

## Speech production in Broca's agrammatic aphasia: Syntactic Tree Pruning

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*Broca's agrammatic aphasia entails a syntactic deficit both in sentence comprehension and in sentence production. This chapter describes the intriguing pattern of deficits in speech production, and shows that this type of inquiry interacts with linguistic theory as well as with knowledge about brain-language relations. The syntactic tree, a syntactic construct that has originally been suggested based on purely linguistic grounds, is shown to be a useful tool to describe the deficit in production in agrammatism, and the role of the impaired brain area in syntactic production. The general idea is that the selective pattern of impairment in Broca's agrammatic aphasia and the dissociations witnessed within and between languages follow from the inaccessibility of high nodes of the syntactic tree to agrammatic speakers. This causes syntactic structures that relate to high nodes of the tree to be impaired in agrammatism, whereas lower structures are unimpaired. The relative order of various syntactic abilities on the tree can also serve to explain degrees of agrammatic severity, as well as the path of spontaneous recovery from agrammatism.*

### INTRODUCTION

Agrammatic aphasia, a deficit that usually occurs following brain lesion in Broca's area and its vicinity in the left hemisphere, causes individuals to lose their ability to produce syntactically well-formed sentences. They can no longer inflect verbs correctly for tense, use subject pronouns, form relative sentences, produce subordination conjunctions, or construct a well-formed Wh question. Even more striking is the fact that at the same time they retain their ability to inflect verbs for subject agreement, use object pronouns, form reduced relatives, produce coordination conjunctions, and they are still able to form yes/no questions in some languages. This pattern is also open to cross-linguistic variability: for example, individuals with agrammatic aphasia who speak Arabic and Hebrew can produce well-formed yes/no questions, but speakers of Dutch, English and German with exactly the same impairment cannot.

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The research was supported by the National Institute for Psychobiology in Israel.

The study of this intricate pattern of dissociations is promising for both the exploration of the functional characterization of various brain areas, as well as for the inquiry of the psychological reality of linguistic constructs. In the realm of brain and function, it suggests a window through which the role of brain areas that are involved in speech production, and specifically the syntactic aspects of production, can be viewed. Once a selective deficit in a specific syntactic function can be described in fine functional details, it can then be related to the brain area that was damaged, with the possible result of the description of brain areas that subserve this specific function.

The selective nature of impairment also makes the exploration of agrammatic aphasia valuable for syntactic theories, as the selectivity of the impairment imposes constraints on the theory of normal functioning of the relevant cognitive ability: linguistic theory. For example, a selective deficit in one type of verb inflection, such as tense (the inflection of the verb for past, present or future tense), which can occur without a deficit in other types of inflection such as agreement (the inflection of the verb for person, gender and number), suggests that syntactic theory should treat tense and agreement inflections as distinct constructs and as functions that are represented or processed by different modules. Therefore, such a finding can be useful when two different linguistic models are suggested for verb inflection: one in which tense and agreement inflections form a single natural class, and one in which tense and agreement belong to two different classes. A finding from aphasia that shows a dissociation between tense and agreement can support the latter model, and bring support for it from a neuropsychological angle. Such a dissociation will be presented in the current study.

For many years, the standard view concerning agrammatic speech production has been that the deficit is very broad. Many researchers in the field claimed that syntactic ability is completely lost in these individuals, and that they merely lean on non-linguistic strategies to concatenate words into a sentence (cf., for instance, Berndt & Caramazza, 1980; Caplan, 1985; Goodglass, 1976; Goodglass & Berko 1960; Saffran, Schwarz & Marin, 1980). Later, the impairment has been presented as a more circumscribed deficit, and attempts have been made to account for it using linguistic terms. In this framework, Kean (1977) suggested to ascribe the deficit to phonological factors such as the fact that grammatical morphology is generally unstressed. Grodzinsky (1984, 1990) convincingly argued that the underlying deficit is syntactic, rather than phonological. He used the distinction between languages that allow “zero morphology”, namely languages in which omission of morphemes is licit, and languages in which it is illicit, to account for the finding that morphology is omitted in some languages and substituted in others. Still, even these accounts that used grammatical terms to explain the pattern of agrammatic impairment in production assumed a very vast deficit in grammatical elements. Grodzinsky, (1984, 1990, see also

Ouhalla, 1993) for example, suggested that all functional elements are impaired in agrammatic speech production.

However, empirical evidence regarding agrammatic aphasia have accumulated in recent years, suggesting that the deficit is actually finer-grained, and that not all functional elements are impaired in agrammatic production. Some syntactic abilities were found to be intact, and some other structures were found to be differentially impaired in different languages following the same lesion. In sentence production, the empirical investigation of different syntactic structures through constrained tests has shown that the impairment in agrammatic production does not involve all grammatical structures and function words. To give just a few examples of elements that have been shown to be intact in agrammatic production, case was shown to be spared in Finnish and Polish (Menn & Obler, 1990), and in Dutch and Hebrew (Ruigendijk & Friedmann, 2002), coordination conjunctions were shown to be spared and even overused (Menn & Obler, 1990), and negation markers and their position relative to adverbs were studied in Italian and French by Lonzi and Luzzatti (1993), and proved to be intact. Even in the domain of verb inflection, some intact abilities were found: De Bleser and Luzzatti (1994) examined past participle agreement in a structured production task, and found a considerable preservation of this inflection. Their participants performed at around 90% correct on most of the tasks in non-embedded sentences. These results called for a systematic exploration of the impaired and unimpaired syntactic abilities in agrammatic production, as well as for an account that will explain why some functions are impaired and what separates them from the unimpaired functions. But before such systematic explorations of various syntactic domains as well as the syntactic generalization are presented, let us start with a short presentation of the syntactic terms that will be required.

According to syntactic theories within the generative tradition (e.g., Chomsky, 1995; Pollock, 1989), when we produce and understand sentences, they are represented as *phrase markers* or *syntactic trees*. In these syntactic trees, content and function words are represented in different nodes (Figure 1). Functional nodes include inflectional nodes: an agreement phrase (AgrP), which represents agreement between the subject and the verb in person, gender and number, and a tense phrase (TP), representing tense inflection of the verb. Finite verbs move from V, their original position within the VP, to Agr and then to T in order to check (or collect) their inflection. Thus, the ability to correctly inflect verbs for agreement and tense crucially depends on the inflectional nodes, AgrP and TP. The highest phrasal node in the tree is the complementizer phrase (CP), which hosts complementizers, which are embedding elements like “that”, and Wh morphemes such as “where” and “what”. Other elements that move to CP are verbs and auxiliaries in Germanic languages that require the verb to be in second position in the sentence, and in yes/no questions in languages like English, German and Dutch, which require movement of the auxiliary

or the verb to the beginning. Thus, the construction of embedded sentences, Wh questions, as well as the position of the verb in some languages, depends on the CP node being intact and accessible. The nodes are hierarchically ordered in the syntactic tree – the lowest node is the Verb Phrase, the nodes above it are the Agreement Phrase and the Tense Phrase (in this order according to Pollock, 1989), and the Complementizer Phrase is placed in the highest point of the syntactic tree. This hierarchical order was suggested on the basis of purely linguistic grounds such as arguments from the relative order of elements of various types (subjects and verbs, inflected verbs and negation, infinitive verbs and adverbs etc.).

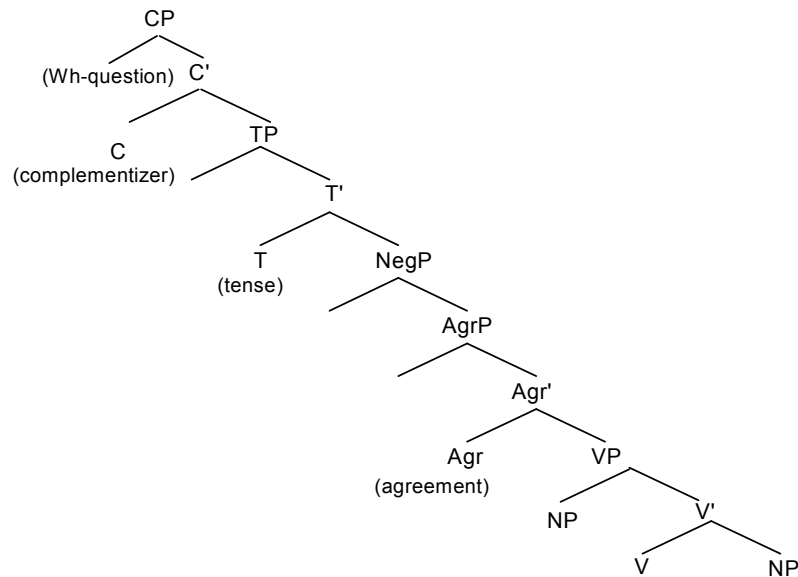


Figure 1. Syntactic tree (Pollock, 1989).

The following sections present a set of experiments that systematically explored the status of syntactic structures that relate to these functional nodes in agrammatic production, proceeding from the bottom to the top nodes: AgrP and TP and then various structures that relate to CP.

The study encompassed a variety of tasks that were administered to 18 individuals with agrammatism following brain lesion in the left hemisphere, 16 speakers of Hebrew and two Palestinian Arabic-speaking agrammatic aphasics. Following these studies, a portrait of the selective syntactic impairment in agrammatic production with respect to these functional nodes and a syntactic characterization will be presented. The spared and impaired abilities will be shown to form two natural classes when looking at them from the point of view of syntactic trees. It will be suggested that what underlies the syntactic deficit in agrammatic production is the inability to project syntactic trees up to their highest nodes (the Tree Pruning Hypothesis, Friedmann, 1998, 1999; Friedmann & Grodzinsky, 1997, 2000). This has implications for syntactic theory, and at a later stage it would also allow conclusions regarding the brain areas that subserve various syntactic functions.

## 1. Verb inflections

### 1.1 A study in Hebrew and Arabic

Hebrew and Palestinian Arabic serve as excellent testing ground for verb inflection ability, because their inflection is rich: For every finite verb produced, the speaker has to choose between three tenses – past, present and future, and twelve agreement forms – agreeing in person, gender, and number with the subject.

All these inflection forms were examined using two simple tasks - verb completion and sentence repetition. In the completion task, two simple sentences were presented. The first included a verb inflected for tense and agreement. In the second sentence, the participant had to supply the correctly inflected verb. In the **tense** condition, the temporal adverb was changed, and the missing verb differed from the supplied verb in tense only (1); in the **agreement** condition the subject was changed, so that the missing verb differed from the existing verb in one agreement feature only - person, gender, or number (2). Another type of sentence completion test required completion of a verb inflected for both tense and agreement, without a temporal adverb (3).

(1) Tense:

**axshav** ha-yeled holex. gam **etmol** ha-yeled \_\_\_\_\_. (halax)

**now** the boy walks. **Yesterday** too the boy \_\_\_\_\_. (walked)

(2) Agreement:

axshav ha-yeled holex. berega ze gam ha-yeledim \_\_\_\_\_. (holxim)

now the **boy** walks. Right now the **boys** also \_\_\_\_\_. (walk -plural)

(3) Tense and Agreement:

ha-yalda racta likfoc, az hi amda al ha-makpeca ve \_\_\_\_\_. (kafca)

The girl wanted to-jump, so she stood on the diving-board and \_\_\_\_\_. (jump-past, 3<sup>rd</sup>, fem, sg)

In the repetition task, participants repeated short simple sentences of 3-4 words that included a verb inflected to one of the 30 inflection forms (for detailed description of participants, method, and results see Friedmann, 1998).

The results showed remarkable dissociation between the production of tense and agreement inflections. While tense was severely impaired, agreement was relatively intact both in Hebrew and in Arabic (see Figure 2 for the results of the completion task, the Arabic speaking participants were HH and SSH).

Participants made tense substitution errors, but almost no agreement errors. This pattern was consistent for all participants, and each one of them showed significantly better performance on the agreement tests than on the tense tests. Even in the simple repetition task (which was only administered in Hebrew) participants made tense errors, repeating the sentence with the correct verb in a wrong tense inflection. They made no agreement errors (0)<sup>1</sup>.

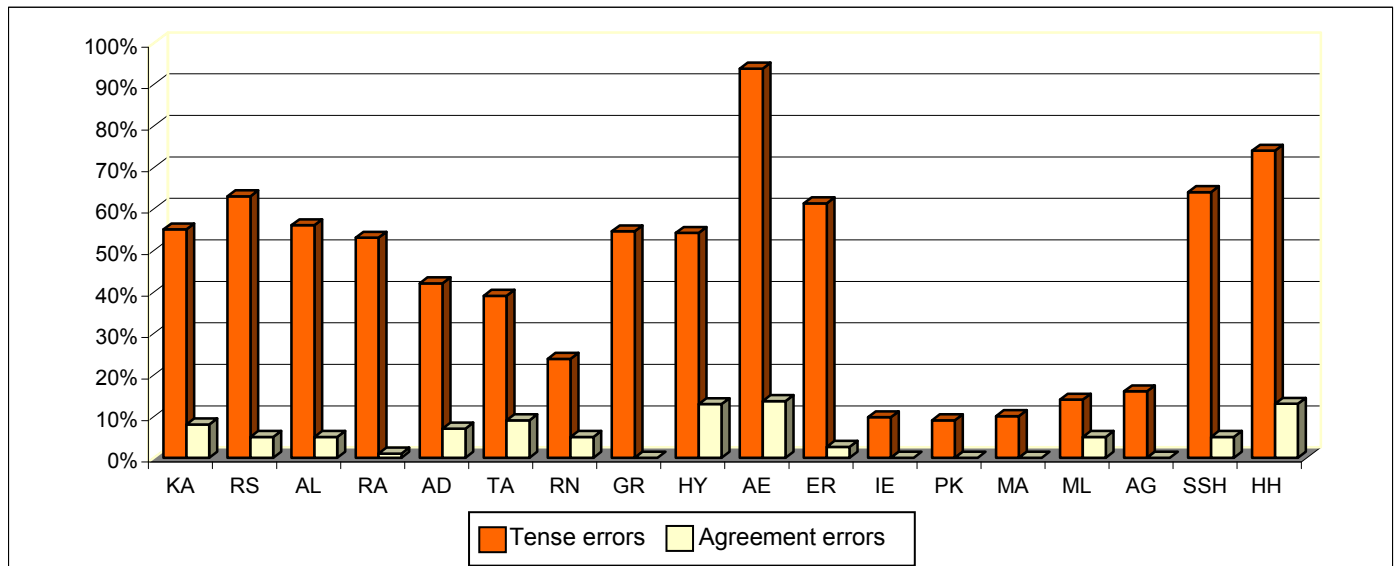


Figure 2. Performance of individual participants in the agreement and tense completion task – percent errors.

Tense was significantly poorer than agreement in both the completion and the repetition tasks, using Wilcoxon signed rank test,  $W = 6$ ,  $p < .0001$ , for both comparisons in Hebrew. In Arabic, we used  $\chi^2$  because there were only two participants, and the difference was significant too,  $\chi^2 = 34.82$ ,  $p < .0001$ .

<sup>1</sup> The repetition task yielded better performance than the completion task. This means that repetition is easier than completion, and that completion is a more sensitive task for verb inflection assessment. These methodological considerations are not at the focus of this paper, but notice that although this difference between different tasks prevents us from directly comparing performance in different tasks, it allows for a comparison within a task: for example, in both completion and repetition tasks, tense was significantly more impaired than agreement. This should also be borne in mind in the next sections with respect to the comparisons between different tasks: the exact rate of success in question elicitation task cannot be compared to the rate in the relative clause elicitation task, which was different in nature, but conclusions can be drawn on the basis of general success or failure in the tasks.

Sentence repetition task: % errors (number of inflection errors/total number of inflected verbs)

Hebrew (n=12)	Tense errors	Agreement errors
Repetition	16% (143/912)	0% (4/912)

In contrast to Germanic languages, in which the infinitives are the preferred substituting forms (Kolk & Heeschen, 1992), in Hebrew the infinitive was not used instead of the finite verb. In the repetition task, 0% of the errors were toward the infinitival form. An additional completion task with half infinitives and half finite verbs as target forms was administered to the 12 Hebrew-speaking patients. In this test, only 2% of the substitutions were from finite to infinitive verbs, and the large majority of errors was within the finite paradigm. (See Friedmann, 2000 for a possible account for this cross-linguistic difference.)

## 1.2 Inflection in other languages

Studies in other languages point in the same direction. In Spanish, too, verb agreement was found to be much better preserved than tense inflection: using a sentence completion procedure, Benedet, Christiansen and Goodglass (1998) reported that the six Spanish-speaking agrammatics they tested produced only 5.5% correct verbal tense, but produced 63.8% correct subject-verb agreement. They found a similar pattern of results in English for the seven agrammatics they examined, but with a smaller difference: the English-speaking agrammatics produced 42% correct agreement and around 15% correct tense. The same was found in French: the agrammatic patient Mr. Clermont, reported in Nespoulous et al. (1988, 1990), had only tense errors in spontaneous speech, but no verb agreement errors. Ferreiro (2003) tested 14 agrammatic aphasics in Catalan and Spanish, with the same completion and repetition tasks described above, and reported a similar pattern of dissociations: tense was more impaired than agreement in Catalan and Spanish. Wenzlaff and Clahsen (2004) tested 7 German-speaking agrammatics using forced-choice completion of inflection and also showed a dissociation between completion of agreement which was similar to that of the control subjects (above 90% correct), and completion of tense which was at chance level (68% correct).

Based on these results two main conclusions can be drawn. Firstly, not all functional categories are impaired in agrammatic production. Agrammatism is neither a complete loss of syntax, nor a complete loss of grammatical morphemes or functional categories, as has been claimed in different versions by many researchers of agrammatism over the years (Caplan, 1985; Caplan & Futter, 1986; Grodzinsky, 1984, 1990; Kean, 1977; Ouhalla, 1993). Secondly, a clear dissociation has been demonstrated between two types of verb inflection: tense and subject agreement. Tense is severely impaired, whereas agreement is relatively intact.

### ***What can account for the dissociation between tense and agreement?***

The split inflection syntactic tree suggested by Pollock (1989) (see Figure 1), seems to offer a natural syntactic way to capture the dissociation found between good agreement and poor tense. In this tree, tense and agreement are represented in two different functional phrases, Tense phrase (TP) and Agreement Phrase (AgrP). This allows for a selective impairment of one but not the other. The finding that agreement is always better than tense, and never vice versa, can also be explained by this syntactic representation. As TP is situated higher than AgrP on the syntactic tree, we might suggest that higher nodes are harder for agrammatic aphasics to access or project. Thus, while agreement node is accessed appropriately, and therefore subject-verb agreement is intact, tense is higher and therefore less accessible, and tense errors follow. Thus, two properties of Pollock's tree allow for an explanation of the dissociation found in agrammatic speech. The split of the inflectional phrase into two inflectional nodes allows for the selectivity in impairment, and the hierarchical order accounts for the asymmetry of this impairment.<sup>2</sup>

Based on these results, Friedmann (1994, 1998, 2000, 2001) and Friedmann and Grodzinsky (1997) suggested the Tree Pruning Hypothesis (TPH), according to which the syntactic tree of agrammatic aphasics is pruned and higher nodes are inaccessible in agrammatism.<sup>3</sup> The dissociation in verb inflection follows from this: Agrammatic aphasics can project AgrP, therefore agreement is intact, but they frequently fail to project (or access) TP, which causes tense errors.

If indeed individuals with agrammatism are impaired in getting as high up as the Tense node, this would have rather radical empirical consequences, as it would mean that they would fail to access nodes above TP as well. This implies that all structures that depend on the highest node of the tree, the CP, are predicted to be impaired in agrammatism.

Therefore the next step was to examine structures that require the CP. Recall that the CP hosts Wh elements of Wh questions, complementizers of embedded clauses, and verbs and auxiliaries that move to second position of the sentence. The study thus proceeded with examining the production of questions embedding and verb position in Hebrew and Palestinian Arabic as well as with perusal of the cross-

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<sup>2</sup> Tense above Agr is the order proposed by Pollock (1989, 1993) for English and French, and by Demirdache (1988) and Ouhalla (1994) for Arabic. It is, nevertheless, the opposite of the relative order suggested by Belletti (1990) for Romance and Chomsky (1995), who later gave up the representation of Agr on the tree altogether. At this point, it seems that there is no definitive linguistic argument for either order (especially given that checking and inflection collection yield opposite results), and it might be that results from neuropsychological studies, of the sort suggested here, can be taken as argument for the tense-above-agreement ordering.

linguistic literature. If agrammatic aphasics are unable to project the syntactic tree up to its highest nodes, the prediction is twofold. First, Wh questions, embedding structures and verbs in second position are expected to be impaired. Furthermore, while questions and embeddings that require the high node would be impaired, questions and embedded clauses that do not require CP should be unimpaired (in the absence of additional impairments).

## 2. Production of questions

The first step toward evaluating the status of the CP node in agrammatic production was to assess patients' ability to produce questions. A wh-question such as (4) is formed from (5), by means of movement of the Wh-morpheme to the beginning of the sentence (to spec-CP). Because the production of Wh-questions involves CP, the highest node of the tree, an impairment in CP should entail a deficit in Wh questions. Studies by Shapiro, Thompson, and their group (see Shapiro's chapter in this volume) focused on treatment of the production of Wh questions in English, and reported very poor baseline abilities to produce questions (Thompson, Shapiro, & Roberts, 1993; Thompson & Shapiro, 1995; Thompson, Shapiro, Tait, Jacobs, Schneider, 1996; Thompson, et al., 1997). Thompson and Shapiro (1995) reported that all of the 17 Broca's aphasics who participated in five different studies were unable to produce Wh questions before the onset of treatment.



(4) Ma<sub>i</sub> Miri mecayeret \_\_?

*what Miri paints?*

What does Miri paint?

(5) Miri mecayeret ma?

*Miri paints what?*

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<sup>3</sup> See section 6 for data on two degrees of agrammatic severity: patients whose syntactic tree is pruned at TP, who are impaired in structures related to TP and CP, and milder patients whose syntactic tree is pruned at a higher point, at CP, who are impaired only in structures related to CP.

## 2.1 Wh questions in Hebrew and Arabic

To assess patients' ability to form questions, we used analysis of spontaneous speech as well as two constrained tasks: question repetition and question elicitation. Spontaneous speech was collected from 12 Hebrew-speaking agrammatic patients and from one Arabic-speaking agrammatic patient, from free conversation between the subjects and the experimenter. The structured tests were administered to 10 Hebrew- and one Arabic-speaking agrammatic patients, and to matched control subjects without neurological deficit.

In the question repetition task, participants were asked to repeat simple 4-5 word Wh questions. In the elicitation task, participants heard a declarative sentence with a missing detail, signified by non-specific words like "someone" or "something", and were required to ask a question about the missing detail (see example (6) ). (For more details on the tests, the individual results and discussion see Friedmann, 2002)

(6) Experimenter: Danny ate **something**. You want to ask me about this thing. So you ask....

Target: ma dani axal?

what Danny ate?

'What did Danny eat?'

The results showed a severe impairment in Wh question production across all types of assessment. In spontaneous speech, most Wh questions that were produced were ill-formed. Out of 2272 utterances in Hebrew and Arabic, attempts for 100 Wh questions were made. Out of these 100 Wh questions, only 13 were grammatical. In the elicitation task, all agrammatic participants showed a clear deficit in Wh question production (see Figure 3). The matched control participants were 100% correct in this task.

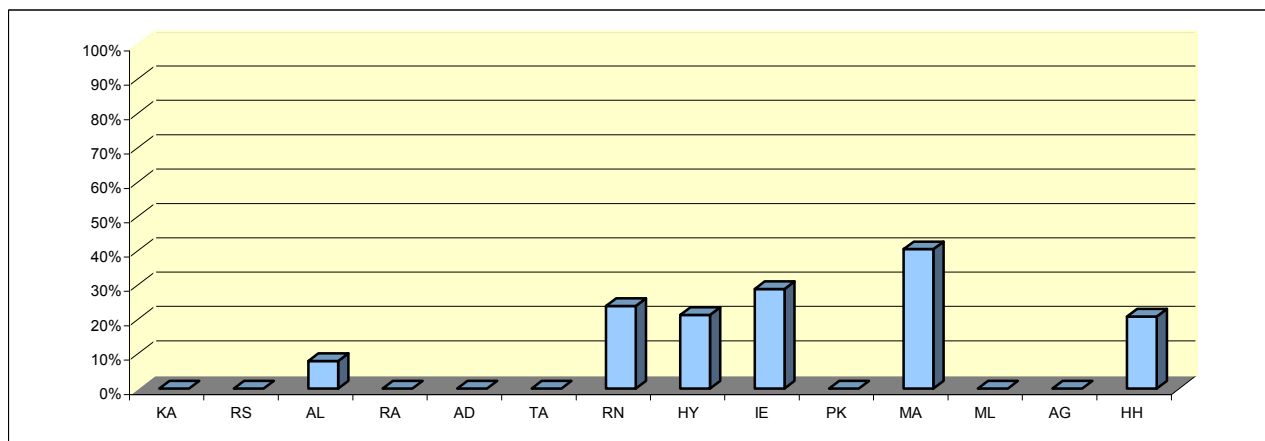


Figure 3. Performance of individual participants in the Wh questions elicitation task – percent correct.

Even in the relatively easy repetition task, all participants showed a clear deficit in Wh question production. 0 presents the performance on the repetition task. In this analysis, inflectional errors and lexical substitutions were disregarded, and included in the correct responses if the syntactic structure of the question was well preserved.

<u>Wh question repetition task. %correct (correct/total)</u>	
Repetition (n=10)	Wh questions
Agrammatic	57% (188/327)
<i>Control</i>	100% (200/200)

An analysis of the errors the participants produced while trying to produce a Wh question shows that the most common error types were production of yes/no questions instead of Wh questions (7), production of only the Wh-morpheme without the rest of the question (8), various ungrammatical questions, and Wh in situ (9).

(7) **Yes/no questions** instead of Wh questions (in the elicitation task):

Experimenter: The sun rose today at a certain hour. You want to know about the hour.  
So you ask...

Patient: beshesh... hashemesh zarxa... hashemesh hayom... lo yodaat. Hashemesh zarxa hayom?  
at-six... the-sun rose... the-sun today...(I) don't know. The-sun rose today?

(8) **Wh morpheme sequence** (in spontaneous speech)

ma... lama? ma, lama?  
what... why? what, why?

(9) **Wh in situ** (in the question repetition task)

Target : *eifo dani sam et hamafteax?*  
where Dani put ACC the-key?

Patient: *dani sam et hamaftex eifo?*  
Dani put ACC the-key where?

These errors offer two important hints regarding the nature of the agrammatic deficit in question production. The production of Wh morpheme sequences and of Wh-in-situ shows that it is not a lexical problem of Wh morpheme retrieval that underlies the difficulty in question production. The Wh-in-situ errors suggest that the deficit is structural, and that the movement of the Wh element to the beginning of the sentence cannot take place.

## 2.2 Wh vs. yes/no questions in Hebrew and Arabic

In contrast to Wh questions, yes/no questions in Hebrew and Palestinian Arabic do not require the highest node as they do not require any overt morpheme in CP (in the beginning of the sentence). In Hebrew, for example, unlike in English, a yes/no question like “Do you like Hummus?” can be asked without any morpheme in the beginning of the sentence (see example (10)).

- (10) ‘at ohevet xummus?  
you like hummus?

So if the deficit that underlies the impairment in Wh question production is indeed the inaccessibility of the high syntactic nodes and not a general problem with questions, then the production of yes/no questions in Hebrew and Arabic should show a completely different pattern from that of Wh questions. In fact, they are expected to be unimpaired. A first hint that this was indeed the case could be seen in that patients often provided yes/no instead of Wh questions. In order to examine this prediction empirically, we compared the production of yes/no questions to that of Wh questions in spontaneous speech, in the same corpus of 2272 utterances produced by 13 of the participants, and in the question elicitation test.

The performance in spontaneous speech and in the elicitation task confirmed this prediction. Yes/no question production was much better than Wh question production. Both in spontaneous speech and in elicitation, a much higher percent of yes/no questions was produced correctly (0). Using Wilcoxon signed ranks test, Wh questions were elicited significantly worse than yes/no questions,  $W = 45$ ,  $p = .002$ ).

Question production in spontaneous speech % correct (correct / total questions produced), and in question elicitation task % correct (correct/total).

	Wh questions	Yes/no questions
Spontaneous speech (n=13)	13% (13/100)	96% (81/84)
Elicitation (n=11)	22% (64/285)	87% (148/170)

Thus, the deficit cannot be ascribed to a general problem with the speech act of asking questions as some have claimed, but it is rather a structural deficit. A dissociation is found between Wh questions, which require the highest nodes, and are therefore impaired, and yes/no questions, which can be produced without the high nodes in Hebrew and Arabic, and are thus spared.

### 2.3 Question production in English Dutch and German – the dissociation disappears

A completely different pattern is expected in languages in which yes/no questions *do* require the high nodes. In English for example, yes/no questions start with an auxiliary (11), and the auxiliary resides in the high node C. If the C node is impaired, yes/no questions are expected to be impaired in such a language.

(11) Do you like pasta?

In fact, several studies indicate that yes/no questions are impaired in the speech of English-speaking agrammatic aphasics. Goodglass, Gleason, Bernholtz, and Hyde (1972) tested the production of various sentence structures in English, among them yes/no questions. Their patient made errors on all his yes/no questions trials (0/14 correct). Thompson et al. (1993) observed that the English-speaking agrammatic aphasics they examined produced mainly questions that did not include movement of any kind - neither Wh movement nor subject/auxiliary inversion. Their patients only used rising inflection to express a question. These English-speaking patients were impaired also in yes/no questions, and produced them without the initial “do” (e.g., “you like eggplants?”). The same tendency was also reported by Myerson and Goodglass (1972). Although they did not refer specifically to yes/no questions, they remarked that their three English-speaking agrammatics used intonation alone to indicate a question in their spontaneous speech.

We also administered the same tests we used in Hebrew and Arabic for the elicitation of Wh and yes/no questions to one English-speaking individual with agrammatism. He failed to produce both Wh and yes/no questions (Friedmann, 2002). Similarly, data from Dutch and German indicate that individuals with agrammatic aphasia fail to produce both Wh- and yes/no-questions (De Bleser & Friedmann, 2003; Ruigendijk, Kouwenberg, & Friedmann, 2004). To conclude, the data on question production in languages in which yes/no questions require the CP node indicate that in English, Dutch and German, unlike in Hebrew and Arabic, yes/no questions are also impaired.

We see that whether or not a structure involves high nodes is the critical factor for its status in speech production. Wh questions in Hebrew, Arabic, Dutch German and English, and yes/no questions in English Dutch and German require high nodes and are thus impaired, whereas Yes/no questions in Hebrew and Arabic do not require high nodes and are therefore spared.

### 3. Embedding

The next function of CP we studied was embedding – the ability to embed one sentence to the other, usually using “that”. We tested the ability of the agrammatic aphasics to produce embedded structures, while comparing embeddings that require the CP to embeddings that do not. Again, two types of analysis were used: First, we analyzed spontaneous speech in Hebrew and in Palestinian Arabic, and searched for embeddings in order to obtain general information regarding embedding ability. Later, in order to receive a quantitative and accurate measure in which the target sentence can be controlled, structured tests were devised - embedded sentence repetition, and relative clause elicitation.

#### 3.1 Spontaneous speech analysis

The spontaneous speech of 11 Hebrew-speaking and one Palestinian Arabic-speaking agrammatic aphasics was analyzed for embedded sentences of two types: embeddings that require full CP such as sentential complements and full relative clauses, and embeddings that involve lower structures such as untensed embeddings like infinitival complements and reduced relatives. For each type of embedding, the number of grammatical vs. ungrammatical sentences was reckoned.

This analysis of spontaneous speech showed that embedding was impaired whenever CP was involved. Compared to speakers without language impairment, very few CP-embedded structures were present, and the embedded structures that did appear were ill-formed (Thompson, Shapiro, Schneider, & Tait, 1994 report a 1.1 : 1 rate of complex/simple sentences for normal speakers of English, our counting in normal Hebrew yielded an even higher rate of 1.8 : 1, whereas the spontaneous speech of our patients included an extremely low rate of 1 : 18.) On the other hand, untensed embeddings that do not require any morpheme in CP were almost always grammatical (0).

Subordination production in spontaneous speech – CP embedding  
vs. untensed embedding. %correct (correct / total embeddings produced)

Spontaneous speech (n=12)	CP embedding	Untensed embedding
1950 utterances	12% (13/110)	99% (93/94)

#### 3.2 Structured tasks: embedded sentence repetition and elicitation

Repetition and elicitation tasks were used to quantitatively assess subordination production in agrammatic speech. The repetition task included repetition of relative clauses (12) and sentential complements of nouns and verbs (13).

(12) Yoxanan ra'aa et ha-ish she-hit'atesh.

John saw the-man that-sneezed.

(13) Yoxanan ra'aa she-ha-ish hit'atesh.

John saw that-the-man sneezed.

In the subject-relative clause elicitation task, patients were shown two drawings of a person involved in some action, and were asked to depict each picture in one sentence in a specific way. Example (14) shows the (translated) experimenter presentation of the question, and (15) is the target relative clause response. The control condition for this test was elicitation of adjectival modification, using the same type of elicitation method ("This is the red fish, this is the blue fish").

(14) Here are two men. One man is playing tennis, another man is rowing a boat. Which man is this?

Start with "This is the man...".

(15) Target: ze ha-'ish **she**-xoter besira.

this the-man that-rows in-boat

*'This is the man **who** rows a boat.'*

The results of the two tests again indicated a severe deficit in embedding production. In repetition, both sentential complements and relative clauses were impaired, with a mere 33% correct in the simple repetition task (0).

This lack of difference between relative clauses and sentential complements indicates that the agrammatic deficit in production is a structural deficit that involves the CP node rather than a movement deficit. Given that only relative clauses include a movement, a movement deficit entails that only relative clauses but not sentential complements would be impaired. Structural impairment of the CP node, on the other hand, accounts for the impairment of both structures, which involve CP.

Embedded sentence repetition %correct (correct/total)

Repetition (n=10)	Relative clauses (Mary knew the man that sneezed)	Sentential complements (Mary knew that the man sneezed)
Agrammatic	33% (50/152)	33% (29/87)
Control	100% (100/100)	100% (100/100)

In the elicitation test, full subject relative clauses were very poorly produced, both in Hebrew and in Arabic (see Figure 4 for the performance of individual participants). Adjectival modifications were significantly better than the relative clauses, with average 98% correct, compared to 22% for the relative clauses. The good performance in the adjectival modification control items shows that the failure in relative clauses was not due to lack of comprehension of the task or a general deficit of predication.

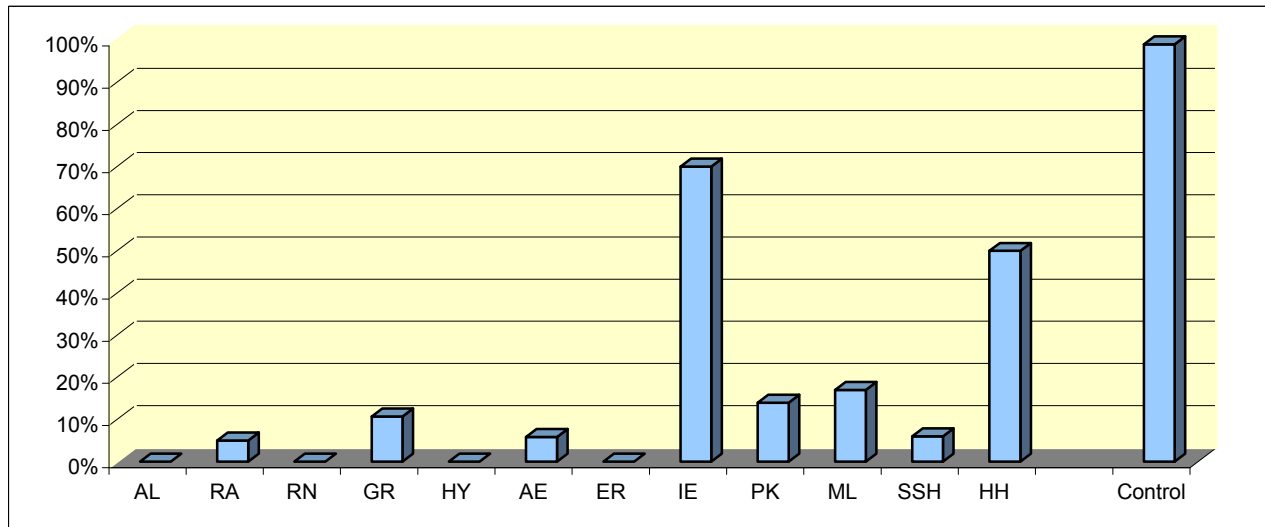


Figure 4. Performance of individual participants in the relative clause elicitation task – percent correct.

In order to further compare the production of embedded structures that involve CP to embedded structures that do not involve CP, we included these two types of embedding in an additional repetition test. In this test, patients were asked to repeat comparable sentences with tensed (16) or untensed (17) sentential complements of verbs.

(16) Tensed: yoxanan xashav she-Sharon rakda  
John thought that Sharon danced

(17) Untensed: yoxanan ra'a et Sharon rokedet  
John saw ACC Sharon dance-participle

Repetition of tensed and untensed embedding in Hebrew. %correct (correct/total)		
Repetition (n=6 )	Tensed embedding	Untensed embedding
Agrammatic	31% (50/162)	92% (130/141)
Control	100% (120/120)	100% (120/120)

The results, presented in Table 6, again show a clear dissociation between tensed and untensed sentences. This dissociation cannot be related to sentence length, because sentence length was identical in the two conditions, nor can it be ascribed to meaning. Rather, it relates to the different syntactic properties of the two types of subordination -- untensed sentences are analyzed syntactically as structures that do not involve CP or TP nodes of the syntactic tree; the tensed sentences in this study require CP.

The most frequent error types in the spontaneous speech and the structured tests were: use of direct instead of indirect speech; no embedded sentence after the complementizer (in sentential complements); ungrammatical CP: filled trace, unrelated embedded etc.; complementizer omission; "and" instead of a complementizer, all indicating inability to use CP to embed one sentence to the other.

Another interesting type of response that appeared in the repetition and elicitation tasks in Hebrew was the use of participial relative (18) or semi-relative instead of a full relative. According to Siloni (1994, 1997), and Friedemann and Siloni (1997), reduced relatives do not contain either CP, AgrSP, or TP. This probably allows the agrammatic aphasics to produce subordination even when CP is inaccessible.

- (18) zo ha-yalda ha-roxevet al ofanayim  
This the-girl the-riding-participle on bicycle.

A similar preference for "low" relatives can also be found in the data of Ni, Shankweiler, Harris and Fulbright (1997) in English. In a relative clause elicitation task, their patients did not produce a single correct full relative clause, but instead they produced 12/32 reduced relatives. A study we conducted with an English-speaking agrammatic aphasic showed similar results: KCL was unable to repeat sentences with CP embeddings. He repeated only 3 out of 56 relative clauses and sentential complements (5% correct). In marked contrast, he could repeat sentences with small clauses much better: He repeated correctly 29 of 41 comparable sentences with small clauses, which is 71% correct (Friedmann & Taranto, 2000). The spontaneous speech of agrammatic aphasics in French and Japanese tells a similar story: while their CP embeddings are scarce and ill-formed, they produce untensed embeddings correctly (Nespoulous et al., 1988, 1990; Sasanuma, Kamio & Kubota, 1990).

The deficit in embedding is a very robust phenomenon that occurs across all languages in which agrammatic production was studied. Data from spontaneous speech in various languages show the same picture: agrammatics have severe difficulties in the production of embeddings, which manifest in their avoidance of complex sentence, and in errors when they do try to produce them. This was found in English (Thompson et al., 1994, 1996, 1997; Bates, Friederici, Wulfeck, & Juarez, 1988), in Italian and

German (Bates et al., 1988), in French, (Nespoulous, et al., 1988, 1990), in Japanese, (Hagiwara, 1995), in Hindi (Bhatnagar, 1990; Bhatnagar & Whitaker, 1984), and in Dutch, Swedish, Polish, and Finnish in Menn and Obler's (1990) corpora.

To summarize, embedding is severely impaired in agrammatic production, but, just like in the case of the production of questions, the impairment is selective. In Hebrew and Arabic embeddings that do not involve CP are better preserved than CP embeddings. Indications for the same dissociation can be found also in English, French and Japanese. The impaired structures are those that involve the highest nodes of the syntactic tree (TP, CP), whereas embedded structures that do not include these nodes are intact. Thus, full relatives and tensed sentential embeddings that require a complementizer in C and a finite verb are impaired. Semi-relatives, reduced relatives and untensed embeddings do not include TP and CP and are therefore spared.

#### 4. Verb inflection and position in Germanic languages

Another structure that requires access to CP is the inflected verb that moves in some languages to the second position of the sentence, which, on the tree, is a movement of the verb to C. This happens obligatorily in Germanic languages such as Dutch, German, Icelandic and Scandinavian languages, and it is optional in Hebrew. In Germanic languages, the finite verb in every main clause moves to the second position of the clause, following the first constituent - the subject or any other constituent (see examples (19),(20) in Dutch). Non-finite verbs (participles and infinitives), do not move, and in Dutch and German stay in sentence-final position (21). This phenomenon of finite verb in second position (V2) is analyzed syntactically (at least in the case of non-subject first constituent) as a movement of the verb from its base-generated position at the end of the VP to C (Koster, 1975).

(19)  $V_{fin}$  2nd: De boer **melkt** de koe  
the farmer milks the cow

(20)  $V_{fin}$  2nd: Langzaam **melkt** de boer de koe  
slowly milks the farmer the cow

(21)  $V_{inf}$  final: De boer wil de koe **melken**  
the farmer wants the cow milk-inf

Consider how a deficit in the high nodes of the syntactic tree might affect verb production in such V2 sentences. If TP and CP are not accessible, the verb will not be able to move to C (through T). Thus, the

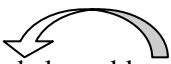
prediction is that in V2 languages, the verb will not appear in second position but rather in final position. Given the close relation between verb inflection and verb movement (Pollock, 1997), whenever a verb cannot move to the high nodes it will also be uninflected. Therefore, although main verbs in sentences without auxiliaries should always be inflected, many matrix verbs can be expected to appear uninflected in sentence final position, instead of inflected in second position. In sentences in which the speaker succeeds in moving the verb, the verb will be inflected and in second position.

Data from structured tests and spontaneous speech verify this prediction: Many matrix verbs in German and Dutch appear in an infinitival form in sentence final position (when they are supposed to be finite, and in second position), and when finite verbs are produced, they appear in second position. This has been found for Dutch and German (Bastiaanse & van Zonneveld, 1998; Kolk & Heeschen, 1992), and some indications for verb position implication were also found for Swedish and Icelandic (see Friedmann, 2000 for a review).

A study of verb movement to C in Hebrew yielded similar results. In Modern Hebrew the basic word order is SVO (Subject, Verb, Object) (22).

- (22) etmol ha-yalda axla xumus.  
 yesterday the-girl ate hummus  
 'The girl ate hummus yesterday.'

However, in Hebrew it is also possible to move the verb to the second position of the sentence, immediately after a non-subject phrasal constituent. This movement creates an XVSO structure such as (23) (Shlonsky 1987, 1997; Shlonsky & Doron 1992).

- (23) etmol axla ha-yalda xumus.  
 yesterday ate the-girl hummus  
 'The girl ate hummus yesterday.'
- 

According to Shlonsky and Doron (1992) and Shlonsky (1997), the XVSO structure in Hebrew is created by a non-subject constituent at spec-CP, which triggers the movement of the verb to C. Thus, XSVO and XVSO structures in Hebrew form a minimal pair with respect to movement to CP. The comparison of the two structures might suggest an additional indication about whether or not movement to CP is possible in agrammatism. If indeed agrammatic aphasics are unable to access the high nodes of the syntactic tree, they are expected to fail on the XVSO structure that involves movement to these nodes.

The production of verb movement to CP was assessed using a sentence repetition task that included 40 sentences. Half were XVSO, i.e., structures with verb movement to CP, and the other half were XSVO. The XSVO and XVSO sentences were matched for length (Friedmann & Gil, 2001).

The results were that the repetition of sentences with verb movement to CP was profoundly impaired in all agrammatic participants, as seen in Figure 5. Repetition of the XVSO structures was significantly worse than the XSVO structures (for the group, paired *t*-test, one tailed,  $t(4) = 12.17$ ,  $p = .0001$ ,  $M = 24\%$  and  $83\%$  respectively; and for each individual participant, using Fisher exact test,  $p < .002$ ).

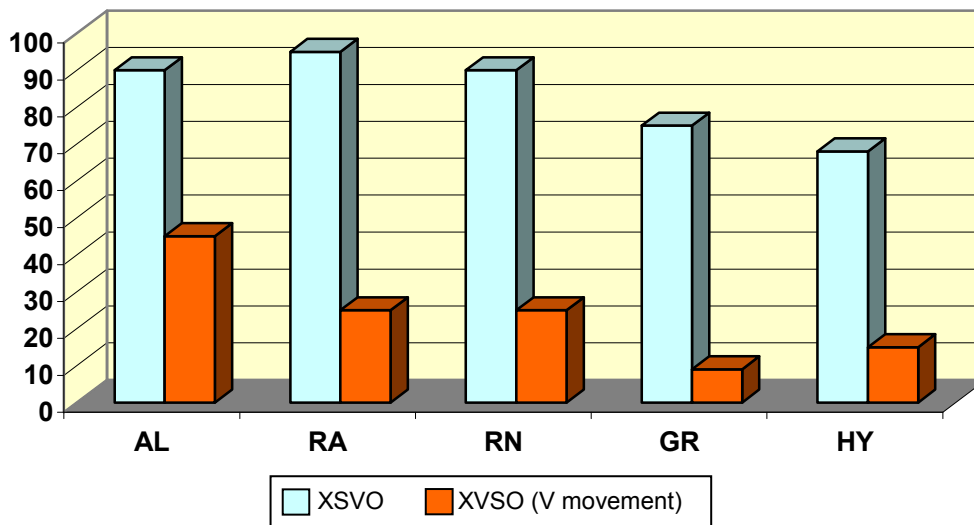


Figure 5. Percent correct repetition of sentences with and without verb movement to second position.

The two most common error types in repeating XVSO sentences were inversion of verb-subject order to subject-verb order, and verb omission. Inversion errors were far more frequent in XVSO (56 inversions) than in XSVO (only 2 inversions),  $t(4) = 4.43$ ,  $p = .005$ . Verb omissions occurred more frequently in XVSO sentences than in XSVO sentences: There were 17 verb omissions in the sentences containing verb movement, compared to 6 verb omissions in the sentences without verb movement. These results also have an implication for the nature of verb omission in agrammatism. Many studies have reported that agrammatic aphasics have difficulties in verb production (Luzzatti et al., 2002). There are different explanations of this deficit: Some researchers hold that agrammatic aphasics have a selective deficit in the lexical retrieval of verbs (Zingeser & Berndt, 1990; Kim & Thompson, 2000). Others have suggested that the deficit is syntactic rather than lexical (Friedmann, 2000). The results of the current study further confirm that the syntactic deficit is involved in verb omissions, as sentences that were similar in all but the movement of a verb yielded a different rate of verb omission – verbs were omitted three times more from sentences with verb movement to C than from sentences without verb movement. These results are

similar to those of Bastiaanse and van Zonneveld (1998) and Zuckerman, Bastiaanse, and van Zonneveld (2001) in Dutch, who used a verb completion test and found a clear difference between verb retrieval in verb-second position and sentence-final position. Their patients retrieved significantly fewer verbs in second position (when the verb was to be positioned in C) than when they had to complete a sentence-final verb. In addition, data from treatment studies indicate an improvement in verb retrieval following treatment of syntactic domains such as movement to CP (Friedmann, Wenkert-Olenik, & Gil, 2000) and tense inflection (Weinrich, Shelton, Cox, & McCall, 1997). These results confirm that verb retrieval failure in agrammatic aphasia has syntactic underpinnings. When, due to syntactic tree pruning, agrammatics fail to raise their verbs to inaccessible nodes in the tree, they either drop them or leave them unraised in a low node. When the accessibility of high nodes is improved following treatment, verb retrieval improves as well.

To conclude, data from V2 in Hebrew and in Germanic languages support the claim that the highest node of the syntactic tree, the CP, is impaired in agrammatic production, and this impairment causes the agrammatic speakers not to be able to move their verbs to second position of the sentence, before the subject. This also causes the agrammatic aphasics to frequently produce uninflected verbs at their base-generated position at the end of the sentence, and to omit verbs.

## **5. Interim summary – impaired and intact syntactic structures**

Where do we stand now? It definitely seems that not all functional elements are impaired in agrammatic production, but, furthermore, it seems that the dissociations, both within and between languages, behave very regularly along syntactic lines that are drawn by the syntactic tree. In the realm of inflections – a dissociation was found between tense and agreement inflection: tense is impaired, but agreement seems to be intact. This can be accounted for by the hierarchy of the syntactic tree: the node in which agreement is checked (or collected) is located lower than the node that is responsible for tense inflection. Therefore, if the syntax of an individual with agrammatism allows only access to lower node, agreement might be fine, but tense is impaired. Another cluster of findings relates to all structures that require the highest node, CP. These structures, embedding, Wh questions, yes/no questions in Germanic languages, and verb movement to second sentential position, are impaired for all the participants. Importantly, when a question or an embedded structure does not involve the highest node (such as yes/no questions in Hebrew and Arabic, or reduced relative clauses), it is produced correctly, pointing to the CP node as the source of difficulty in the production of these structures.

## 6. Degrees of agrammatic severity and the tree

Do all individuals with agrammatism show the same pattern of impairment? The next step was to look at the performance of each of the individual participants on structures that relate to the three syntactic levels. Several researchers in the field have pointed to the variability that exists between individuals with agrammatism, to the point that there were calls to dispense with the concept of a neuropsychological syndrome of agrammatic aphasia altogether. This makes the intra-syndrome variability another important target to study.

For this aim the performance of the 18 participants on agreement completion, tense completion and an average score of Wh question and relative clause elicitation was pitted together in Figure 6. When looking at the performance of each individual patient, two very clear patterns emerge. One pattern, manifested by the more severe patients, is that of intact agreement, impaired tense, and impaired Wh questions and embedded sentences. The milder patients (shown on the right hand side of the chart) show a different pattern. In their production, both tense and agreement are relatively intact (with agreement at 100% and tense at around 90% correct), but Wh-questions and embedded sentences are impaired.

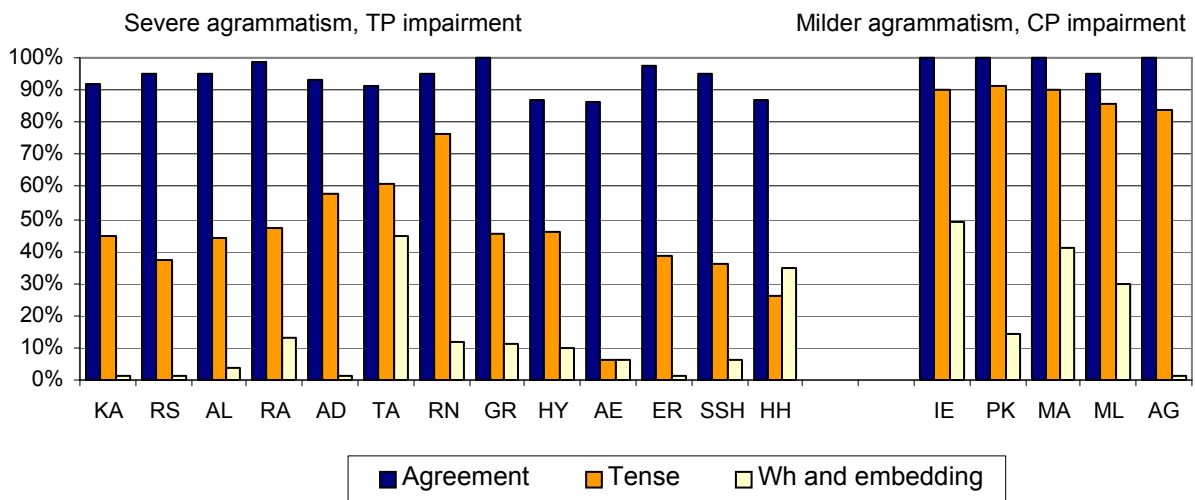


Figure 6. Individual performance in agreement, tense, Wh questions and embedding tests.

This difference in severity is easily captured by the height of the deficit on the tree. The severe patients are impaired both in TP and in CP; the milder impaired patients are only impaired higher up, in CP (Figure 7). Crucially, none of the patients showed a deficit in TP without a deficit in CP, or a deficit in AgrP without a deficit in TP and CP. So a deficit at a specific level on the tree entails a deficit in all levels above it. The higher a patient can access (the higher the pruning site is), the milder the impairment, because more functional nodes can be accessed. The lower the impaired node is on the syntactic tree, the more severe the clinical manifestation of agrammatism, because less functional nodes are available.

Notice that in every other respect, except the functional categories C, T, and Agr, these patients share all the standard clinical sign of agrammatism. The speech of all of them is non-fluent, and impaired in aspects of their grammar - they have short phrase length, they produce ungrammatical sentences, and in particular, they cannot embed or ask questions. So it seems that indeed the impairment of all these participants belongs to the same general clinical generalization, but in different degrees of severity. The crucial point here is that there is a single principle that distinguishes them from one another, the level in the syntactic tree at which the pruning occurs. This is how the tree pruning hypothesis provides a flexible conception of a neuropsychological syndrome, that may have more than a single manifestation. Yet this generalization is highly constrained, as it has strong predictions with respect to what is *not expected* as a pattern of agrammatic production. Specifically, given that inaccessibility to a certain node prevents access to higher nodes, we do not expect to find individuals with impaired functions that relate to TP (subject case, tense inflection, subject pronouns), but with intact CP functions such as Wh question production, and production of CP-embedded sentences. Similarly, if agreement-related structures are impaired, we expect both TP and CP to be impaired.<sup>4</sup>

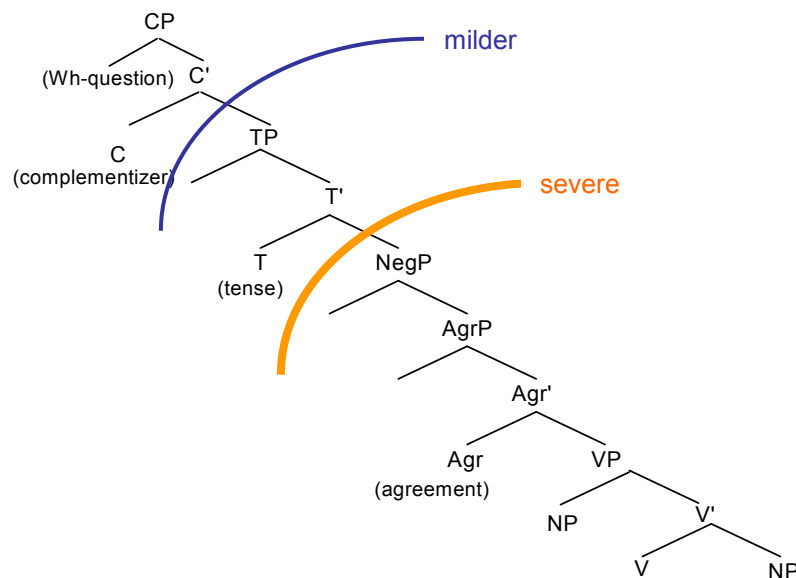


Figure 7. Degrees of agrammatic severity: Pruning at CP describes a milder impairment than pruning at TP.

<sup>4</sup> Note that morpho-phonological impairments that also induce verb inflection errors (such as the one witnessed in reproduction conduction aphasia) are not expected to be characterized by the syntactic tree and therefore can appear with unimpaired CP.

## 7. Recovery on the syntactic tree

So far, the syntactic performance of the participants was assessed in one point in time, after spontaneous recovery has completed. But what is the path spontaneous recovery follows? Can it also be captured by the hierarchical order on the syntactic tree? A study we recently conducted asked exactly this question (Friedmann, in press). We continuously tested the production of functional elements and syntactic structures of SB, a young woman with agrammatic aphasia following Traumatic Brain Injury (TBI), and left craniotomy which resulted (according to a CT done 4 month later) in vast hypodense area in left hemisphere including temporal, parietal and frontal lobes, lateral ventricle enlarged, and right hemiplegia. SB was 20 years old, native speaker of Hebrew, who had 12 years of education.

Her syntax was systematically tested since she started speaking again, 4.5 months post her injury, and then regularly until 18 months post injury. Her abilities that are related to Agr, T and C were tested: She was tested in agreement inflection, tense inflection, and relative clause and question production. The results, as can be seen in Figure 8, are that during the first stage, four and a half months post injury, all the tested functions were impaired: She had both agreement and tense inflection substitutions in production tasks, and she was completely unable to construct either Wh questions or embedded relative clauses (neither subject nor object relative clauses). Two months later, 6.6 months post injury, she was already able to inflect verbs for agreement, but still had many errors of tense inflections, and could not construct embedding and Wh questions. Tense inflection recovered around 15 month post injury, at which point relative clauses were still not produced. 18 months post injury, relative clauses started to emerge in elicitation tasks, indicating the occasional access to the highest node of the tree, CP. At this time she could also produce some Wh questions and some sentential complements of verbs.

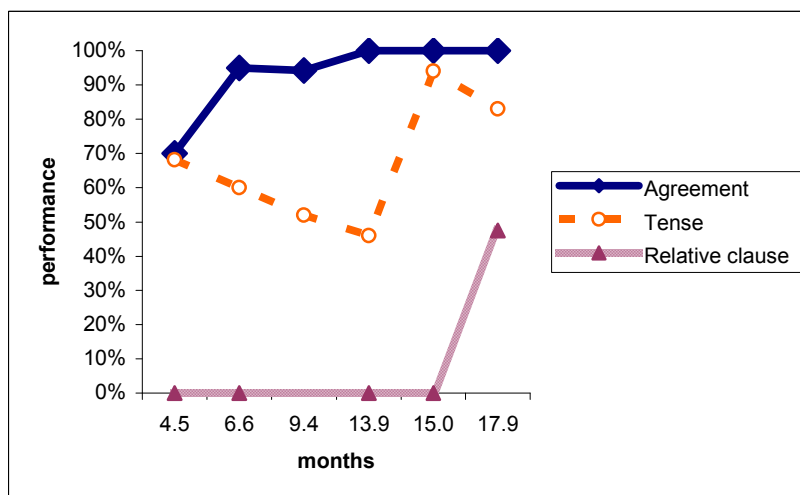


Figure 8. The spontaneous recovery of SB in agreement, tense, and relative clause production.

Thus, it seems that the recovery of SB can be described as gradual climbing on the syntactic tree, at each stage obtaining access to a higher node of the tree (see Figure 9). First, AgrP, TP and CP are not accessible. Then, around 6 months after injury, AgrP becomes available, and TP and CP are still not accessible. Then, 15 months after the injury, TP becomes available, but CP is still out of reach. The final stage is characterized by access to AgrP and TP, and partial access to CP.

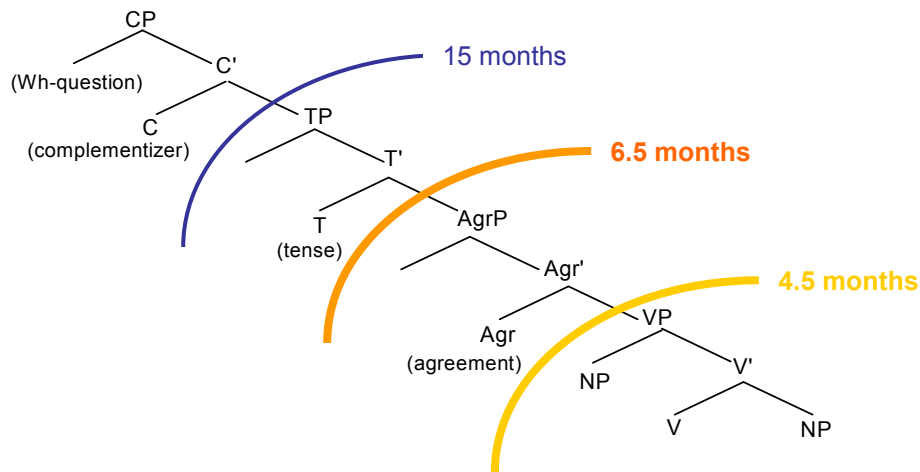


Figure 9. SB - gradual recovery on the syntactic tree.

Apart from indicating that syntactic recovery might be described by the hierarchy on the syntactic tree, these results, also have another important contribution. Recall that in the last section all participants had either TP and CP impairment, or only CP impairment. SB shows an additional pattern, that goes very well with the severity generalization. At 4.5 months post onset she had a deficit that included also AgrP (as well as TP and CP). This suggests that the fact that only individuals with a tree pruned at TP or pruned at CP were reported in the initial study of 18 participants (see section 6), may have resulted from the fact that we included in the initial study only individuals at a stable stage who had sentences of two words and more. It might be that the individuals who are impaired in agreement too are either not yet in a stable condition, or produce very short sentences. They also show the three different degrees of severity, characterized by three different pruning sites, AgrP, TP, and CP in one and the same patient, during recovery from very severe to mild agrammatism.

## **SUMMARY**

The study of speech production in Broca's agrammatic aphasia showed that not all functional elements and not all syntactic structures are impaired, and that the deficit is highly selective. This selective pattern can be captured using theoretical syntactic notions such as the hierarchical structure of various functional nodes on the syntactic tree. The Tree Pruning Hypothesis (TPH) suggests that individuals with agrammatism fail to project their syntactic tree all the way up to the treetop. This leads to the dissociations between the production of structures that depend on high parts of the tree, which are impaired, and lower structures, which are preserved. This approach also enables an account for the way the same deficit manifests differently in different languages.

Thus, within a language, dissociations are found between structures, depending on their position on the syntactic tree. For example, a deficit in TP impairs the production of structures that require TP or the node above it, CP, but leaves the structures that relate to AgrP intact. So tense inflection, full relatives and embeddings, Wh questions, yes/no questions in English and German and verbs in second position are impaired. On the other hand, agreement inflection, reduced relatives, infinitival sentential complements, yes/no questions in Hebrew and Arabic, and non-finite verbs can make do with the lower part of the syntactic tree, and are therefore produced correctly. Thus, these seemingly unrelated deficits are all part and parcel of the same underlying deficit – the inability to project the syntactic tree up to its highest nodes, and the site of pruning determines which structures can be produced, and which structures are impaired. Differences between languages for individuals with the same structural deficit are accounted for by the difference in the syntactic structure similar sentence types have between languages. For example, as is the case with yes/no questions, when one language requires the use of an impaired node, and the other language suffices with a lower node, only speakers of the first language would be impaired in yes/no questions.

The hierarchical nature of the syntactic tree also accommodates findings regarding differences in performance between individuals. While some patients are impaired both in TP-related abilities (like tense inflection), and in CP-related abilities (such as Wh questions and embedding), others are impaired only in CP-related abilities. If, with linguistic theory, we assume that CP is higher than TP, this pattern follows: milder patients can access higher parts of the tree, and thus can access TP but not CP, but more severe patients cannot even reach TP and are thus impaired both in TP and in CP. The most severely impaired patient, at the first stage of her agrammatism, was not able to access either AgrP, TP, or CP. Crucially, the hierarchy of the functional nodes on the tree forms a perfect Guttman scale (Guttman,

1944), namely, when a lower node is impaired, all nodes above it are always impaired too. When a node is intact, it means that all nodes below it are intact.

This hierarchy has been shown as a possible description for spontaneous recovery of syntactic abilities after brain damage as well. A longitudinal study of the syntactic abilities of a woman with agrammatism has shown that she started without being able to access any functional node, and failing in agreement and tense inflection as well as in the production of embedded sentences. The next step brought her to access AgrP but not TP or CP, then she could access both AgrP and TP but not CP, and the final step involved partial recovery of CP.

Apart from allowing for an accurate description of the agrammatic deficit, these findings offer support for the psychological reality of syntactic trees from a neuropsychological angle. That is to say, the finding that tense and agreement can be selectively impaired indicates that tense and agreement are indeed checked (or affixed) in distinct nodes, as was originally suggested by Pollock (1989). Furthermore, the finding that some agrammatic individuals are impaired in Wh questions and subordinations but not in tense inflection, suggests that tense resides in a different functional node than Wh questions and embeddings. Thus, we have support for three phrasal nodes, parallel to AgrP, TP and CP, that have been assumed in the linguistic literature for independent reasons. The pattern of asymmetric dissociations also supports a specific hierarchical order of these nodes.

The possibility to characterize the selective pattern of agrammatic impairment by terms of functional nodes and their hierarchical order on the syntactic tree, argues for the psychological reality of the syntactic tree. But the syntactic tree is not only psychologically real: it is also neurologically real. The findings and accounts presented in this chapter suggest that the brain areas implicated in agrammatic aphasia, which are typically Broca's area and its vicinity, are involved in the structuring and projection of the syntactic tree. It might be that a lesion in these area restricts the number of phrasal nodes that can be projected (represented or processed) in the syntactic tree.

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