	RD is a male who suffered two left CVAs—one in 1976 and a second in 1977. A CT taken in 1978 indicates two lesions, one in Broca's area with deep extension to left frontal horn and involving lower motor cortex (face and lip regions) and the other in the left temporal lobe sparing Wernicke's area but encompassing the anterior portion of BA22.
JB	Broca's	JB is a female who suffered a left CVA in 1996. A CT scan taken at that time shows a large left fronto-parietal lesion involving all of the inferior frontal gyrus including all of Broca's area and the white matter underlying it. The lesion is described as involving insular cortex area and the lateral putamen with posterior extension across the anterior temporal isthmus. The temporal lobe, however, is spared.
HB	Broca's	HB is a male who suffered a left CVA in 1994. We were unable to obtain scan information for this participant.

Procedure. The 50 experimental and 50 foil sentences were randomized and recorded by a native speaker of English. Before each session, there was a training period of 5 sentences to allow the subject to get used to the task. Simultaneously with the presentation of each sentence a set of two pictures was presented. Each set contained the correct depiction and the depicted semantic foil. Patients were instructed to match the sentence just heard with the picture that most closely represented the meaning of the sentence. Each question was asked accompanied by a hand gesture that emphasized each option. Subjects responded by pointing to one of the two pictures. They were allowed to listen to each sentence as many times as they wanted to. Each subject was tested once on the 100 sentence list in a session that lasted approximately 1 h, including several breaks.

Results

Our normal control patients performed flawlessly in both conditions. This shows that the experimental sentences were easy to understand and that the pictures constituted clear depictions of the sentences. Regarding our experimental groups, Table 2 illustrates the contrast in performance between Broca's and Wernicke's subjects. Broca's patients performed at above chance on both the transparent ($X^2 = 19.92, p < .05$) and the

TABLE 2
Complement Coercion in Broca's and Wernicke's Aphasia
(Number and Percentage Correct of Responses)

Clinical Diagnosis	Patient	Condition	
		Transparent	Enriched
Broca's	HB	24 (96%)	22 (88%)
	RD	23 (92%)	20 (80%)
	JB	24 (96%)	24 (96%)
	Mean	23.66 (94.6%)	22 (88%)
Wernicke's	WN	21 (84%)	17 (68%)
	CC	25 (100%)	20 (80%)
	Mean	23 (92%)	18.5 (74%)

enriched conditions ($X^2 = 14.44, p < .05$). Moreover, they showed no difference in performance between the two conditions [$t(2) = 1.88, p = .09$, one-tailed]. By contrast, the Wernicke's patients although also showing a significant difference in performance for the two conditions [$X^2_{\text{transparent}} = 17.64, p < .05$ versus $X^2_{\text{enriched}} = 5.76, p < .05$], nonetheless, clearly understood syntactically transparent sentences better than enriched sentences. This is revealed by the significant difference found between those two conditions for this subject group [$t(2) = 9, p = .03$, one-tailed].

EXPERIMENT 2: ASPECTUAL COERCION

Method

Subjects. Nine subjects participated in this study: three normal controls, three Broca's patients (JB, JC, and RD), and three Wernicke's patients (CC, JM, and WN). Again, description of the lesion site for each of these patients is included in Table 1. The Broca's patients ranged in age from 59 to 77 years, the Wernicke's patients from 57 to 69 years. All aphasic patients had at least a high school education. Three subjects with no history of brain damage participated as normal controls, all matching the aphasic patients in age and level of education.

Materials. Sixteen pairs of experimental sentences were constructed, each pair containing a sentence for which semantic composition was syntactically transparent and its counterpart sentence requiring enriched composition—that is, the pasting-in of extra meaning. For each such pair, sentences were matched for length (range of 8 to 11 words per sentence). Given that the coercion function is expected to be triggered by the aspectual incompatibility between the verb, its complement, and the bounding phrase, we manipulated the presence of the bounding phrase in each pair leaving the rest of the context equal for both sentences. The following contrast illustrates this point:

- (6a) The horse jumped over the fence yesterday. (transparent sentence)
 (6b) The horse jumped for an hour yesterday. (enriched sentence)

Procedure. The sentences were randomized and recorded by a native speaker of English. Before the testing session, there was always a training period of five sentences to allow the subject to get used to the task. After the presentation of each test sentence a question was asked as to whether the action had occurred "once" or "many times" as in, "Did the horse jump over the fence once or many times?" Each question was accompanied by a hand gesture that emphasized each option. Subjects responded either out loud, or by pointing to the hand that represented the desired answer [for (6a) the correct answer would be "once" and for (6b) the correct answer would be "many times"]. Each subject was tested once, the session lasting for about an hour, including rest breaks.

Results

Just as in Experiment 1, our normal control participants performed at ceiling levels on both conditions. Table 3 illustrates the contrast in comprehension performance

TABLE 3
 Aspectual Coercion in Broca's and Wernicke's Aphasia
 (Number and Percentage Correct of Responses)

Clinical Diagnosis	Patient	Transparent	Enriched
Broca's	JC	14/16 (87.5%)	13/16 (81.2%)
	RD	12/16 (75%)	14/16 (87.5%)
	JB	16/16 (100%)	16/16 (100%)
	Mean	14/16 (87.5%)	14.3/16 (89.3%)
Wernicke's	WN	14/16 (87.5%)	9/16 (56.2%)
	JM	12/16 (75%)	8/16 (50%)
	CC	16/16 (100%)	10/16 (62.5%)
	Mean	14/16 (87.5%)	9/16 (56.2%)

between Broca's and Wernicke's patients. As can be seen in this table, the Broca's patients performed at above-chance levels on both the transparent and enriched conditions. The Wernicke's patients performed at above chance only on the transparent condition; for the sentences requiring enriched composition their comprehension was at chance. Specifically, a paired t test between conditions for each group reveals a significant difference in performance between enriched and transparent conditions for Wernicke's patients exclusively [$t(2) = 8.66, p = .006$, one-tailed]. Moreover, performance on the enriched condition for this group was no different from chance ($X^2 = .25, p > .05$). By contrast, Broca's patients performed at above-chance levels for both conditions: transparent ($X^2 = 9, p \ll .05$) and enriched ($X^2 = 9.92, p \ll .05$); and they showed no difference between conditions [$t(2) = -.37, p = .37$, one-tailed].⁵

GENERAL DISCUSSION

The findings we have presented reveal a clear pattern. The Broca's patients showed no significant impairment for either semantic operation. That is, they performed at the same level for both transparent and enriched conditions. We think that the few errors that were observed for these patients in each of the experiments reflect the

⁵ A reviewer has suggested that the Wernicke's patients' failure to carry out aspectual coercion may be better understood as a failure to resolve ambiguity—this having to do with the fact that contexts can be chosen in which point-action verbs like *die* are stretched out interminably as in (7a) *The native culture died over a 200-year period* and in which noniterative verbs become iterative as in (7b) *The girl slept until dawn although she woke 19 times during the night*. Consequently, the phenomena we describe here as coercion would in fact be a type of semantic ambiguity (both the iterative and noniterative meanings are equal possibilities in the interpretation of the VP). Two facts have to be mentioned on this point: (1) Examples (7a) and (7b) do not illustrate the intended claim. In the case of (7a) *died* is still a bounded verb (it has an intrinsic beginning and an end); so the fact that the action takes 200 years to be completed does not make it an activity, it only makes it an extended point-action event; in the case of (7b) it is still the case that *slept* is an unbounded activity verb and "slept until dawn" a noniterative event. What creates iteration in (7b) is the event in the subordinate clause ("waking up 19 times"). So it is the case that the complete sentence involves iteration. However, such iteration is syntactically transparent given that the temporal properties of "slept until dawn" are compatible with those of "waking up 19 times," so no coercion is required. In our case, what matters is that up to "until dawn," the VP is a noniterative event, indicating that no coercion has taken place. (2) The notion of ambiguity cannot explain our data. This is so because only the iterative interpretation proved difficult for the Wernicke's patients. We explain this asymmetry in terms of having to generate a piece of semantic content (the repetition function); invoking ambiguity resolution (however described) does not explain this asymmetry.

memory load imposed by the tasks: the requirement that information be held in memory either while examining the pictures (Experiment 1) or while the tape was stopped and the two-choice question asked (Experiment 2). But whatever the cause, it must be emphasized that the few errors were evenly distributed over the enriched and transparent conditions.

By contrast, for Wernicke's patients, the results show that even though they had no problem understanding individual word meanings, they were nonetheless unable to implement complement and aspectual coercion—two different semantic operations that have in common the pasting-in (the generation) of information that is indispensable for a sentence's semantic well-formedness. That is, the Wernicke's patients were unable to carry out "enriched" semantic composition at the sentence level.

The difference in performance observed for the two aphasic groups indicates that aspectual and complement coercion involve computations requiring the integrity of the left posterior cortical region associated with Wernicke's area, but not the integrity of the left anterior cortical region associated with Broca's area. This type of finding thus impels a line of research on the properties of semantic processing and their associated cortical regions. It provides a model whereby the functional distribution of language is cortically dissociable and governed by linguistically motivated distinctions that seem to emerge most clearly in investigations at the sentence level: syntax—"Broca's" area; semantic composition—"Wernicke's" area.

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