A Memory-based Account of Linear Order Effects in English[*]

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1 Introduction

The traditional wisdom in syntax is that sentences should be analyzed in terms of hierarchical structure. However, there are such data whose acceptability patterns can only be captured in terms of linear order, not in terms of configuration.

We argue that the data in question all follow a general pattern, which we attempt to accounts for uniformaly by proposing a memory-based proccesing model. We will demostrate how our model account for the (un)acceptability of those examples that are problematic for configuration-based analyses.

2 Data and Problems

2.1 Background

Kaplan and Bresnan (1982), Bresnan (2000) and Falk (2001) observed that topicalization alters the acceptability of the sentence, a paradoxical observation for movement-based accounts.

(1) a. *Ken was thinking about [that he was wrong].

b. [That he was wrong] Ken was thinking about.

Observationally, (1a) is ungrammatical because the subordinate clause *that he was wrong* is the complement of the preposition *about*.[1] They analyzed this contrast in terms of grammatical functions, within the non-derivational LFG framework.

In LFG, a *that*-clause is mapped to a discource function such as TOP by Lexical Mapping Theory (LMT) and its hierarchical position is determined by PS-rules. On the other hand, an object NP is mapped to the fuction OBJ. In the LFG accounts, (1a) is ungrammatical because a OBJ cannot be realyzed as a *that*-clause. Therefore, the value of the OBJ is null, which violates "completeness condition", which is one of the three conditions that an f-structure is required to meet. On the other hand, (1b) is grammatical because the value of TOP and that of OBJ are co-shared by "functional uncertainty"(kaplan and Zaenan, 1989).

$$
{}^{*}\begin{bmatrix}
\text{PRED} & \text{`think of}\langle(\uparrow\text{SUBJ})(\uparrow\text{OBJ}_{of}\text{OBJ})\rangle\text{'} \\
\text{SUBJ} & \begin{bmatrix}\text{PRED} & \text{`John'}\end{bmatrix} \\
\text{TENSE} & \text{PAST} \\
\text{OBL}_{of} & \begin{bmatrix}\text{PCASE} & \text{OBL}_{of} \\ \text{OBJ} & \underline{\qquad}\end{bmatrix}
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{TOP} & \begin{bmatrix}\text{PRED} & \text{`be}\langle(\uparrow\text{SUBJ})(\uparrow\text{OBJ})\rangle\text{'} \\ \text{SUBJ} & \begin{bmatrix}\text{PRED} & \text{`he'}\end{bmatrix} \\ \text{OBJ} & \begin{bmatrix}\text{PRED} & \text{`stupid'}\end{bmatrix} \\ \text{TENSE} & \text{PAST}\end{bmatrix} \\
\text{PRED} & \text{`think of}\langle(\uparrow\text{SUBJ})(\uparrow\text{OBJ}_{of}\text{OBJ})\rangle\text{'} \\
\text{SUBJ} & \begin{bmatrix}\text{PRED} & \text{`John'}\end{bmatrix} \\
\text{TENSE} & \text{PAST} \\
\text{OBL}_{of} & \begin{bmatrix}\text{PCASE} & \text{OBL}_{of} \\ \text{OBJ} & \end{bmatrix}
\end{bmatrix}
$$

Figure 1: The f-structures of (1a) (left) and (1b) (right)

[1] It is adjacent to the head. Lexically, prepositions cannot take a *that*-clause complement.

Indeed, the above LFG accounts successfully deal with the contrast in (1). However, does this account extend to other seemingly similar examples?

2.2 Data and Problems

The above LFG analysis fails in predicting the (un)acceptabilites of the following examples:

(2) a.*Ken was thinking about [that he was wrong] and [his girlfriend].

b. Ken was thinking about [his girlfriend] and [that he was wrong].

(2a–b) differ only in the order of the complement conjuncts. Given that the f-structures of the conjuncts are integrated as a set (Kaplan 1995, Falk 2001), the order of the conjuncts should not affect the resulting f-structures. In this case, the f-structure of (2a) and that of (2b) are the same.

Thus the defect of the LFG accounts is that no attention is paid to the order of the conjuncts. This theoretical observation leads us to suspect that the data in question should be accounted for in terms of linear order, rather than further refinements of f-structure machineries.

The following Right Node Raising examples also exhibit a similar linear order effect.

(3) a.*John denied, but Ken agreed with [that Mike was wrong].

b. Ken agreed with, but John denied [that Mike was wrong].

In (3), what affects the acceptability is the order of the incomplete conjuncts: *John denied* and *Ken agreed with*. (3a) is unacceptable because *with* takes a *that*-clause as its complement instead of an NP. However, in spite of the fact that the head-complement relation is the same as (3a), (3b) is acceptable.

2.3 An Observational Generalization

What we can observe from (1) to (3) can be summarized as an informal generalization (4):

(4) The Linear Order Effect:
The syntactic requirement imposed by the head on an argument is effective only to the extent that the argument is "near enough" to the head in linear order.

As far as the examples dealt with here are concerned, we can safely assume that "near enough" amounts to adjacency.[2] (1b) is adjacent to the head and hence is acceptable since the head *about* is not adjacent to its topicalized argument and therefore, the head fails to exert its syntactic constraints on *that he was wrong*. However, the argument in (1a) is required to fully obey the constraints imposed by the head, resulting in unacceptability.

Likewise, in (3b), although *that Mike was wrong* is the argument of both *with* and *denied*, the head which is adjacent to the argument is the latter, and therefore the constraints imposed by the former do not have to be obeyed by the *that*-clause.

This generalization is strongly supported by the observation that insertion of a modifier phrase or a pause between the head and the argument contributes to acceptability.

(5) a.*Ken was thinking about [that he was wrong]. (=1a)

b.?Ken was thinking about (PAUSE) [that he was wrong].

c. Ken was thinking about, by the way, [that he was wrong].

These contrasts can only be captured in terms of passage of time, rather than grammar.

3 The Memory-based Model

The contrasts in (5) also suggest that the observation in question should be accounted for not in terms of an adjacency-based grammatical mechanism but rather in terms of real-time processing. In this section we attempt to theoretically explain the observational generalization in terms of real-time processing.

[2]The notion of "near enough" needs to be refined when the coverage of the analysis is broadended so as to include those cases where a single head takes more than one complement.

3.1 The General Idea

We assume that syntactic information is expelled once the meaning of the sentence is obtained.

The intuitions behind this assumption are (i) that syntactic information is necessary only in as much as it helps reconstruct the semantic content of the sentence, and (ii) the capacity of working memory is severely limited. If syntactic information is stored in working memory, then, we are naturally lead to expect that syntactic information is expelled from, or deactivated at, working memory as soon as it has played the role of contributing to the reconstruction of the semantic content.

3.2 The Memory-based Model

From the observed generalization and the general idea mentioned in the previous subsection, we propose the Memory-based model:

(6) The Memory-based Model:
Syntactic information [3] is expelled or decayed as soon as the semantic predicate-argument structure is assumed to have been constructed or time passes by.

When the processor takes in a word, it constructs a tree for the input, and as the tree is successfully constructed, the processor predicts the forthcoming input on the look-ahead basis and expands the tree.

When the inputed word is a head, the processor immediately constructs its complement node on a look-ahead basis and imposes various syntactic/semantic constraints on the complement, which has not been actually encountered yet. If the phrases with expected part-of-speech information appears and the predicate-argument content is completed, then the whole syntactic information of the sentence is expelled and only the semantic structure is left.

Let us consider to the case of comlement coordination. Upon encountering the head, the parser constructs the complement node, on which the head imposes various constraints. When the parser is fed with the first conjunct, which satisfies the constraints, the syntactic information is expelled since the parser assumes that predicate-argument structure is completed. However, as a conjunction such as "and" is inputed, the parser has to modify the complement tree, so as to dominate a newly constructed node for the second conjunct. When the second conjunct is actually inputed, the constraints imposed by the head have already lost their effects. Therefore, the sentence is acceptable even if the second conjunct fails to obey the syntactic constraints imposed by the head, provided that the semantic constraints are all satisfied. This processing is illustrated in Figure 3.

4 Demonstrations

In this section, we will demonstrate how the examples (1)–(5) are accounted for in terms of our memory-based model.

4.1 Topicalization

In our model, (1a) is unacceptable because the syntactic constraints imposed by the head *about* is incompatible with the *that*-clause complement.

On the other hand, in (1b), the subordinate clause is not adjacent to the head in (1b). In our model, although the syntactic information of the topicalized phrase is initially stored in working memory, it has been decayed enough by the time when the parser encounters the preposition, which should have imposed syntactic constraints on it. Thus the incompatibility between the head's requirement and the syntactic category of the complement does not make the sentence unacceptable. Figure 4.1 shows how the (1b) is processed.

4.2 Complement Coordination

We assume that, when dealing with a constituent coordination structure with two conjuncts, the human parser initially constructs initially a structure containing only the first conjunct before reading the conjunction (*and*) and the second conjunct; the structure is subsequently modified into a coordinate structure when the conjunction and the second conjunct are encountered (see Figure 4.2 for an illustration). This assumption is experimentally supported by Sturt and Lombardo (2005). With this assumption in hand, the pattern in (2) can be explained as follows.

[3] By "syntactic information" we mean part-of-speech and agreement information; we remain neutral as to whether constituent structure is retained in working memory.

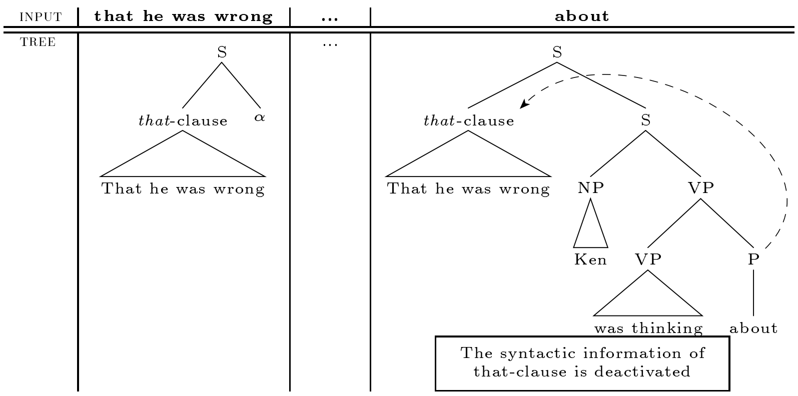

Figure 2: The processing of (1b)

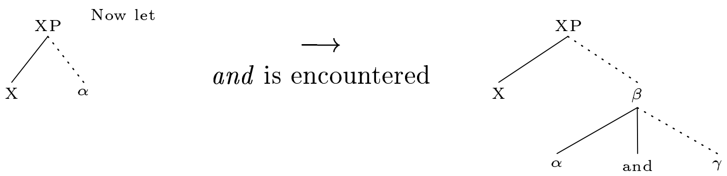

Figure 3: The initial partial tree and the reconstructed partial tree

Upon encountering *about*, the parser constructs its complement NP node. When the parser is fed with the first conjunct, which happens to be an NP (α in Figure 4.2), the syntactic information is expelled since the parser (wrongly) assumes that predicate-argument structure is completed (the left figure in Figure 4.2). Figure 4 shows the processing of (2b).

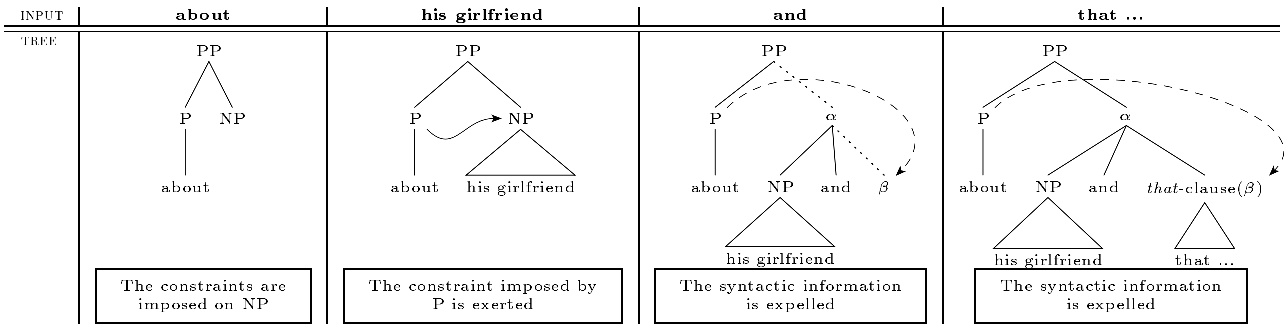

Figure 4: The processing of (2b)

4.3 Insertion

In our model, the contrasts in (5a–c) are due to the presence of a time interval between the head and the complement (the pause in (5b) and the inserted adjunct in (5c)). The difference between (5b) and (5c) is probably due to the processing complexity of an inserted overt phrase. An inserted phrase consumes processing resources more than a mere pause, a natural assumption given the nature of working memory. Since the syntactic constraints become more deactivated through processing an inserted phrase than through an inserted pause, the acceptability of (5c) is better than (5b).

4.4 Right Node Raising (RNR)

In our model the Right Node Raising examples (3a–b) in which the linear order seems to affect their acceptability status are accounted for as follows: In (3a), *about* and the "raised" phrase *that Mike was* *wrong* are adjacent, while in (3b), they are not. In our model, the constraints imposed by the head are loosened or deactivated as time passes by. Moreover, since the forces of constraints imposed by the first conjuncts in each sentence are more deactivated than those of the second conjunct; it is the second conjunct that contains the head selecting, and adjacent to, the raised complement; the syntactic constraints of the first conjuncts in each sentence are lost by the time when the parser encounters the raised complement, and the constraints imposed by the second conjunct have to be fully obeyed. Therefore, (3a) is unacceptable while (3b) is acceptable. Figure 5 shows the processing of (3b).[4]

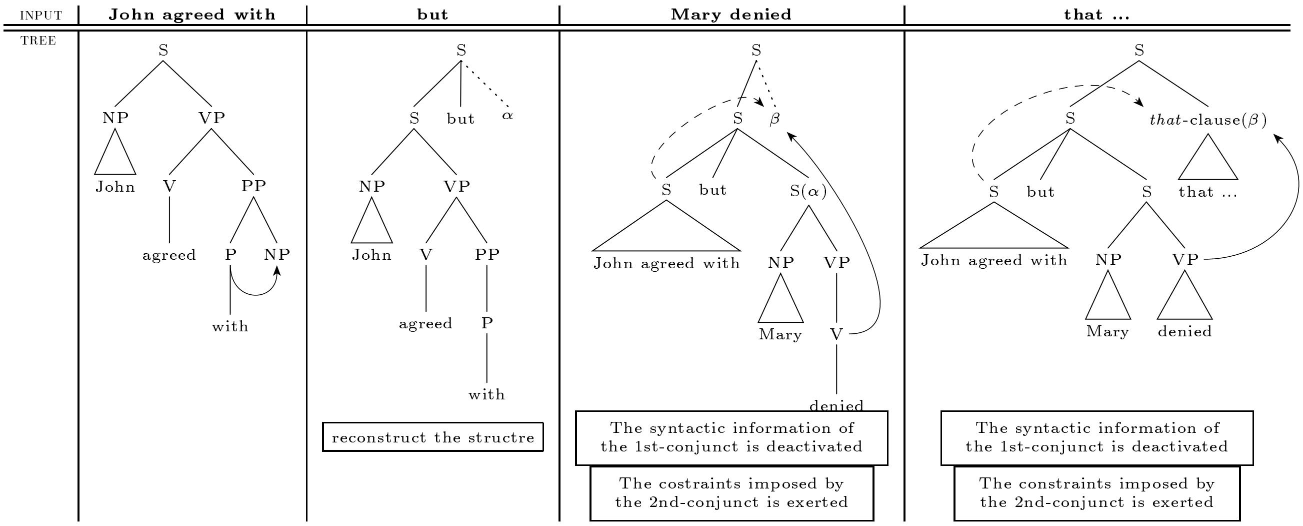

Figure 5: The Processing of (3b)

5 Remaining Problems

There are some examples that remain unaccounted for at present. In (2), if the first conjunct is substituted with a pronoun, the result turns out to be unacceptable:

(7) a. Ken was thinking about [his girlfriend] and [that he was wrong]. (=2b)

b.*Ken was thinking about {me/her/himself/it} and [that he was wrong].

c.*Ken was thinking about {me/her/himself/it}, which I can hardly blame him for, and [that he was wrong].

Currently, our model wrongly predicts that both (7b-c) should be acceptable. Note that, as seen in (7c), consuming processing resources of working memory with an overt complex pharase (a non-restrictive relative clause in this case) does not help. At present we do not know why using pronouns, reflexive or not, makes such a big difference.

Also on our future research agenda is a psychological exeperiment to confirm our claim that syntactic information is expelled or deactivated. Probaly some kind of dual-task experiment should be conducted, but at present this task has to be left for future research.

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[4]We do not distinguish sentences with gaps from full sentences here.

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