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

TAKAHASHI Kei
The University of Tokyo
kei-ta@phiz.c.u-tokyo.ac.jp

ISHIKAWA Kiyoshi
Hosei University
kiyoshi@i.hosei.ac.jp

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-rule. On the other hand, an object NP is mapped to the fuction OBJ. In the LFG account, (1a) is ungrammatical because *that*-clause cannot be realized as OBJ. 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".

*
$$\begin{bmatrix} \text{PRED} & \text{'think of}\langle(\uparrow \text{SUBJ})(\uparrow \text{OBJ}_{of}\text{OBJ})\rangle\text{'} \\ \text{SUBJ} & [\text{PRED} \quad \text{'John'}] \\ \text{TENSE} & \text{PAST} \\ \text{OBL}_{of} & \begin{bmatrix} \text{PCASE} & \text{OBL}_{of} \\ \text{OBJ} & \_\_ \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \text{TOP} & \begin{bmatrix} \text{PRED} & \text{'be}\langle(\uparrow \text{SUBJ})(\uparrow \text{OBJ})\rangle\text{'} \\ \text{SUBJ} & [\text{PRED} \quad \text{'he'}] \\ \text{OBJ} & [\text{PRED} \quad \text{'stupid'}] \\ \text{TENSE} & \text{PAST} \end{bmatrix} \\ \text{PRED} & \text{'think of}\langle(\uparrow \text{SUBJ})(\uparrow \text{OBJ}_{of}\text{OBJ})\rangle\text{'} \\ \text{SUBJ} & [\text{PRED} \quad \text{'John'}] \\ \text{TENSE} & \text{PAST} \\ \text{OBL}_{of} & \begin{bmatrix} \text{PCASE} & \text{OBL}_{of} \\ \text{OBJ} & \end{bmatrix} \end{bmatrix}$$

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

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

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

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].

(2) differs only in the order of the complement conjuncts. Given that the f-structures of the conjunct 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 ungrammatical 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, ratherthan grammar.

Johannessen (1994) proposed a GB/MP analysis for the asymmetric agreement in coordination. In Johannessen's analysis, coordinated phrase is assumed to be a maximal projection headed by a conjunction such as *and* or *or*, and the head and its specifier agree. Thus, in complement coordination, especially in the head initial language, the selectional head always agrees with the fisrt conjunct, i.e. the constraints imposed by the head selecting the coordinated phrase is exerted on the maximal projection, in which the head agrees with the first conjunct. This analysis predicts different pattern from our observation because in our model, the nearer conjunct agrees with the selecting head. For example, in the subject coordination, Johannessen's analysis predicts that the main verb agrees with the first conjunct. On the other hand, our observation, it is the nearset conjunct to the verb that the head agrees with. Also, Johannessen's analysis does not deal with the phenomena that a insertion or passage of time increases acceptabilities such as (5).

[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 The Memory-based Model

The contrasts in (5) also suggest that the observation in question should be accounted for not in terms of a 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.

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.

Experimentally, Sturt and Lombardo (2005) have experimentally shown 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. This result is not against our intuition (i) that the reconstruction of a syntactic structure occures only when it helps to construct the semantic content.

On the other hand, it is known that the reconstruction of the head-complement relation is more costly than simply replacing the category of the argument (cf. intransitive verbs vs. transitive verbs; Sturt, Pickering and Crocker, 1999). This result also is not against to our intuition (ii) that syntactic information is expelled as the semantic content of a sentence is obtained since the working memory is severly limited.

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.

Figure 2 shows how the string " The boy kissed the girl" is processed. As the parser encounters a determiner *the*, the local NP (NP_1) node is constructed on the look-ahead basis and stored in working memory. Note that the syntactic information kept in working memory is gradually deactivated as time passes by. (In figure 2, the deactivated information by time is bracketed.) Next, as the V is encountered, the processor constructs a VP node, together with a complement node (NP_2). The complement is required to fully obey the constraints imposed by the head.

S: The Boy kissed the girl.

	1	**2**	**3**	**4**	**5**
input	**the**	**boy**	**kissed**	**the**	**girl**
look-ahead	part of NP_1	VP	NP_2	part of NP_2	-
working memory	NP_1	NP_1	VP	VP, NP_2	VP, NP_2
deactivated	-	(NP_1)	(NP_1)	(NP_1)	NP_1, VP

Figure 2: The processing of the sentence "The boy kissed the girl"

[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.

Let us now turn 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.

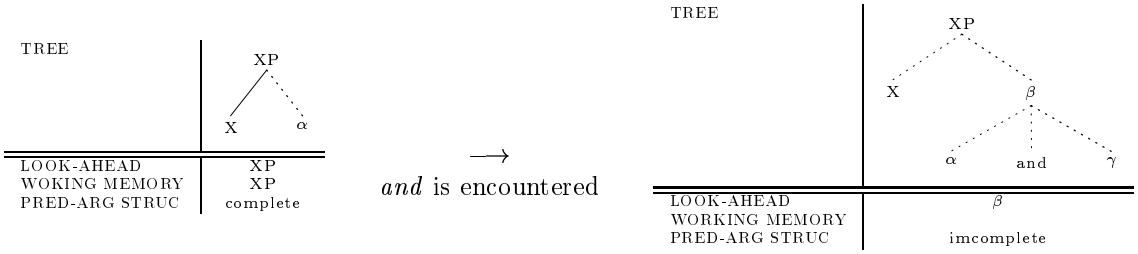

Figure 3: The initial partial tree and the reconstructed partial tree

Note that in "PRED-ARG STRUC"column, parser assumes that the predicate-argument structure is completed in left hand since the conjunct *and* is not encountered yet. On the other hand, in the right hand, because the second conjunct is not encountered yet, the predicate-argument structure is incomplete.

4 Demonstrations

In this section, we will demonstrate how the examples (1)–(5) are predicted 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 shows how the (1b) is processed.

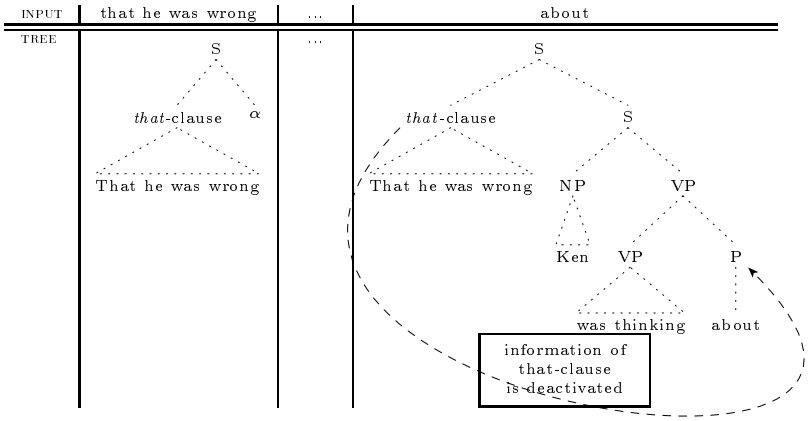

Figure 4: The processing of (1b)

4.2 Complement Coordination

Similarly, in (2a), the *that*-clause is the first conjunct and adjacent to the selecting head *about*; the syntactic constraints fully exert their force on the *that*-clause. However, in (2b), the *that*-clause is not adjacent to *about*, and the conjunct adjacent to it obeys the part-of-speech requirement imposed by the preposition. When this first conjunct is encountered, the parser (wrongly) assumes that the head-complement combination is complete, as in the tree on the lefthand side of Figure 3. As a result, the part of speech information on the compelment node is expelled from working memory. Thus, by the time the second conjunct in (2b) is encountered, the part of speech requirement imposed by *about* has already lost its force, hence the acceptability of (2b). In short, examples in which the first conjuct is NP (2b) is acceptable and ones in which the first conjunct is not an NP (2a) is unacceptable. Figure 5 shows the processing of (2b).

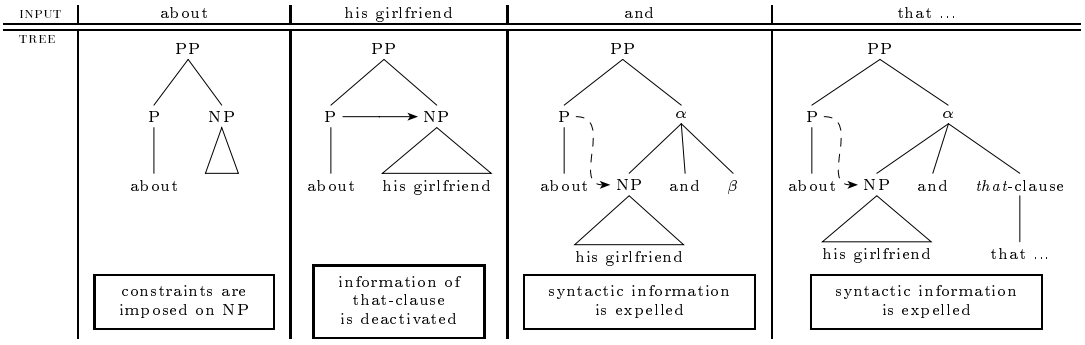

Figure 5: The processing of (2b)

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 are more deactivated as the inserted phrase is processed than when the pause is inserted, the acceptability of (5c) is better than (5b).

4.4 Right Node Raising (RNR)

In our model the Right Node Raising examples 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.

5 Remaining Problems

There are some examples that remain unaccounted for at present. First, 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].

Also, (7) indicates that even insertion of a relative clause between the first conjunct and second conjunct does not increase the acceptability. 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.

We have to refine how the deactivation or expell from working memory occures to account for this effect in the future. Also, to verify whether our model is on a right track is a task for the future. We are planning a psycological experiment. However, what kind of experiment is effective is under discussion .

References

Bresnan, Joan. 2000. *Lexical-functional Syntax*. Oxford: Blackwell.

Falk, Yehuda N. 2001. *Lexical-Functional Grammar: An Introduction to Parallel Constraint-Based Syntax*. Stanford: CSLI Publications.

Johannessen, Jonne B. 1998. *Coordination*. Oxford: Oxford University Press.

Kaplan, Ronald M., and Joan Bresnan. 1982. Lexical-Functional Grammar: A Formal System for Grammatical Representation. *The Mental Representation of Grammatical Relations*, ed. Joan Bresnan, 173–281. Cambridge, MA: MIT Press.

Kaplan, Ronald M., and Annie Zaenan 1989. Long-Distance Dependencies, Constituent Structure, and Functional Uncertainty. *Alternative Conception of Phrase Structure* , ed. Mark R. Bartin and Anthony S. Kroch, 17–42, Chicago: University of Chicago Press.

Kaplan, Ronald M. 1995. The Formal Architecture of Lexical-Functional Grammar. *Formal Issues in Lexical-Functional Grammar*, eds. Mary Dalrymple, Ronald M. Kaplan, John T. Maxwell and Annie Zaenen. 7–27. Standord: CSLI Publication.

Sturt, Patrick, Martin J. Pickering and Matthew W. Crocker. 1999. Structual Change and Reanalysis Difficulty in Langage Comprehension. *Journal of Memory and Language* 40, 136–150.

Sturt, Patrick and Vincenzo Lombardo. 2005. Processing Coordinated Structures: Incrementality and Connectedness. *Cognitive Science* 29(2), 291–305.

Takahashi, Kei and Kiyoshi Ishikawa. 2004. An Adjacecy Constraint on Argument Selection. *Language, Information and Computation: Proceedings of the 18th Pacific Asia Conference*. ed. Hiroshi Masuichi, Tomoko Ohkuma, Kiyoshi Ishikawa, Yasunari Harada, and Kei Yoshimoto. 23–34. Tokyo: The Logico-Linguistic Society of Japan.