

The fragile nature of the left periphery: CP deficits in agrammatic aphasia

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Syntactic trees, or phrase markers, have originally been suggested as a representation of syntax in the mind based on purely linguistic grounds. In this paper, the psychological reality of syntactic trees and hierarchical ordering is explored from another perspective -- that of the neuropsychology of language breakdown. The study reported here examined several syntactic domains that rely on different nodes in the tree – tense and agreement verb inflection, subordinations, interrogatives, and verb movement - through a study of 14 Hebrew and Palestinian Arabic-speaking agrammatic aphasics, and perusal of the cross-linguistic literature. The results show that the impairment in agrammatic production is highly selective, and lends itself to characterization in terms of a deficit in the syntactic tree. The complex pattern of dissociations follows from one underlying deficit - the inaccessibility of high nodes of the syntactic tree to agrammatic speakers. Structures that relate to high nodes of the tree are impaired, while "lower" structures are spared. These findings from neurolinguistics also bear on theoretical questions in linguistics such as the psychological reality of linguistic constructs, split inflection and relative order of functional categories.

INTRODUCTION

This study examines the nature of a striking phenomenon in the neuropsychology of language: Following brain damage to the left cerebral hemisphere, people lose their ability to correctly inflect verbs for tense, use subject pronouns, form relative sentences, produce subordination conjunctions, and their ability to construct well-formed Wh questions. 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 their ability to form yes/no questions in some languages. The selective nature of this deficit can suggest some constraints from neurolinguistics to syntactic theories.

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In what follows, a portrait of these dissociations is presented, based on a study of 14 Hebrew and Palestinian Arabic-speaking agrammatic aphasics, and a syntactic characterization is suggested, according to which 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, 2001, 2002; Friedmann & Grodzinsky, 1997, 2000). It is shown that the deficit is selective, and that the spared and impaired abilities form two natural classes when looking at them from the point of view of syntactic trees. The possibility to characterize language breakdown by means of syntactic trees sheds some light on the psychological reality of syntactic trees, and supports a specific hierarchical ordering of functional nodes suggested by Pollock (1989).

Agrammatic aphasia is a language deficit following damage to the left cerebral hemisphere, usually in Broca's area and its vicinity (Zurif, 1995). The standard view concerning agrammatic speech production is that the deficit is very broad. Many researchers in the field claim that syntactic ability is completely lost in these patients, and that they lean on non-linguistic strategies to concatenate words into a sentence (Berndt & Caramazza, 1980; Caplan, 1985; Goodglass, 1976), or that all functional elements are impaired in their speech production (Grodzinsky, 1984; Kean, 1977; Ouhalla 1993).

However, empirical evidence regarding agrammatic aphasia has accumulated in recent years, suggesting that this picture is incorrect and that the deficit is actually finer-grained. 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 the domain of agrammatic comprehension, the research of selective impairment is already very advanced. Impaired and preserved syntactic abilities in comprehension were investigated in detail, and studies show that the impairment is highly selective and that it lends itself to principled syntactic characterization. The impairment is now described in linguistic terms, and even contributes to the discussion of issues debated in current syntactic theory (cf. Grodzinsky, 1990; Grodzinsky et al., 1993).

In language production, the empirical investigation of different syntactic structures through constrained tests is still developing, but several studies have already 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 remain intact in agrammatic production, case was shown to be preserved in Finnish and Polish (Menn & Obler, 1990), Coordination conjunctions were shown to be spared and even overused (Menn & Obler, 1990), negations and postpositions in Japanese were found to be intact (Hagiwara, 1995) and negation markers and their position relative to adverbs, studied in Italian and French by Lonzi and Luzzatti (1993), proved also to be intact. Even in the domain of verb inflection, intact abilities were found: De Bleser and Luzzatti (1994) have examined past participle agreement in a structured production task, and found considerable preservation.

This selective pattern is what makes the exploration of the agrammatic impairment in production especially interesting and valuable for theories of normal syntax, as the selectivity imposes constraints on the theory of normal functioning of the relevant cognitive ability: linguistic theory. Reciprocally, linguistic theory provides students of agrammatism with the descriptive tool kit that enables a more precise derivation of the behavioral pattern witnessed in this impairment, leading to better diagnosis and subsequently to better treatment of the pathology.

In the following sections a set of experiments is reported that were aimed at exploring the status of several structures and functional categories in agrammatic production such as verb inflection, subordination, questions and verb movement.

1. Are all verb inflections equally impaired in agrammatism?

1.1 A study in Hebrew and Arabic

The first syntactic domain explored was the production of verb inflection. Fourteen Hebrew and Palestinian Arabic-speaking agrammatic patients participated in the study. Hebrew and Arabic serve as excellent testing ground for verb inflection ability, as they are richly inflected: 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.

We examined all these inflection forms using two simple tasks - verb completion and sentence repetition.

In the completion task, two sentences were presented. The first included a verb inflected for tense and agreement. In the second sentence, which was to be completed with a missing verb, either the temporal adverb or the subject's person, gender, or number was changed. The patient had to supply the correctly inflected verb. In the **tense** condition, the missing verb differed from the supplied verb in tense only (1); in the **agreement** condition the missing verb differed from the existing verb in one agreement feature only (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:

berega ze ha-yeled holex. gam **etmol** ha-yeled _____. (Halax)

Right now the boy walks. **Yesterday** too the boy _____. (walked)

(2) Agreement:

berega ze ha-yeled holex. berega ze gam ha-yeladim _____. (holxim)

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

(3) Tense and Agreement:

ha-yalda racta likpoc, az hi amda al ha-makpeca ve _____ (kafca)

The girl wanted to jump, so she stood on the diving-board and _____ (jump-past, 3rd, fem, sg)

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

The results show remarkable dissociation between tense and agreement inflections.² While tense was severely impaired, agreement was relatively intact both in Hebrew and in Arabic (Table 1, Table 2). Subjects made tense substitution errors, but almost no agreement errors. This pattern was consistent for all patients, and all subjects showed a significantly better performance on the agreement tests than on the tense tests. Even in the simple repetition task, patients made tense errors but no agreement errors (Table 1).

| Hebrew (n=12) | Tense errors | Agreement errors |
|---------------|---------------|------------------|
| Completion | 41% (383/931) | 4% (35/782) |
| Repetition | 16% (143/912) | 0% (4/912) |

Table 1 Hebrew verb completion and repetition task: % errors (number of errors/total)

| Arabic (n=2) | Tense errors | Agreement errors |
|--------------|--------------|------------------|
| Completion | 69% (31/45) | 9% (4/46) |

Table 2 Arabic verb completion task: % errors (number of errors/total)

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. For example, De Bleser and Luzzatti (1994) have examined past participle agreement in a structured production task, and found considerable preservation of this inflection. (Most of the tasks in non-embedded sentences were performed at around 90% correct for both

patients.) In Spanish, too, verb agreement was found to be much better preserved than tense inflection: using a sentence completion procedure, Benedet et al. (1998) found that the six Spanish-speaking agrammatics they tested produced only 5.5% correct verbal tense, but produced 63.8% correct subject-verb agreement. In English they found a similar pattern of results 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. The same dissociation was also found recently in Dutch and German (Kolk, 2000)

To summarize, a clear dissociation has been found between two types of verb inflection: tense and subject agreement. While tense has shown to be severely impaired, agreement was relatively intact.

These results show that not all functional categories are impaired in agrammatic production. They show that 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).

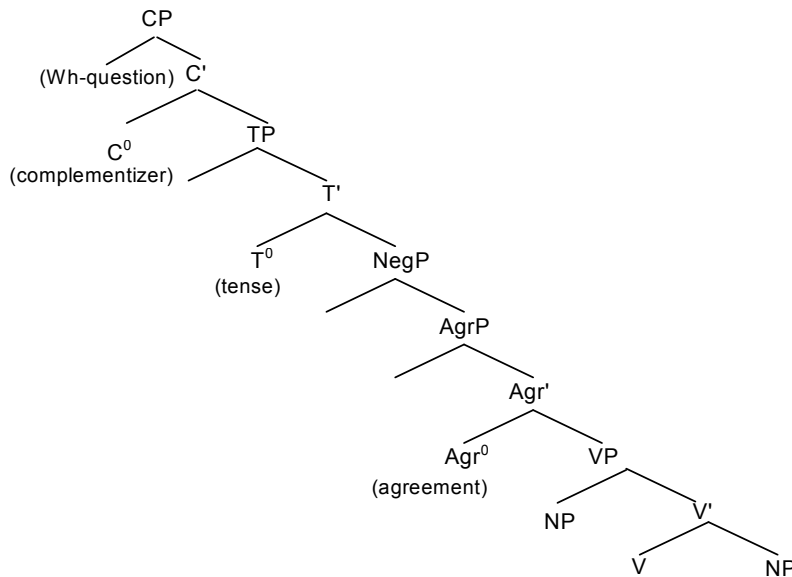


Figure 1 Pollock (1989) split inflection syntactic tree

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 bad tense. In this tree, tense and

² All the dissociations reported in this paper are significant at the level of 0.01, using χ^2 of the Mantel-Haenszel test for collection of 2x2 tables.

agreement are represented in two different functional heads, T and Agr. These two heads project two different 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 agrammatics to access. 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.

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

If indeed agrammatics 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 the strong prediction that all structures that depend on the highest node of the tree, the CP, would be impaired.

Therefore the next step was to examine structures that require the CP. The CP hosts Wh elements of Wh questions, complementizers of embedded clauses, and verbs in Germanic languages that move to second position. The study thus proceeded with examining the production of embedding and questions in Hebrew and Palestinian Arabic as well as with perusal of the cross-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, and verbs that do not move to C, should be unimpaired (in the absence of additional impairments).

³ See section 5 and Friedmann (1998) for data on two degrees of agrammatic severity: patients whose syntactic tree is pruned at T, who are impaired in TP and CP, and milder patients whose syntactic tree is pruned at a higher point, at C, who are impaired only at CP.

2. Is embedding ability impaired in agrammatism?

The first step toward evaluating the status of the CP node in agrammatic production was to assess patients' ability to produce embedded structures, while comparing embeddings that require the CP to embeddings that do not. In order to examine patients' ability to embed, we used two types of analysis: First, we analyzed spontaneous speech in Hebrew and in Palestinian Arabic, and searched for embeddings in order to obtain a qualitative general information regarding embedding ability. Later, in order to receive a quantitative and accurate measure, structured tests were devised - embedded sentence repetition test, and relative clause elicitation test.

2.1 Spontaneous speech analysis

The spontaneous speech of 11 Hebrew-speaking and one Arabic-speaking agrammatic aphasics was analyzed for embedded sentences of two types: full CP embeddings such as sentential complements and full relative clauses, and 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 normal speakers, 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 (Table 3).

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

Table 3 Subordination production in spontaneous speech – CP embedding vs. untensed embedding. %correct (correct / total embeddings produced)

2.2 Structured tasks: embedded sentence repetition and elicitation

Two types of structured tasks were used to quantitatively assess subordination production in agrammatic speech - repetition and elicitation tasks. Ten agrammatic subjects and ten control subjects without neurological deficit participated in the study. The repetition task included repetition of subject and object relative clauses (4) and sentential complements of nouns and verbs (5).

- (4) This is the man who sneezed.
- (5) John thought that Mary sneezed.

In the 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 (see example (6) for the (translated) experimenter presentation of the question, and (7) for the target relative clause response). The control condition for this test was elicitation of adjectival modification, using the same type of elicitation method.

- (6) 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...”.
- (7) 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 subordination production. In repetition, both types of CP embedding were impaired to the same degree. Sentential complements and relative clauses yielded a mere 33% correct in the simple repetition task (Table 4).⁴

| Repetition (n=10) | Relative clauses (This is the man who sneezed) | Sentential complements (John thought that Mary sneezed) |
|-------------------|---|--|
| Agrammatics | 33% (50/152) | 33% (29/87) |
| Control | 100% (100/100) | 100% (100/100) |

Table 4 Embedded sentence repetition. %correct (correct/total)

In the elicitation test, full relative clauses were very poorly produced, both in Hebrew and in Arabic (see Table 5). 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 (as claimed by Kolk, 1978).

⁴ The 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. A movement deficit entails that only relative clauses but not sentential complements would be impaired, as only relative clauses include a movement. However, structural impairment of the CP node predicts impairment of both structures.

| Elicitation (n=7) | Relative clause | Adjectival predicate |
|-------------------|-----------------|----------------------|
| Agrammatics | 22% (54/243) | 98% (98/100) |
| Control | 99% (125/126) | 99% (83/84) |

Table 5 Relative clause elicitation in Hebrew and Arabic. %correct (correct/total)

The most frequent error types in tensed subordination production in the spontaneous speech and the 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.

Another interesting type of response that appeared in the repetition and elicitation tasks in Hebrew, was the use of participial relative or semi-relative instead of a full relative (8). According to Siloni (1994, 1997), and Friedemann and Siloni (1997), reduced relatives do not contain either CP, Agr_SP, or TP (according to them, the highest phrasal node in these constructions is Agr_PP.) This probably allows the agrammatic aphasics to produce subordination even when the C node is inaccessible.

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

A similar preference for “low” relatives can also be found in the data of Ni et al. (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. The spontaneous speech of agrammatics 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 et al., 1990).

In order to further compare the production of tensed and untensed embedded structures, we included these two types of embedding in an additional repetition test. In this test, patients were asked to repeat comparable sentences with tensed (9) or untensed (10) sentential complements of verbs. Six Hebrew-speaking agrammatic aphasics and six matched control subjects participated in the study.

- (9) Tensed: yoxanan xashav she-ha-'isha rakda
John thought [that the woman danced]

(10) Untensed: yoxanan ra'a et ha-'isha rokedet

John saw [ACC the woman dance-participle]

The results again show a clear dissociation between tensed and untensed sentences (Table 6). This dissociation is related neither to sentence length nor to meaning but rather, we would suggest, 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.

| Repetition (n=6) | Tensed embedding | Untensed embedding |
|------------------|------------------|--------------------|
| Agrammatics | 31% (50/162) | 92% (130/141) |
| Control | 100% (120/120) | 100% (120/120) |

Table 6 Repetition of tensed and untensed embedding in Hebrew. %correct (correct/total)

The deficit in subordination 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 embeddings production, which manifests in their avoiding from complex sentence production, and in errors when they do try to produce them. This was found in English (Thompson et al., 1994, 1996, 1997; Bates, et al., 1988), in Italian and German (Bates et al., 1988), in Japanese, (Hagiwara, 1995), in French, (Nespoulous, et al., 1988, 1990), in Hindi, (Bhatnagar, 1990; Bhatnagar & Whitaker, 1984), and in Dutch, Swedish, Polish, and Finnish in Menn and Obler (1990) corpora.

To summarize, subordination is severely impaired in agrammatic production, but the impairment is selective. In Hebrew and Arabic infinitival embeddings are better preserved than CP embeddings, and reduced relatives are better preserved than full relatives. 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), while the 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.

3. What about question production?

The next domain we studied was another function of CP, question production. As Wh-morphemes reside in the highest node of the tree (after they move to spec-CP), we started with assessment of Wh questions in the speech production of Hebrew and Palestinian Arabic-speaking agrammatic aphasics.

3.1 Wh questions in Hebrew and Arabic

To assess patients' ability to form questions, we again used analysis of spontaneous speech as well as two constrained tasks: question repetition and question elicitation. Spontaneous speech was collected from 14 Hebrew and Arabic-speaking agrammatics, from free conversation between the subjects and the experimenter. The structured tests were administered to 10 Hebrew and Arabic-speaking agrammatic patients, and to 10 matched control subjects without neurological deficit.

In the question repetition task, subjects were asked to repeat simple 4-5 word Wh questions. In the elicitation task, subjects 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 (11)). (for more details on the tests, the individual results and discussion see Friedmann, 2002)

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

Target: ma dani axial?

what Danny ate?

The results showed a severe impairment in Wh question production across all tasks. 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 repetition and elicitation, all subjects showed a clear deficit in Wh question production (Table 7, Table 8).

| Repetition (n=10) | Wh questions |
|-------------------|----------------|
| Agrammatics | 57% (188/327) |
| Control | 100% (200/200) |

Table 7 Wh question repetition task. %correct (correct/total)

| Elicitation (n=10) | Wh questions |
|--------------------|----------------|
| Agrammatics | 23% (63/274) |
| Control | 100% (240/240) |

Table 8 Wh question elicitation task. %correct (correct/total)

The deficit in Wh question production in Hebrew and Arabic is in line with previous findings about Wh question production in English by Thompson, Shapiro and their group (Thompson et al., 1993, 1996, 1997; Thompson & Shapiro, 1995). This group examined the effect of syntactic-based treatment on Wh question production in agrammatic patients, and found a severe deficit in Wh question production prior to treatment for all their patients. 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. In constrained sentence production tasks, their patients failed to produce Wh questions.

An analysis of our Hebrew and Arabic-speaking patients' errors while trying to produce a Wh question shows that the most common error types were production of yes/no questions instead of Wh questions (12), production of only the Wh-morpheme without the rest of the question (13), various ungrammatical questions, and Wh in situ (14).

(12) **Yes/no questions** instead of Wh questions:

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?

(13) **Wh morpheme sequence**

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

(14) **Wh in situ**

(In question repetition task)

Target : *eifo dani sam et hamafteax?*

where Dani put ACC the-key?

Patient: *dani sam et hamafteax 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 is blocked. The preference of yes/no over Wh questions shows that the patients do not suffer a general deficit in question asking. But why are yes/no questions preferred?

3.2 Wh vs. yes/no questions in Hebrew and Arabic

If the deficit that underlies the impairment in Wh question production is indeed the inaccessibility of the highest node CP, then the production of yes/no questions in Hebrew and Arabic should show a completely different pattern from that of Wh questions. In contrast to Wh questions, yes/no questions in Hebrew and Arabic do not require the highest node as they do not require any overt morpheme in CP. 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 (15)).

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

So if the deficit is a structural deficit in the high syntactic nodes and not a general problem with questions, yes/no questions in Hebrew and Arabic should be fine. This is probably why patients often provide 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 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 (Table 9, Table 10).

| Spontaneous speech (n=14) | Wh questions | Yes/no questions |
|---------------------------|--------------|------------------|
| out of 2272 utterances | 13% (13/100) | 96% (81/84) |

Table 9 Spontaneous speech - Wh vs. yes/no questions. %correct (correct / total questions produced)

| Elicitation (n=10) | Wh questions | Yes/no questions |
|--------------------|----------------|------------------|
| Agrammatics | 23% (63/274) | 87% (127/146) |
| Control | 100% (240/240) | 99% (238/240) |

Table 10 Question elicitation task - Wh vs. yes/no questions. %correct (correct/total)

Thus, a dissociation is found between Wh questions, which require the highest nodes, and are therefore impaired, and yes/no questions, which are produced without the high nodes, and are thus spared.

3.3 Question production in English – 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 (16), and the auxiliary resides in the high node C⁰. Thus, in such a language yes/no questions are bound to be impaired if the C node is impaired.

(16) Do you like pasta?

In fact, several studies indicate that yes/no questions are impaired in the speech of English-speaking agrammatics. Goodglass et al., (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 aphasic patients 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 guava?”). 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. Preliminary results from one English-speaking patient for whom we devised the elicitation tests of Wh and yes/no questions, point in the same direction. The patient failed to produce both types of questions (Friedmann, 2002). To conclude, the data on question production in English-speaking agrammatics indicate that in English, unlike in Hebrew and Arabic, both Wh questions and yes/no questions are impaired.

Again, 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, and English, and yes/no questions in English require high nodes and are thus impaired, but Yes/no questions in Hebrew and Arabic do not require high nodes and are therefore spared.

4. Verb movement in Hebrew: Triggered inversion structures

Another structure that involves movement to high nodes and is therefore interesting to explore in agrammatic production is Triggered Inversion. In Modern Hebrew the basic word order is SVO (17).

(17) etmol ha-yalda axla xumus.
yesterday the-girl ate hummus
‘The girl ate hummus yesterday.’

However, Hebrew is a language in transition between VSO and SVO (Borer, 1995) and it is also possible, in some respects similarly to Verb Second in Germanic languages, 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 (18). This structure is termed *Triggered Inversion* (Shlonsky, 1987, 1997; Shlonsky & Doron, 1992) or *Stylistic Inversion*.

- (18) 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 C⁰ (through Agr⁰ and T⁰, see Figure 2). Borer (1995) has a different analysis for this structure. According to her, the verb moves only up to I⁰ and the first constituent is in spec-IP (under a split inflection analysis as was adopted here, probably to T⁰ and spec-TP respectively, see Figure 3).

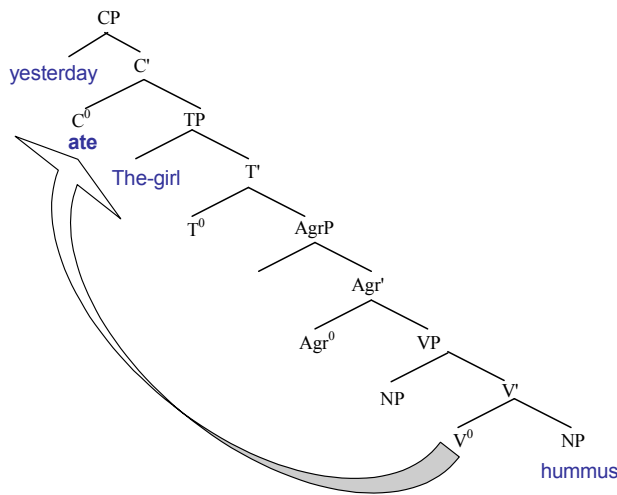


Figure 2 Triggered Inversion according to Shlonsky and Doron (1992) and Shlonsky (1997)

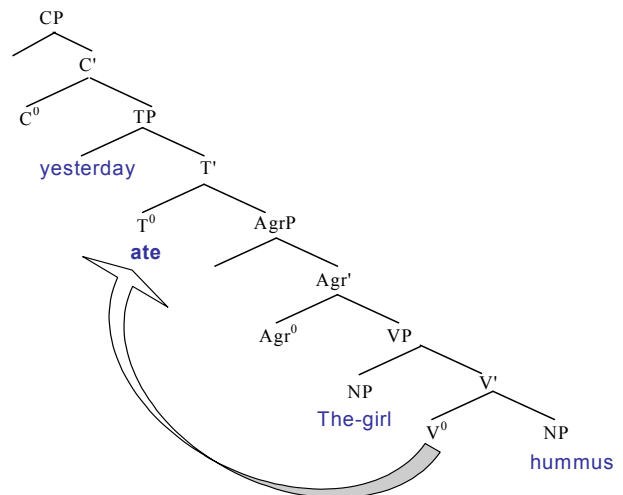


Figure 3 Triggered Inversion according to Borer (1995)

Thus, XSVO and XVSO structures in Hebrew form a minimal pair with respect to verb movement. The comparison of the two structures will have implications both for the description of verb movement in agrammatism and for syntactic theory. If indeed agrammatic aphasics are unable to access the high nodes of the syntactic tree, they are expected to fail on structures that involve movement to these nodes. In addition, the performance in the triggered inversion structure can serve as a critical test case that will determine between the syntactic accounts – between movement to C and movement to I. Here is how: Agrammatic aphasia manifests in different degrees of severity that can be characterized by the different

sites of tree pruning. Milder agrammatic aphasics are impaired only in CP but the more severe patients are also impaired in TP (see Friedmann, 2001). For the more severe patients, who are impaired in CP and in TP, both Shlonsky (1997) and Borer (1995) predict failure in the production of XVSO. They differ, however, with respect to the milder patients. While Shlonsky's account predicts a failure in XVSO structures even for the milder patients because the verb has to move to CP, and the milder patients are impaired at CP, Borer's account predicts that the milder patients will be able to produce XVSO because the verb under this analysis moves only up to TP, which is unimpaired in these patients. Thus, the performance of the milder patients on the XVSO sentences might indicate whether the verb moves to C or only up to T in this structure. We therefore compared XSVO to XVSO structures, and the performance of CP-pruned patients was compared to that of TP-pruned patients.

4.1 Participants

Five agrammatic aphasic patients aged 19-33 years who were native speakers of Hebrew participated in this part of the study. Based on their performance in an extensive battery of syntactic production (BAFLA, Friedmann 1998), the participants were divided into milder patients, who were impaired in wh-questions and embedding, but were above 95% in tense inflection, and severe patients, who were impaired in wh-questions and embedding as well as in tense inflection. According to this classification, two patients had milder agrammatism, and three had severe agrammatism. In addition, 10 psychology students, native speakers of Hebrew without language impairment, participated in the experiment as a control group.

4.2 Method

The production of Triggered Inversion structures was assessed using sentence repetition task.. When word order matched the target order, the repetition was scored as correct; Inflection substitution and preposition errors were disregarded in this analysis of repetitions into correct and incorrect order. Errors were classified into four types: verb-subject inversion, verb omission, subject omission, and other. In addition, tense inflection of the verb was assessed in each sentence, and the number of tense errors was compared between cases in which the verb was produced in second position (successful XVSO) and cases in which it did not necessarily raise (i.e. the rest of the sentences).

Forty Hebrew sentences were included in the repetition task. Half were XVSO, i.e., structures with verb movement to a position after a trigger and before the subject, and the other half were XSVO. The first constituent was always a temporal adverb, of either a single word (*etmol*=yesterday) or two words (*ba-shana ha-ba'a*=next year). The XSVO and XVSO sentences were matched for length. The verbs were in all three Hebrew tenses – past, present and future - distributed evenly across the two sentence types. All verbs were transitive, some with NP complement and some with PP complement. The sentences were randomly ordered and no more than two sentences of the same type appeared consecutively.

4.3. Results

The agrammatic repetition of sentences including verb movement to the position after the trigger and before the subject was profoundly impaired in all participants. Repetition of the XVSO structures was significantly worse than the XSVO structures (for the group, paired *t*-test, one tailed, $t(4) = 12.17, p = .0001$; and for each individual participant, using Fisher exact test, $p < .002$) (Table 11).

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 than in XSVO (Table 2, $t(4) = 4.43, p = .005$, Table 12). 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. Subjects were omitted 10 times in the XVSO sentences and once in the XSVO.

The participants produced 33 tense errors while repeating the sentences. Crucially, no tense error occurred in successful repetitions of XVSO (as can be seen in Table 13). Namely, whenever the verb was successfully raised, tense was correct. In marked contrast, when the verb did not raise to second position, namely when the patients produced XSVO order, either as a repetition of an XSVO sentence or after inversion of a XVSO sentence, which indicates failure to raise the verb, 33 tense errors occurred.

As shown in Table 11, both the patients with severe agrammatism (GR, RA, and HY, who had impairment at TP and above) and the patients with milder agrammatism (AL, RN, who are impaired at CP) showed inability to produce the XVSO sentences.

| | Patient | XSVO | XVSO |
|---------------|-------------|------------|------------|
| TP- pruned | GR | 75% | 10% |
| | RA | 95% | 25% |
| | HY | 65% | 15% |
| CP- pruned | AL | 90% | 45% |
| | RN | 90% | 25% |
| | Mean | 83% | 24% |

Table 11 Percent correct repetition of sentences with and without Triggered Inversion

| Patient | Inversion errors in XSVO SV → VS | Inversion errors in XVSO VS → SV |
|--------------|-------------------------------------|-------------------------------------|
| Total | 2 | 56 |

Table 12 Number of inversion errors in repetition with and without verb movement

| Patient | Tense errors in correct XVSO | Tense errors in XSVO Target XSVO | Tense errors in incorrect XVSO (Inversion or subject omission) |
|----------------|------------------------------|----------------------------------|--|
| Total | 0 | 17 | 16 |

Table 13 Tense errors

The participants in the control group performed well on both XSVO and XVSO, and with no significant difference between the sentence types (average performance for the control group was 98.5% correct on the XSVO and 100% correct on the XVSO). Interestingly, Hebrew-speaking second-grade children (seven-year-olds), who were tested with the same test, already repeated both types of sentences very well (even when they counted to ten before repeating the sentence), and showed no significant difference between XSVO and XVSO (94% on XSVO and 89% correct on XVSO, Novogrodsky & Friedmann, 2002). An error that emerged almost only in the control group (and in the children's repetitions) but not in the agrammatic group was inversion of the XSVO to XVSO. This might be taken as further evidence for the inclusion of the Triggered Inversion structure in the syntax of the control group participants.

The main finding of this experiment was that agrammatic aphasics could not produce sentences with verb movement to second position, even in a simple task like sentence repetition. This pattern is consistent with descriptions of agrammatism that attribute the deficit in production to the inaccessibility of the high syntactic nodes – due to pruning at TP for the severe agrammatic aphasics and at CP for milder agrammatism (Tree Pruning Hypothesis, Friedmann & Grodzinsky, 1997; Friedmann, 2001).

The finding that even the milder agrammatic aphasics failed to produce triggered inversion structures bears upon a point of controversy in syntactic theory. Two analyses have been proposed for Hebrew Triggered Inversion structures. Borer (1995) suggested that in these structures the first constituent is in spec-IP, and the verb moves only up to I^0 (or spec-TP and T^0). Shlonsky and Doron (1992) and Shlonsky (1997) suggested a different analysis according to which the first constituent is in spec-CP, and the verb moves to C^0 . Our results support Shlonsky and Doron's analysis, as two of the participants who showed impaired production of Triggered Inversion and inversion of VS to SV (AL and RN), were impaired only in CP, and showed relatively normal functioning of TP (as evinced by their above 95% correct tense inflection in inflection completion tests). Given that they were impaired in CP and not in TP, the finding that they were still impaired in Triggered Inversion suggests that the verb in Triggered Inversion sentences moves to an impaired node, namely to C, and not to T (see also Goldberg 2001 for linguistic arguments in support of Shlonsky's analysis and against Borer's).

Within the framework of Shlonsky's analysis and the Tree Pruning Hypothesis, the success in XSVO and failure on XVSO are readily explained. If CP is inaccessible to agrammatic aphasics they cannot move the

verb to C^0 , to a position before the subject.⁵ However, they are still able to produce a smaller tree in which the subject and the verb are located in lower nodes, in VP, with the subject in spec-VP and the verb in V, in their base-generated positions (or possibly in spec-AgrP and Agr). As a result, they can produce XSVO but not XVSO. The error pattern follows from this too: because they cannot produce XVSO but can produce XSVO in lower nodes, they produce XSVO instead of XVSO, and hence the inversion errors. The findings regarding tense errors are explained along similar lines. Tense errors never occurred when the agrammatics succeeded to move the verb to a position before the subject (to raise the verb to C). A verb that has managed to get all the way up to C would have had to move through a preserved TP, and therefore its tense would be correct. However, in most cases agrammatics are unable to raise the verb because their TP is impaired and these are the cases in which the verbs are incorrectly inflected. This, in turn, offers another hint regarding the syntactic analysis of Triggered Inversion structures: it indicates that the verb in these structures is located at least as high as the point at which tense is checked.

The 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.

⁵ They cannot move the verb only up to Agr and leave the subject in situ in VP because if AgrP is accessible and functioning, the verb and the subject need to be checked in spec-head configuration, so if the verb moves to AgrP, so would the subject.

To conclude, Hebrew-speaking agrammatical aphasics cannot produce Triggered Inversion sentences. The pattern of performance of patients who can access TP but not CP indicates that Triggered Inversion in Hebrew should be analyzed as a trigger in spec-CP which triggers movement of the verb to C^0 .

5. Verb inflection and position in Germanic languages

In Germanic languages such as Dutch, German, Icelandic and Scandinavian languages the inflected verb also moves to C^0 . The finite verb 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^0 , through I^0 (T^0 and Agr^0) (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 these V2 languages. A tree pruning account according to which TP and CP are not accessible for agrammatical speakers entails that the verb will not be able to move to T and consequently to C. 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 cases in which the speaker succeeds in moving the verb, it will be inflected and in second position.

Data from structured tests and spontaneous speech verify this prediction: Many matrix verbs 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).

In a study by Bastiaanse and van Zonneveld (1998), 10 Broca's aphasics were asked to complete sentences with a verb missing either in second or in final position, in matrix or embedded clause. The results showed that agrammatics easily produced verbs at the end of the sentence, in their base-generated position, but they encountered difficulty producing verbs in the moved position (2nd position). The difference between finite and non-finite verbs was striking: 110/111 verbs in final position were non-finite. In marked contrast, verbs in second position were much harder to retrieve than verbs in final position, and were frequently substituted by non-finite forms. Since the test elicited only a single verb and not the whole sentence, it might be that verbs that appeared uninflected when required in second position would have appeared in final position in spontaneous speech.

This conjecture is borne out by data from spontaneous speech in Dutch and German: Kolk and Heeschen (1992) report a massive use of infinitives in matrix clause in the spontaneous speech of 10 German-speaking and 8 Dutch-speaking patients. Their data indicate exactly the result expected by a tree pruning account. Both in German and in Dutch, almost all the inflected main verbs were produced in second position, and when infinitives were produced as main verbs without an auxiliary, they appeared in sentence final position, the position of verbs that have not moved up the tree. Similar results have been reported for Dutch by Bastiaanse and van Zonneveld (1998): In the spontaneous speech of the three Dutch-speaking agrammatics tested, half of the matrix verbs were non-finite. All nonfinite verbs but one appeared in final position; all finite verbs were produced in second position.

To conclude, data from V2 Germanic languages are consistent with the claim that the highest node of the syntactic tree, the CP, is impaired in agrammatic production, and this impairment causes the agrammatic speakers to frequently produce uninflected verbs at their base-generated position at the end of the sentence.

6. Degrees of agrammatic severity and the tree

As mentioned earlier in section 4, when looking at the performance for each individual patient, two patterns emerge. One pattern, that is manifested by the more severe patients, is that of intact agreement, impaired tense, and impaired Wh questions and CP embeddings. The milder patients 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 subordinations are impaired. Figure 4 presents the data from patients who participated in the tasks described in sections 1-3 and shows, per each patient, the performance on agreement completion, tense completion, and a joined score for embedding and Wh-question production. The two different patterns are easily captured by the height of the deficit on the tree. The severe patients are impaired

both in TP and in CP; the mild patients are only impaired higher up, in CP. Crucially, no patient was found that showed a deficit in TP without a deficit in CP, or a deficit in AgrP without a deficit in TP and CP.

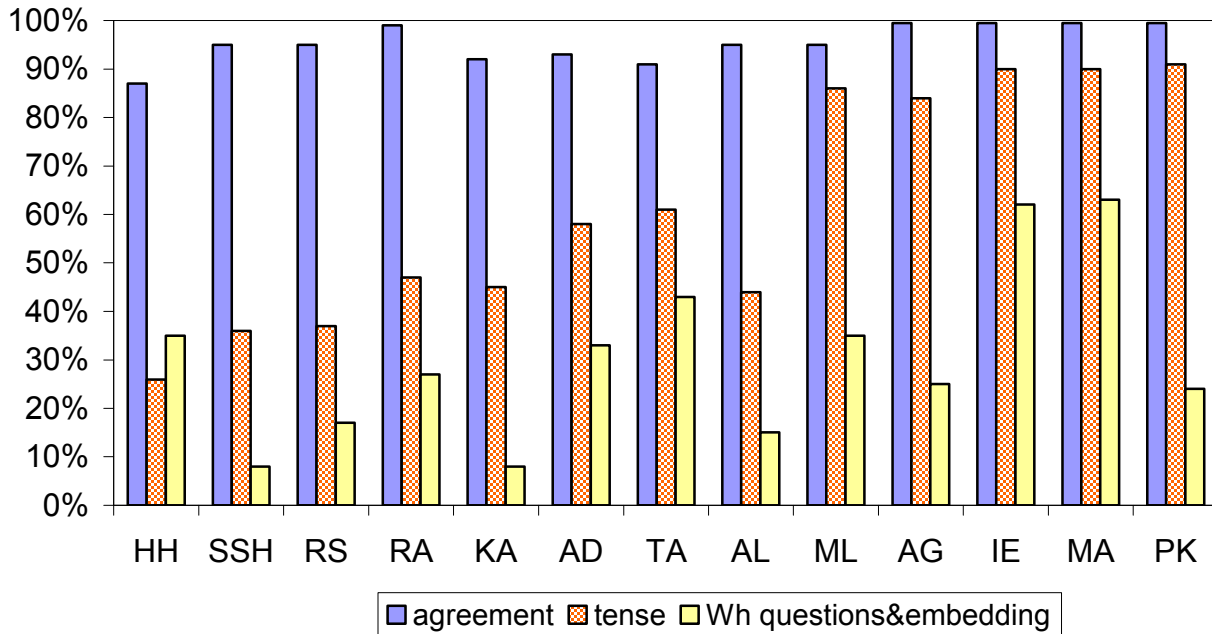


Figure 4 Individual performance in agreement, tense, Wh questions and embedding tests-degrees of severity.

7. A note on syntactic-based treatment

Another finding that is explained by the tree pruning account, is the improvement of sentential embedding production after Wh-question treatment. Thompson et al. (1996) were very successful in their treatment program. Their patients made progress in the trained Wh-questions types, and also in questions requiring similar operations. Furthermore, they also reported an improvement in their patients' complex sentence production: following treatment, the patients produced a greater proportion of complex sentences, and more embedded clauses per utterance. They report that following treatment their patients produced a greater number of relative clauses and, crucially, also "that-clauses" (sentential complements of verbs and nouns).

The improvement in sentential complements following Wh-production treatment again suggests a relationship between Wh-question production impairment and subordination production impairment. This relation does not lend itself to explanation under a movement account (as sentential complements do not involve movement), but is naturally explained within the Tree Pruning Hypothesis. Since the whole CP node is affected, question formation is impaired together with sentential embedding. A successful treatment that manages in some way to improve the accessibility of CP, should also improve the production of other structures that depend on CP, among them embedding constructions.

The Tree Pruning Hypothesis, taken together with these results, suggests a promising direction for treatment. If indeed treating one aspect of CP can improve the production of other functions of CP, then treating Wh-questions should be an effective way to treat embedding production (and probably also vice versa). Furthermore, given the nature of the syntactic tree, an intact node does not promise the intact functioning of a higher node (see also Friedmann, 1998, 2001 for data regarding patients who only experience deficit in CP, with intact TP), but a functioning high node guarantees the functioning of the nodes below it. Thus, treating CP should also affect TP and improve the production of structures that require TP, such as tense inflection (see related results regarding effectiveness of treating the complex structure first in Thompson, Ballard, & Shapiro, 1998).

Preliminary results from a treatment study (Friedmann, Wenkert-Olenik & Gil, 2000; Friedmann, 2002) confirm this direction. A Hebrew-speaking agrammatic patient who suffered left frontal CVA five years prior to treatment, and was impaired both in TP and CP (showing impairment in tense inflection, embedding and question production), received only Wh-question production treatment for three months. Following treatment, not only his Wh-questions significantly improved (24% correct before treatment, 89% after), but also his ability to produce embedded sentences (significant improvement in relative clause elicitation and in untensed embedding repetition, non-significant improvement in relative clause repetition). Importantly, his ability to correctly inflect verbs for tense also improved significantly following the Wh-question treatment (from 76% correct before to 91% after). These results support the treatment direction suggested by the TPH. Somewhat counter-intuitively, we suggest that treatment should start at the treetop, with the functions of CP. Once the tree is established up to this node, an improvement of other structures that rely on lower nodes in the syntactic tree should follow.

SUMMARY

This research showed, primarily, that the syntactic deficit in agrammatic production is selective, and that it is possible to capture the pattern of dissociations within and between languages using a unified syntactic account, the Tree Pruning Hypothesis (TPH). According to the TPH, agrammatics frequently fail to project their syntactic tree all the way up to the treetop. This leads to the dissociations found between structures depending on high parts of the tree, which are impaired, and lower structures, which are preserved.

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 by agrammatic aphasics. On the other hand, tense inflection, full relatives and embeddings, Wh questions, yes/no questions in English and verbs in second position require the high nodes of the tree, and are

therefore impaired in agrammatic production. 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 – TP and CP.

The hierarchical nature of the syntactic tree accommodates an additional finding regarding differences in performance between patients. 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.

Apart from allowing for an accurate description of the agrammatic deficit, these findings also offer support for the psychological reality of syntactic trees from 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 agrammatics 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. The pattern of asymmetric dissociations also supports a specific hierarchical order of these nodes. As agreement is not impaired, tense is impaired in some patients, and questions and embeddings in all patients, the data support a relative order of CP above TP above AgrP.

The fact that it is possible to characterize the agrammatic impairment by natural classes on the syntactic tree, defined by abilities that relate to different functional nodes, argues, we believe, for the psychological reality of the syntactic tree representation.

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