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# Impairments of sentence comprehension

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## SUMMARY

We examine two different forms of comprehension impairment, ‘semantic dementia’ and ‘asyntactic comprehension’, focusing on the assignment of thematic roles: the determination of *who* did it to *whom*. We show, first, that the loss of word meaning does not impede thematic assignment in semantic dementia, demonstrating that syntactic information, along with some knowledge of the verb, is sufficient for the assignment of thematic roles. Studies of normal subjects indicate, however, that this process is normally subject to semantic influences; asked to judge the plausibility of sentences, subjects respond faster when thematic assignment is semantically constrained. The sentence plausibility judgments of ‘asyntactic’ comprehenders (aphasics with diminished syntactic control over thematic assignment) show increased effects of these semantic constraints. We discuss these results in relation to current issues in sentence processing.

## 1. INTRODUCTION

Sentence comprehension is normally accomplished with high reliability, little effort, and no hint of the complexities that underlie it. But consider: to understand a sentence it is necessary to extract individual words from a continuous speech signal, determine the meaning and grammatical class of each word, compute the syntactic relationships among those elements, and integrate the syntax with the meanings of the words to arrive at an interpretation. These operations must be executed in a timely manner and smoothly articulated with one another. Memory capacity is also required, as partial products must be stored until they can be fully interpreted.

The comprehension deficits that result from brain damage in adults offer compelling evidence of this complexity. These disorders take a variety of forms that reflect impairment to different components of the comprehension process. In this paper we focus on two disorders, which are roughly complementary. The first involves semantic aspects of sentence processing; the second, syntactic.

We focus our discussion of these disorders on one important type of information that sentences convey, namely, the matter of *who* did it to *whom*. The technical term for this process is Thematic Role Assignment. Thematic roles such as Agent (cause of an action) and Theme (that which is affected) are assigned to the entities denoted by nouns and other constituents of sentences. Much of human communication concerns these sorts of relations; and children

very early acquire linguistic mechanisms for encoding them (see, for example, Bloom 1970). Because thematic role assignment requires the convergence and integration of different types of information, it is a good vantage point from which to examine the breakdown of the comprehension process.

The mechanisms by which thematic role assignment is normally accomplished are not completely understood (see, for example, Frazier 1990). It is apparent, however, that the process must largely be syntactically driven. If it were not – if we depended heavily on word meanings for assigning thematic roles – we would take the physician to be the Agent in this sentence:

(1) The sick child cured the doctor.

But we do not: we assign this role to the child, in accordance with the syntax of the sentence.

The assignment of thematic roles must involve at least the following procedures. (a) Parse the input string for the verb and major syntactic constituents. In (1) *cures* is the verb; *the sick child* is subject of the sentence, *the doctor* is direct object. (b) Look up the lexical entry for the verb to determine what thematic roles it assigns, and how. *Cure* assigns to the grammatical subject the role of Agent and to the direct object the role of Theme. In contrast, the semantically related verb *recover* assigns the Theme role to the grammatical subject. (c) Interpret the relevant syntactic phrases in accordance with their assigned roles; for syntactically complex sentences this may require tracking elements that have been moved

out of their deep structure positions. For example, in a passivized version of (1), the Theme becomes the grammatical subject:

- (2) The doctor was cured by the sick child.

Thus, thematic role assignment requires lexical processes (look-up of the thematic assignments of the verb) and syntactic processes (parsing syntactic phrases and mapping thematic roles onto these constituents). In the next section, we present neuropsychological evidence that demonstrates that these processes are sufficient for thematic assignment.

## 2. THEMATIC ASSIGNMENT WITHOUT SEMANTICS

The fact that we take the child to be the healer in (1) suggests that our knowledge of the meanings of nouns has little or no impact on the assignment of thematic roles. One way to test this inference is to examine thematic assignment in patients whose knowledge of these words is severely compromised. This is the state of affairs in the disorder first described nearly twenty years ago by Elizabeth Warrington (1975) and recently termed 'semantic dementia' (Snowden *et al.* 1989; Hodges *et al.* 1992). The semantic loss is the result of a degenerative disease process that predominantly affects the temporal lobes (although it spares the superior temporal lobe structures concerned with auditory processing and with non-semantic aspects of language). This relatively rare disorder is first manifested as anomia – an impairment in naming things – and gradually extends to word comprehension as well.

Semantic dementia patients tend to speak fluently and grammatically although the content of their speech is often quite empty. Sentence comprehension data for these patients are limited; we know of only three cases in which sentence processing has been examined in any detail. The first is that of WLP, a case we reported some years ago (Schwartz *et al.* 1979). In that study we showed that WLP was able to use sentence contexts to disambiguate the meanings of words that she no longer understood. So, for example, given the word *dog* and pictures of a dog and a cat, she was likely to choose the wrong picture, and similarly when given the word *cat*. However, given a picture of a cat chasing a dog along with a sentence describing that picture, she was able to label the animals quite accurately, performing well on both active voice sentences (e.g., *The cat is chasing the dog*) and passives (e.g., *The dog is chased by the cat*). This improvement in her labelling performance was clearly mediated by a preserved capacity to assign thematic roles (*cat* = grammatical subject = Agent of *chase* = animal doing the chasing). Although WLP's ability to perform the labelling task in this manner also suggests some knowledge of the meaning of verbs, this aspect of her semantic knowledge was not explicitly tested.

Breedin and her colleagues (Breedin *et al.* 1994; S. D. Breedin & E. M. Saffran, in preparation) recently investigated this question in another patient with semantic dementia. The patient, DM, demon-

strated a general loss of word meaning (performing, for example, below the first percentile on a standard test of word comprehension) but with greater severity for concrete words than for abstract ones. This pattern emerged across tasks that included providing definitions for words (e.g. *ink*: 'something that covers'; *try* 'to endeavour to accomplish something') and selecting, from among three words, the one least related in meaning (e.g., *stream*, *brook*, *puddle*; *loyalty*, *obsession*, *allegiance*). Asked to perform this same Synonymy Triplet task on verbs (e.g. *to allow*, *to encourage*, *to permit*) matched in frequency to concrete nouns (e.g. *automobile*, *truck*, *car*), DM performed significantly better on the verb set than on the noun set. (This is, of course, consistent with the general advantage for abstract stimuli; verbs tend to be more abstract than concrete nouns (Allport & Funnell 1981).)

To further investigate the status of verbs in DM, Breedin *et al.* (1994) used the Synonymy Triplet paradigm to probe specific aspects of verb knowledge. Although markedly impaired on judgments that hinged on 'manner' features of verbs, which specify how an action is carried out (sample item: *to gulp*, *to gobble*, *to gnaw*), DM performed within the normal range on triplets that probed his knowledge of the relationships between thematic roles and syntactic constituents (sample item: *to buy*, *to purchase*, *to sell*). For example, in *buy* and *purchase*, the subject of the verb designates the person who gives the money and receives the item; in *sell*, the subject designates the source of the item and recipient of the money. Control subjects did not show this pattern; in fact, their reaction times were slower on 'thematic role' triplets, suggesting that they found these items more difficult than the comparisons based on manner.

Detailed investigation of DM's syntactic abilities yielded no evidence of impairment (S. D. Breedin & D. M. Saffran, in preparation). Thus, he performed at normal levels in judging the grammaticality of sentences in a task that included a range of syntactic violations. His performance on sentence processing tasks was impaired only when semantic information was at issue. For example, DM performed a word-monitoring task in which he heard a word and was instructed to press a key when the word reappeared in a pair of sentences that followed. Following a design developed by Marslen-Wilson & Tyler (1980), this experiment included three conditions: the sentence was (a) well structured and semantically coherent (normal prose); (b) well structured, but meaningless (anomalous prose); (c) neither well structured nor semantically coherent (scrambled prose). Normal subjects show faster word-monitoring in (a) than in (b), and in (b) than in (c) (table 1). Presumably this is because the on-line computation of syntactic constraints in (b), and of semantic as well as syntactic constraints in (a), increases the predictability of the target word, thereby decreasing reaction time. DM's response times were in the normal range on conditions (b) and (c), and he demonstrated the usual advantage for anomalous prose over scrambled strings (table 1). However, unlike the control subjects, he did not show any further advantage for the semantically coherent

Table 1. *DM's performance on the word-monitoring task compared with that of control subjects (n = 22)*

sentence type	mean RT (msec)		
	DM	controls	range
scrambled prose	440	463	(357–386)
anomalous prose	418	444	(342–597)
normal prose	407	373	(281–546)

sentences. Hodges *et al.* (1994) recently observed the same performance pattern on the word-monitoring task in another semantic dementia patient.

DM's ability to assign thematic roles was assessed in a task similar to the one administered to WLP. The items used in this task were selected on the basis of a pre-test, which involved matching an animal name to one of two toy models. Pairs that elicited poor performance (0–70% correct) were used in the thematic assignment task, in which DM heard a sentence (e.g. 'The pig is carrying the lamb. Which one is the lamb?') as the experimenter demonstrated either the corresponding action (pig carrying lamb) or, on half the trials, the reverse (lamb carrying pig). DM's labelling performance was 100% correct on trials where the sentence matched the action. On trials where the enacted roles were the reverse of those specified in the sentence, his labelling performance declined to zero. In other words, DM's assignment of names to the animal figures was governed by the syntax of the sentence, along with the requisite knowledge of the verb. Moreover, his ability to recover thematic role information was not affected by sentence complexity. His performance on passives ('The lamb is carried by the pig') and object clefts ('It is the lamb that the pig is carrying') did not differ from his performance on simple active voice sentences.

The data from semantic dementia demonstrate that a structural analysis of the sentence, along with thematic mapping information contained in the verb entry, is sufficient for the assignment of thematic roles. They also indicate that syntactic processing can proceed normally in the face of considerable semantic loss, a finding that poses difficulty for recent attempts to build 'integrative' models of sentence comprehension in which syntactic and semantic constraints are embedded in a single network (see, for example, McClelland *et al.* 1989).

### 3. SYNTACTIC SPECIFICATION OF THEMATIC ROLES: SUFFICIENT, BUT HOW EFFICIENT?

Although structural and mapping information may suffice for the correct assignment of thematic roles, studies of normal subjects suggest that this process is not immune from semantic influences<sup>†</sup>. Results of an

<sup>†</sup> Some verbs allow more than a single set of thematic roles; much of the work on thematic processing in normals is concerned with factors that affect selection of the appropriate 'thematic grid' (see, for example, Carlson & Tanenhaus 1988). We will not review this literature here.

experiment performed in our own laboratory are illustrative (E. M. Saffran, M. F. Schwartz & M. Linebarger, in preparation). In this study we asked normal listeners to judge the plausibility of sentences that differed in the degree of semantic constraint on thematic assignment. Each sentence described an event involving two participants. In one set of sentences, both nouns were plausible candidates for both of the thematic roles licensed by the verb; in this condition (which we termed 'Global'), the plausibility of the sentence depended on the relationship between the two noun arguments. Thus, in (3), both mice and cats can carry, but only one of them is capable of carrying the other.

- (3a) The cat carried the mouse.  
(3b) The mouse was carried by the cat.

In the other set of sentences (the 'Local' condition), one of the nouns was a plausible filler of only one thematic role; in (4), for example, only the mouse is capable of eating.

- (4a) The mouse ate the cheese.  
(4b) The cheese was eaten by the mouse.  
(4c) The tornado demolished my car.  
(4d) My car was demolished by the tornado.

As inspection of (3) and (4) will indicate, these sentences can be rendered implausible by reversing the positions of the two nouns, and the implausible sentences in this study were created in this manner. We also varied the syntactic structure of the sentences; two of the structures that we used (actives and passives) are exemplified above. Response time (RT) for the plausibility judgment, measured from the onset of the last word in the sentence, was the dependent variable. Because implausibilities were often evident prior to the last word, the analysis focused on the plausible sentences.

Although both Global and Local sentences were plausible (and had in fact been judged equally plausible in a separate rating study), subjects responded significantly faster to plausible Local sentences (mean RT = 723 ms) than to Global ones (mean RT = 906 ms). We attribute this difference in

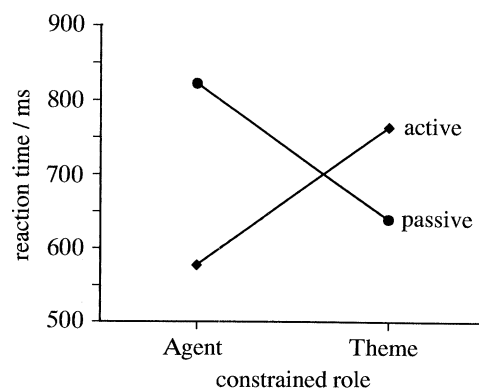


Figure 1. Effect of the position of the semantically constrained thematic role filler on plausibility judgment RTs. The Agent appears early in active sentences, late in passives; the reverse holds for the Theme.

response time to the semantic constraints on thematic assignment that were present in the Local sentences. Moreover, reaction times were affected not only by the presence of a constrained argument but also by its position in the sentence. As indicated in figure 1, subjects were faster to respond to Local sentences in which the thematically constrained noun occurred early in the sentence (4*b*, *c*) than when it occurred later (4*a*, *d*). Thus, RTs to the ‘tornado demolished car’ scenario were faster for actives, where the constrained role (Agent) came first, than for passives; the opposite pattern held for the ‘mouse ate cheese’, where the position of the constrained role (Theme) is the reverse.

These data are compatible with a processing model in which lexical semantic information facilitates – although it does not govern – thematic assignment. Carlson & Tanenhaus (1988, p. 286) suggest the following scenario: ‘thematic roles become available upon opening a verb’s lexical entry, and . . . thematic assignments are made on-line as soon as possible’ to nouns that are potential fillers of those thematic roles. On this view, ‘a preliminary semantic interpretation is defined on an incomplete syntactic representation and is maintained unless inconsistent information arrives’ later in the sentence. Although there may be some cost to revising these provisional assignments, sentences usually occur in discourse contexts where semantic constraints are highly predictive; hence the benefits, in terms of faster processing, are likely to outweigh the costs.

Although semantic constraints can facilitate thematic assignment, they are not decisive, as we saw from the child–doctor example considered earlier, at least not for those whose language faculties are intact. The effect of these constraints is considerably magnified, however, in the aphasic disorders described in the next section.

#### 4. THEMATIC ASSIGNMENT UNDER DIMINISHED SYNTACTIC CONTROL

Sentence comprehension is impaired in most aphasics; the performance pattern of one group has been of particular interest. These are patients with Broca’s aphasia, a disorder associated with lesions to the left frontal lobe in which language production is predominantly affected; speech is non-fluent, generally poorly articulated, and often ‘agrammatic’: that is, sentence structure is reduced or absent. Comprehension is good at the single-word level and also at the sentence level as long as the interpretation of the sentence is strongly constrained by its lexical content, as in (5):

(5) The apple that the boy ate was red.

In contrast, these patients are likely to perform poorly on semantically reversible sentences like (6), that is, where the only constraints on thematic assignment are syntactic (see, for example, Caramazza & Zurif 1976):

(6) The dog that the cat chased was black.

The aphasics’ performance pattern across these two types of sentences suggested that they were unable to exploit syntactic structure for the purposes of sentence comprehension: that, in addition to being agrammatic speakers, they were ‘agrammatic’ (or ‘asyntactic’) comprehenders as well. Further support for a syntactic deficit came from the finding that their performance on reversible sentences was sensitive to syntactic complexity. Thus, agrammatics generally perform better on simple active declaratives than on passives and other structures that do not conform to the canonical (subject–verb–object) order of constituents in English sentences (see, for example Schwartz *et al.* 1980; Caplan & Futter, 1986)‡.

The dominant view some years ago was that agrammatism reflected an underlying loss of syntactic knowledge: this theory offered a parsimonious explanation of the co-occurring ‘asyntactic’ patterns in production and comprehension (see papers in Kean (1985) for exposition and refutation of this view). The finding that ‘asyntactic’ comprehenders are sensitive to a wide range of grammatical violations has seriously undermined this position (Linebarger *et al.* 1983; Linebarger 1989, 1990). Patients who perform at chance on semantically reversible passives on sentence–picture matching tasks have proven to be extremely sensitive to violations of passive morphology, as in (7*a*) and to violations, as in (7*b*), where structures are not only locally well-formed (*How many do you have? Do you have friends in Philadelphia?*) but also involve such grammatical complexities as wh-movement and gaps left by moved elements.

(7*a*) \*John was finally kissed Louise.

(7*b*) \*How many do you have friends in Philadelphia?

To account for the disparity between grammaticality judgment and sentence comprehension performance, Linebarger *et al.* (1983) proposed that the deficit involved the inability to map from syntactic structures to thematic roles (the ‘mapping’ hypothesis).

Initially greeted with scepticism, the basic result of the Linebarger *et al.* (1983) study – that agrammatic Broca’s aphasics are much better at judging the grammaticality of sentences than at comprehending them – has been widely replicated (see, for example), Berndt *et al.* 1988; Shankweiler *et al.* 1989; Wulfeck & Bates 1991)§. Moreover, the use of methods that

‡ In fact, this performance pattern is not limited to agrammatic aphasics. Most aphasics perform worse on semantically reversible sentences, and show effects of syntactic complexity as well (see, for example, Goodglass & Menn 1985). The feature that distinguishes the performance of agrammatic Broca’s aphasics is that their performance on non-reversible sentences, and on single-word comprehension tasks, is very good. This is not true, for example, for Wernicke’s aphasics. Other patients who consistently show the ‘asyntactic’ comprehension pattern are those with markedly reduced verbal memory spans (see, for example, Vallar & Shallice 1990). Although it is of considerable theoretical interest, we will not discuss this disorder further here.

§ There are, however, some exceptions to their sensitivity to grammatical violations. The patients tend to be insensitive to violations that involve failures of agreement of number, gender, etc., as in the following examples:

examine sentence processing 'on-line', such as the word-monitoring task described earlier, has confirmed that the syntactic capabilities that these patients manifest in the metalinguistic judgment task are exploited in the ordinary business of processing sentences (see, for example, Tyler 1992).

There is general agreement, at this point, that knowledge of the grammar is at least largely spared in agrammatic Broca's aphasics, and that these patients are recovering at least some types of syntactic information from the sentences they hear. However, the extent to which syntactic knowledge and/or processing are preserved remains controversial, as does the general interpretation of the comprehension impairment. On the one hand, there are attempts to characterize the deficit in terms of the constructs of recent linguistic theories (see, for example, Grodzinsky 1990; Hickock *et al.* 1993; Maunder *et al.* 1993). Other proposals attribute the deficit to processing limitations due to such factors as perturbations in timing (Kolk & van Grunsven 1985; Friederici *et al.* 1992), reduced computational resources (see, for example, Caplan & Hildebrandt 1988; Frazier & Friederici 1991) or limitations in working memory (Miyake *et al.* 1994). These accounts are alike, however, in attributing the comprehension failure to some impairment in syntactic analysis *per se*. In contrast, the 'mapping' hypothesis assumes that the patients recover the structural information that is required for thematic assignment, but fail to integrate it with the thematic information supplied by the lexical entry (Linebarger *et al.* 1983; Schwartz *et al.* 1987). More data are required to settle these issues; we will not discuss these proposals in detail here. For present purposes, we will simply assume that syntactic input to the thematic assignment process is reduced, without specifying the nature or cause of that reduction.

The effect of this limitation is to magnify the effect of the semantic influences that determine the rate or efficiency, but not the outcome, of sentence processing in normals. Consequently, the patients have no difficulty in interpreting sentences in which thematic assignments are semantically constrained; problems arise only with reversible sentences, where these constraints are absent. We would also expect these patients to be somewhat insensitive to implausibilities of the child-cure-doctor type that we considered earlier, where semantic and pragmatic biases conflict with the syntactically based assignments.

Evidence to this effect has, in fact, been obtained in several studies of 'asyntactic' comprehenders (see, for

example, Heeschen 1980; Schwartz *et al.* 1987). We present some recent data here, obtained in a companion study to the plausibility judgment experiment conducted with normal subjects that we discussed earlier (E. M. Saffran *et al.*, in preparation). The critical feature of the design was the manipulation of semantic constraints on thematic assignment; constraints were present in 'Local' sentences and absent in 'Globals'. Thus, the Local sentence in (8) is implausible by virtue of the thematic assignment of *cheese* as the Agent of *eat*. In contrast, the implausibility of the Global sentence in (9) does not arise from any semantic constraint on individual thematic assignments, but as a consequence of the relationship *between* the two entities that is defined by the proposition as a whole:

- (8) The mouse was eaten by the cheese.  
 (9) The cat was carried by the mouse.

The results, in terms of error rates averaged across several different sentence types (actives, passives, subject clefts and object clefts), are presented in figure 2. Although the implausible Locals appear more anomalous than the Globals (and were rated as such by normal subjects), the patients clearly had more difficulty with these sentences, judging nearly half of them as plausible. This is presumably due to the force of the semantic constraints in the Local sentences, which operate against the anomalous thematic assignments. These results are interpretable on the model sketched earlier, which posits that nouns are provisionally assigned to thematic roles on the basis of semantic and pragmatic knowledge. Where syntactic influences are diminished – as in 'asyntactic' comprehenders – these semantically based assignments are less likely to be overturned.

As noted earlier, there is no agreement on the nature of the impairment that gives rise to this effect. However, from the perspective of the thematic assignment model, accounts that invoke temporal factors seem particularly attractive. Normal sentence comprehension requires not only that the component processes deliver the right products, but also that these products become available at the right time. Brain damage is very likely to disrupt this synchrony (see,

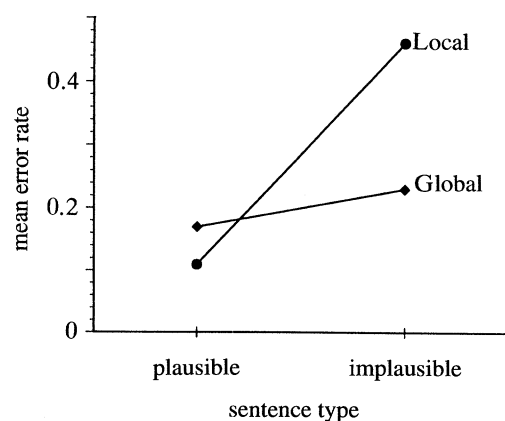


Figure 2. Performance of 'asyntactic' comprehenders ( $n = 7$ ) in judging the plausibility of Local and Global sentences.

1. The girl fixed himself a sandwich. (Linebarger *et al.* 1983)
2. The pencil who he brought was nice. (Linebarger 1990)
3. Sie hatte ihn lange Zeit beobachtet, doch er (third person singular) tanztest (second person singular) nur mit alteren damen. (Friederici *et al.* 1992)
4. Sue are getting a package from the nice lady. (Wulfeck & Bates 1991).

As Linebarger (1989, 1990) has suggested, cross-checking for consistency in these features may well involve a different set of operations from the processes that build constituent structures (i.e. parsing).

for example, Kolk & van Grunsven 1985; Haarman & Kolk 1991); operations such as thematic assignment, which require the convergence and integration of information from different sources, are likely to be especially vulnerable. If syntactic processing is slowed relative to semantic processing in agrammatic comprehenders, provisional assignments made on the basis of semantic constraints are likely to persist. The result: an impairment in 'mapping' syntactic structures onto thematic roles.

This scenario assumes syntactic input to the assignment process to be the only weak element. However, thematic assignment also depends on information provided by the verb entry that specifies the relationships between thematic roles and syntactic constituents; this information is critical for mapping constituents onto thematic roles. Although there is not a great deal of evidence that bears on the status of this knowledge in aphasic patients, there are indications that it may be compromised in agrammatics. Byng (1988) investigated the ability of two agrammatic aphasics to distinguish between thematically related verbs, such as *give* and *take*, by pointing to the corresponding action in a split-screen video. No sentence contexts were provided. The patients were significantly impaired on the thematic pairs relative to other types of verb contrasts. It is possible, then, that 'asyntactic' comprehension reflects not only a weakening of syntactic constraints but also some difficulty with lexical-semantic aspects of thematic role assignment.

## 5. CONCLUSIONS

The two types of disorder we have discussed are, broadly speaking, complementary. In agrammatic comprehenders, sentence interpretation is strongly semantically driven; in contrast, semantic dementia patients utilize syntactic strategies to compensate for their semantic impairments. However, a closer look at the evidence presented here suggests that conceptualizing the two disorders in terms of the dissociation of syntactic and semantic capacities is overly simple. Consider, first, the data from semantic dementia. The impairment pattern that we see in these patients presents the strongest case for dissociation between syntax and semantics. Yet the studies of Breedin *et al.* (1994) indicate that certain aspects of lexical-semantic knowledge – those that articulate with syntactic processes – may be spared. Turning to agrammatic comprehension, it is not yet clear to what extent the comprehension deficit is truly syntactic: the syntactic impairment spares most grammatical knowledge as well as (at least) basic parsing operations, and the status of the lexical knowledge required for thematic role mapping is uncertain. It may be that these disorders do not entirely respect the natural divisions of the language system; or it may be that the natural divisions are somewhat different than theorists have drawn them.

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