1. Introduction

One important phenomenon in modeling human sentence processing is the failure of the sentence processor. That is, when an input sequence contains temporary ambiguities and the analysis for the sequence is incompatible with the later input, the processor must revise the first analysis. In some cases, however, this reanalysis is difficult. This is a 'garden path' (GP) situation as in (1).

(1) The horse raced past the barn fell.

(Bever (1970: 316))

In (1), raced can be ambiguous between the interpretation of the main verb and that of a reduced relative until the input of barn. The interpretation with raced as the main verb is preferred, but this interpretation is incompatible with fell. The preceding interpretation must be revised, but this reanalysis is extremely difficult. A native speaker thus feels conscious processing difficulty (GP effect) for (1). It is not
the case, however, that all the reanalyses cause GP effect. In (2), the temporarily ambiguous Mary is first interpreted as the object of knew, and at the input of was, Mary must be reanalyzed as the subject of the embedded clause.

(2) John knew Mary was ill.

However, this reanalysis is not associated with GP effect. A cognitively motivated sentence processing model should thus be restrictive to predict GP effect only for some classes of reanalysis. In this sense, reanalysis and GP play an important role in examining the validity of human sentence processing model. However, most of the previous studies mainly discussed how the first analysis is conducted for an ambiguous phrase and the relatively little attention was paid to the reanalysis process. The book under review is almost the first comprehensive collection of empirical and theoretical studies focusing on reanalysis, which consists of eleven chapters as follows.

1. Prosodic influences on reading syntactically ambiguous sentences by Markus Bader
2. Reanalysis aspects of movements by Marica De Vincenzi
3. Syntactic reanalysis, thematic processing, and sentence comprehension by Fernanda Ferreira & John M. Henderson
4. Attach Anyway by Janet Dean Fodor & Atsu Inoue
5. Sentence reanalysis, and visibility by Lyn Frazier & Charles Clifton, Jr.
6. Diagnosis and reanalysis: Two processing aspects the brain may differentiate by Angela D. Friederici
7. Syntactic analysis and reanalysis in sentence processing by Paul Gorrell
8. Reanalysis and limited repair parsing: Leaping off the garden path by Richard L. Lewis
9. A computational model for recovery by Vincenzo Lombardo
10. Parsing as incremental restructuring by Suzanne Stevenson
11. Generalized monotonicity for reanalysis models by Patrick Sturt & Matthew W. Crocker

We organize this article by the kind of information assumed to be mainly effective on (re)analysis. In the next section, we will discuss the proposals mainly based on syntax as 'syntactic approach.' That is, Structural Determinism by Gorrell, Thematic Monotonicity by Sturt & Crocker as an alternative to Gorrell's model, Reanalysis Model of Thematic Processing by Ferreira & Henderson, computationally moti-
vated Limited Repair Parsing by Lewis and Diagnosis Model by Fodor & Inoue. Further, we will briefly discuss the chapter by Friederici as an empirical support for Diagnosis Model. In the third section, the proposal by Frazier & Clifton will be discussed as a ‘perceptual approach’ that pays special attention to non-structural/perceptual factors. In the fourth section, we will discuss Prosodic Constraint on Reanalysis by Bader as a ‘phonological approach.’ In the fifth section, Competitive Attachment Parser of Stevenson motivated by connectionism will be discussed as ‘network approach.’ In the final section, we will point out the empirical and the theoretical contributions of the book and enumerate the topics to be discussed in the future research as concluding remarks.1

2. Syntactic Approach

2.1. Structural Determinism (Gorrell)

For a sentence to be interpreted, the dependency relations between input items must be specified. Phrase structure marker is generally adopted as the representation for dependency relations. Gorrell also assumes that the parser builds a phrase structure tree, and he proposes a general constraint on structure building as Simplicity in (3).

(3) Simplicity
No vacuous structure building. (p. 212)

Structure building by the parser is driven by the grammar. This is stated as Incremental Licensing in (4).

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1 Because of the limitation of space, we cannot discuss all the chapters in detail. With the empirical coverage and the theoretical consequence on psycholinguistic study of sentence processing as the criterion, we will review nine chapters above. Here we briefly summarize the chapters by De Vincenzi and Lombardo.

De Vincenzi presents the experimental data on the reanalysis of long-distance wh-depencies in Italian. On the basis of the results, she claims that the human parser is sensitive to the difference between an antecedent government chain and a binding chain.

Lombardo defines general computational frameworks and heuristics for sentence processing. His proposal is characterized by three reanalysis modules, namely, (a) symptom evaluation module, (b) diagnostic module and (c) repair module. This proposal is computationally strict, but in the present form, all misanalyses are recoverable. Therefore, for the proposal to be psycholinguistically valid, some constraint is necessary to distinguish easy errors from difficult ones.
Incremental Licensing

The parser incrementally attempts to satisfy principles of grammar. (p. 215)

The main constraints on reanalyses are Structural Determinism (SD) in (5) originally proposed in Gorrell (1995) and Right-Edge Availability (REA) in (6).

5. Structural Determinism (SD): Attachments of new items which alter the dominance and precedence relations of the computed structure are more costly than attachment which preserve these primary relations. (p. 202; footnote omitted)

6. Right-Edge Availability (REA): The parser, when faced with a dispreferred resolution of an ambiguity, searches the right edge of the tree for an abandoned choice point consistent with the new input. (p. 217)

The presence and the degree of GP effect are explained by these two constraints on reanalyses. In the processing of (7), the parser initially attaches the NP (DP) the noise as dominated by the VP, following Simplicity, which is represented in (7').

7. John heard the noise was due to a design flaw. (p. 215)

\[
(7')
\]

\[
\begin{array}{c}
\text{VP} \\
\downarrow \\
\text{V} \quad \text{DP} \\
\downarrow \\
\text{heard} \quad \text{the noise}
\end{array}
\]

(p. 206)

When the next item was is encountered, however, the noise must be reanalyzed as the subject of the embedded clause. In this new structure, the matrix verb still precedes the NP the noise, and the VP dominates it as in (7'').

\[
(7'')
\]

\[
\begin{array}{c}
\text{VP} \\
\downarrow \\
\text{V} \quad \text{IP} \\
\downarrow \\
\text{heard} \quad \text{DP} \quad \text{VP} \\
\downarrow \\
\text{the noise} \quad \text{was}
\end{array}
\]

(p. 206)

Further, in the reanalysis at was, the revised item the noise is at the right edge of the current parse tree. The reanalysis thus violates neither SD nor REA. Hence no processing difficulty in (7). On the
other hand, at the input of *the sock* in the processing of (8), the simplest attachment site in the current structure is as the object of *mend*.

(8) While Mary was mending the sock fell off her lap.  (p. 216) However, this NP (DP) must be reanalyzed to be the subject of the main clause at the input of *fell*. In this reanalysis, the precedence and dominance relations between *sock* and the preceding items are altered. Note here that the revised item *the sock* is at the right edge of the current parse tree on the reanalysis. The reanalysis in (8) thus violates only SD. Hence the mild GP effect in (8). In the processing of Bever’s well-known GP sentence (1), *raced* is initially interpreted as the main verb, following Simplicity again. In this structure the NP (DP) *the horse* precedes the VP. After the reanalysis at *fell*, however, the VP is dominated by the NP. This is a violation of SD. Further, in the reanalysis at *fell*, the revised item *raced* is not at the right edge of the parse tree, which is a violation of REA. The reanalysis in (1) thus violates both SD and REA. Hence the severe GP effect.

Gorrell’s proposal is very clear and its empirical coverage is fairly wide. Some examples, however, pose a problem for his proposal.

The structure building process of the examples in (9) in which the verb in the reduced relative is obligatorily transitive should be the same as (1). The strong GP effect is thus predicted since SD and REA are violated in the reanalyses. A native speaker of English, however, feels no processing difficulty in (9).²

(9) a. The bird found in the store died.  (Pritchett (1988: 562))
   b. The alien examined under a microscope originated from a planet orbiting Polaris.
   c. The monkeys chased out of the cage never returned.
      (Gibson (1991: 161))

² The first PP does not necessarily force the reduced relative interpretation since a heavy NP can be shifted at the end of the sentence as in (i).

( i ) The bird found in the room an insect with four big red wings and two long antennas.

Even when the PP indicates the reduced relative interpretation, SD is still violated at the input of the PP. GP effect is thus wrongly predicted. We have some proposals to explain this contrast between Bever’s (1) and those in (9) (Pritchett (1988), Gibson (1991) etc.). In any event, the difference between optionally transitive *raced* and obligatorily transitive verbs (*found, examined and chased*) should be encoded in the relevant representation.
SD is assumed to be a universal constraint on reanalysis, and REA is claimed to be applicable to left-branching structure. Then, some Japanese examples can be problematic to Gorrell.

(10) Nakamura-ga tyuuko-no pasokon-o katta toki
  name-Nom second-hand PC-Acc bought when
  syuuri-site-kureta.
  repaired (for me)
‘Nakamura, when I bought a second-hand personal computer, repaired it for me.’

(Mazuka and Itoh (1995: 302))

The NP Nakamura-ga (name Nom) is initially interpreted as the subject of the subordinate clause. However, the NP must be reanalyzed as the subject of the main clause at the input of syuuri-site-kureta (repaired for me). Since Nakamura-ga is raised from the subordinate clause to the main clause, the dominance relation between the NP and the subordinate IP is cancelled. This is a violation of SD. Further, the revised item Nakamura-ga is far from the right edge of the parse tree, which is a violation of REA. A strong GP effect comparable to that in Bever’s (1) is thus predicted. However, the processing difficulty perceived by a Japanese native speaker for (10) is not so severe.3

2.2. Thematic Monotonicity (Sturt and Crocker)

Sturt and Crocker (S&C) claim that the main property of human parser is monotonicity. The constraint of monotonicity requires “description” to be preserved where the description is a set of statements describing certain aspects of the syntactic representation. Gorrell’s Structural Determinism is a definition of monotonicity in which the

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3 The mild processing difficulty of (10) has attracted the interest of researchers since a severe GP effect is predicted. In this case again, this mild GP effect is under investigation. We can still point out some factors that may be relevant. That is, (a) lexical ambiguity like raced in Bever’s (1) is not involved. (b) the number of revised constituent is only one, namely Nakamura-ga. The other dependency relations are maintained. (c) In Japanese, the subject referring to the speaker can be always phonetically null. Therefore, the reanalysis requiring an empty subject may be relatively easy. (d) Since the subject referring to the speaker can be phonetically null, when the subject of katta is required to be determined, the interpretation with the subject of katta as the speaker may be retained simultaneously with the interpretation with the subject as Nakamura-ga. If these two interpretations are available at the input of syuuri-site-kureta, the reanalysis is unnecessary.
description consists of dominance and precedence relations in a constituent structure level of representation. S&C claim that SD is too restrictive to provide an account of the available data. The main motivation of their claim is the processing of (11).

(11) [S [NP1 The journalist] interviewed [NP2 the daughter of [NP3 the colonel [RC who had had the accident]]]]. (p. 381)

There are two possible interpretations for (11), corresponding to the attachment of the relative clause as a modifier of daughter on the one hand (high attachment) and as that of colonel on the other (low attachment). Recent experimental evidence from Italian (De Vincenzi and Job (1993) and De Vincenzi and Job (1995)) and Japanese (Kamide and Mitchell (1997)) suggest that, in sentences similar to (11) in these languages, although the initial preference is for the low attachment, the final is revised for the high attachment. In the low attachment, the relative clause is dominated by the NP headed by colonel, but in the revised high attachment, this dominance relation is removed. Since this is a violation of SD, this reanalysis is predicted to be very difficult, which is not the case. The central idea of S&C is that representation types constrained by monotonicity can be defined by picking out, from a phrase structure tree, subsets of nodes which share a certain property. As one possible instantiation, they propose two “thematic nodes” as the relevant nodes, namely, “thematic assigner nodes” and “thematic receiver nodes.”

(12) a. thematic assigner nodes: nodes which share the property of being the (extended) maximal projection of the theta-assigning head.

b. thematic receiver nodes: nodes which have received a thematic role from some theta-assigning head. (p. 384)

In (11), the topmost S, NP2 and RC are assumed to be thematic assigner nodes and NP1, NP2 and NP3 to be thematic receiver nodes. S&C claim that the reanalysis of a modifier is constrained only by the thematic assigner nodes while that of a non-modifier is constrained by the two thematic nodes. This constraint is defined as Visibility in (13).

4 Here S&C make the assumption (along with Frazier and Clifton (1996), De Vincenzi and Job (1995) and Gilboy et al. (1995)) that the noun daughter assigns a thematic role to NP3, the colonel.
Visibility
1. \( A \) is visible to a modifier \( M \) iff \( A \) is a thematic assigner node.
2. \( A \) is visible to a non-modifier \( N \) iff 
   either there is no modifier that dominates \( N \) but not \( A \), and \( A \) is a thematic node (i.e. a receiver or assigner),
   or there is a modifier that dominates \( N \) but not \( A \), and \( A \) is a thematic assigner node. (p. 389)

S&C propose that structural determinism should be observed between the nodes visible to each other. In (11), the thematic assigner nodes visible to the relative clause (RC) are \( S \) and NP2 (enclosed in circles in (11')) while thematic receiver nodes are in squares).

Therefore, even when the RC is reanalyzed as the modifier of NP2 (daughter) from that of NP3 (colonel), the relevant dominance relation between NP2 and RC is not altered. The reanalysis is thus correctly
predicted to be easy.

The ease of reanalysis in (11) by thematic monotonicity is impressive. We must say, however, that S&C’s proposal is too loose to explain some types of GP effect. The GP sentences in (14) with lexical categorical ambiguity will be wrongly predicted to be non-GP.

(14) a. The old train the young.
       b. The prime number few. (Pritchett (1992: 122))

In (14a), when train is processed as a noun and the input items constitute an NP the old train, the parser has encountered no thematic role assigner. Therefore, when the young is input and a reanalysis is invoked, no thematic node is available. Since neither precedence nor dominance relation between thematic nodes is cancelled, processing difficulty is not predicted to arise, which is not the case.

A Japanese GP construction also can be problematic for S&C’s thematic monotonicity.

(15) Taro-ga roopu-o kitta maruta-ni shikkari makituketa.
        name-Nom rope-Acc cut log to tightly bound around

‘Taro bound a rope tightly around the log which he cut.’

When kitta (cut) is processed and the preceding two NPs, Taro-ga (name Nom) and roopu-o (rope Acc) are interpreted as the subject and the object of the predicate respectively, the thematic assigner node is S and the thematic receiver nodes are the subject NP and the object NP. These three nodes are visible to each other since the S and the two NPs are non-modifier and there is no modifier between the three. The S dominates the two NPs and the subject NP precedes the object NP. When maruta-ni (log to) is input, a reanalysis is forced, and finally Taro-ga and roopu-o are interpreted as the subject and the object of the main predicate makituketa (bound around). In this final representation the NP Taro-ga still precedes the NP roopu-o and the topmost S dominates these two NPs. The severe GP effect in (15) is thus not explained by thematic monotonicity.

As Gorrell observes, GP effect is graded. However, the prediction by thematic monotonicity is binary. The grading of GP effect is left unexplained.

2.3. Reanalysis Model of Thematic Processing (Ferreira and Henderson)

Ferreira and Henderson (F&H) performed many experiments asking subjects to make grammatical judgments for stimulus sentences, and,
on the basis of their results, they propose a measure to estimate the cost of a reanalysis.

(16) Processing cost results when:
(a) a thematic processing domain (TPD) is embedded inside another,
(b) two TPDs must interact, and/or
(c) two theta-assigners are adjacent. (p. 97)

A TPD is defined to be the sequence that includes the theta-assigner and all the arguments to which it assigns roles. These three conditions are assumed to be additive. That is, the more conditions are violated in a sentence, the severer processing difficulty arises. No processing difficulty is perceived in (17) (in which two TPDs are indicated by brackets). This is because the two TPDs are entirely independent and the two theta-assigners, scratched and yawned, are not adjacent.

(17) When {the boy scratched the dog} [the girl yawned] loudly. (p. 90)

The comprehension of (18) is a little more difficult than (17). The TPD Op hates Sally is embedded in the bigger TPD in the subordinate clause. This is the reason for the slight processing difficulty in (18).

(18) When {the boy scratched the dog that (Op hates Sally)} [the girl yawned] loudly. (p. 91)

The GP effect in (19) arises because the two TPDs, the boy scratched the dog and the dog yawned overlap, that is, part of one (the dog) is contained inside part of the other.

(19) When [the boy scratched | the dog] yawned. | (p. 92)

The GP effect perceived in (20) is still stronger than (19). This is because two TPDs interact and further TPD Op hates Sally is embedded inside another.

(20) When | the boy scratched [the dog that (Op hates Sally)] yawned] loudly. (p. 93)

The GP effect in (21) is severest because the three constraints are all violated.

(21) When | the boy scratched [the dog that (Sally hates)] yawned] loudly. (p. 95, the brackets by the present author)

The relation of TPD interaction and embedding of (21) is the same with (20), and further two theta-assigners, hates and yawned, are adjacent. Hence the strongest GP effect.

F&H's reanalysis model attributes reanalysis difficulty to the effort in assigning thematic roles correctly to the sentential entities. Since the
main goal of the parser should be to determine the thematic dependency relations between input items, we can say their model is cognitively well-motivated. Further, F&H's model can explain the degree of processing difficulty, and further again, the first and the third conditions are applicable not only to GP sentences but also to center-embedded sentences. This applicability is a good point since there are only few proposals that systematically relate the processing difficulties in GP and center-embedded sentences. We should say, however, that F&H's empirical coverage is not wide, though they do not intend to explain all the processing difficulties associated with various GP sentences. F&H propose the three conditions to explain English GP effects associated with subject-object ambiguity. Many of English and Japanese GP sentences are not discussed. The applicability of TPD and its interaction to the other constructions should be considered in detail.

2.4. Limited Repair Parsing (Lewis)

Parsing procedure of Lewis is mainly characterized by two parsing operators, namely, link and snip. Link operator performs syntactic attachment in a head-driven, bottom up fashion. Snip operator, on the other hand, destroys a bit of structure and then lets link operator take over to finish the structure building. Snip operation is proposed as a way of reformulating the parsing problem space so that it efficiently supports depth-first (serial) search without backtracking. Lewis proposes that snip should be restrictive only for structural relations that are "local" to a detected inconsistency where local is defined as within the maximal projection containing the inconsistency. As an example in which snip operation succeeds, let us consider the parsing procedure of (22).

(22) Thad knows Shaq is tall. (p. 265)

Shaq is initially attached in the complement position of knows by link operator. When is is encountered, it is projected to the sentential complement node CP. Next, link operation attaches the CP in the complement position of knows. This representation, however, contains an inconsistency that the NP Shaq and the CP are competing for

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5 See Gibson (1998) and Babyonyshev and Gibson (1999) as one of the few proposals trying to explain local syntactic ambiguity and center-embedding systematically.
the same structural position. This inconsistency triggers snip operator
to break the link between *knows* and *Shaq*. This operation is possible
because the detached NP *Shaq* is within the maximal projection VP
containing the inconsistency. These operations are shown in (22').
(The boxed nodes identify the locality of the inconsistency.)

(p. 265)

On the other hand, the representation for Bever’s GP sentence (1)
when the final input *fell* is encountered is assumed as (1').

(p. 272)
The inconsistency of two VPs is local to the IP. This inconsistency, however, is claimed not to trigger the required snip operation, that is, the detachment of the inflection *PAST*.

Some English GP sentences are problematic for snip operation. As Lewis admits, the GP sentences in (23) are wrongly predicted to be non-GP since the inconsistency is local to the detached item.

(23) a. The psychologist told the wife that he was having trouble with to leave.
   b. I sent the letters to Ron to Teresa. (p. 270)

Snip operation is restrictive to the domain “within” the maximal projection containing an inconsistency. However, the definition of “within” is not syntactically clear. This can be a theoretical problem.

Further, snip operation is triggered by a grammatical inconsistency, and the locus of the inconsistency is crucial for the success of a snip operation. When no grammatically legitimate site is available for an input item, however, there is no explicit way to decide where to attach the input. This means that the locus of an inconsistency can be arbitrary.

Further again, the presence and absence of GP effect is explained by the success or failure of snip operation, and therefore the degree of GP effect is left unexplained.

2.5. Diagnosis Model (Fodor and Inoue)

The fundamental principle for structure building in diagnosis model by Fodor and Inoue (F&I) is Attach principle in (24).

(24) *Attach*: On receiving a word of the input sentence, connect it to the current partial phrase marker (CPPM) for the sentence in such a way that the resulting CPPM is syntactically well-formed though possibly incomplete at its right edge. (p. 103; footnote omitted)

F&I’s insight for reanalysis is that a reanalysis consists of two operations: the process of establishing what revisions to make and that of restructuring. These two processes are driven by two principles, Attach Anyway and Adjust in (25).

(25) a. *Attach Anyway*: Having established that there is no legitimate site in the CPPM for the current input word, attach the input word into the CPPM wherever it least severely violates the grammar, and subject to the usual preference principles that govern *Attach*. (p. 105; foot-
b. **Adjust**: When a grammatical conflict has been created between two nodes or features X and Y in the CPPM, by either *Attach* or *Adjust*, eliminate the problem by altering minimally (i.e. no more than is necessary for conflict resolution) whichever of X and Y was less recently acted on, without regard for grammatical conflict thereby created between that node and other elements in the CPPM. (p. 106)

F&I’s main claim is that no repair processes are intrinsically costly and repair costs are entirely attributable to the difficulty of the diagnosis process to decide what structural alternations to make. This is the insight of Fodor and Inoue (1994). The difficulty of the diagnosis process depends on whether Adjust operation can find the original error site from an error signal created by Attach Anyway. An Adjust operation succeeds when the operation follows from the Grammatical Dependency Principle in (26).

(26) **The Grammatical Dependency Principle (GDP)**: When a grammar violation has been created in the CPPM by an action on node *n* in accord with *Attach Anyway* or *Adjust*, attempt to eliminate the problem by acting on a node that is grammatically incompatible with *n*. (p. 109)

The difficulty of a reanalysis is explained by GDP and Thematic Overlay Effect in (27).

(27) **Thematic Overlay Effect (TOE)**: The parser does not demote a semantic argument role from overt (lexically realized) to implicit (unrealized). (p. 118; footnote omitted)\(^6\)

The GP effect in (28) is explained by GDP and TOE.

(28) While the boy scratched the big and hairy dog yawned loudly. (p. 114)

The NP *the big and hairy dog* is first attached as the object of *scratched*. When *yawned* is attached to CPPM by Attach Anyway, the error signal is detected. That is, the subject of *yawned* is missing. An Adjust operation seeks for the subject and the only applicant is *the*...
**big and hairy dog.** However, this NP is not available since it is outside of the main clause and therefore there is no grammatical dependency between the two positions. This is a violation of GDP. Further, the thematic role first discharged to the big and hairy dog is not lexically realized after the input of yawned, which is an instance of TOE. Hence the GP effect. On the other hand, the reanalysis in (29) is easily performed.

(29) The boy noticed the big and hairy dog limped badly.

The NP the big and hairy dog, which is first attached as the object of noticed, must be reanalyzed as the subject of limped. This restructuring can be performed by Adjust operation successfully, since the two positions have a grammatical dependency. Moreover, the thematic role first assigned to the big and hairy dog is still lexically realized in the embedded clause. No processing difficulty thus arises. The weak GP effect in (30) is explained by no violation of GDP and the presence of TOE.

(30) a. John warned the children at the day care center were noisy.
   b. John promised the children at the day care center would be good.

The two syntactic positions, the object position of main verb and the subject position of the embedded clause, are grammatically dependent on each other. Adjust operation thus succeeds in restructuring the children at the day care center from the main clause to the embedded. However, the PATIENT thematic role first discharged to this NP is left lexically unrealized, which is an instance of TOE. Hence the weak processing difficulty.

The relation between grammar and parser was unclear for a long time. We should say, therefore, it is a great contribution of F&I that Attach Anyway principle clarifies what role grammar plays in reanalysis. That is, when no legitimate site is available for an input item, grammar can identify the symptom of GP by Attach Anyway operation. Another good point of diagnosis model is that no machinery is necessary to calculate what reanalyses are possible. This is desirable from the viewpoint of language use. Sentences requiring reanalyses are rather rare in the daily language use, and therefore it is unlikely that human mind has a system only for reanalyses.

Wide empirical coverage is not the main concern of F&I. We still
should say, however, GDP and TOE are effective in explaining GP effect only for a few sentences. Many GP sentences including Bever’s (1), Pritchett’s (14), Lewis’s (23b) and (31) are left unexplained.

(31) Todd gave the boy the dog bit the bandage.  

(Pritchett (1992: 12))

In (31), bit requiring a reanalysis has a grammatical dependency with the reanalyzed item the dog. Further, the two theta-roles first assigned to the boy and the dog at the input of dog are reassigned to the complex NP the boy the dog bit and the bandage respectively. Since we find no violation of GDP and no instance of TOE, no processing difficulty is predicted. However, this is not the case.

Further, Attach Anyway principle can pose a computational problem. When there is no legitimate attachment site available, Attach Anyway states that the parser attaches the input word into the CPPM wherever it “least” severely violates the grammar. For one thing, we do not have an explicit way to estimate the degree of grammatical violation. For the second, when there are plural potential Attach Anyway-sites, the parser must calculate which is the least severe violation. If the parser must exhaustively retrieve and examine all the potentially possible attachment sites, the problem of combinatorial explosion arises.

2.6. Event-Related Brain Potentials for Diagnosis Model (Friederici)

Friederici visually presented German sentences with a temporarily ambiguous phrase die Professorin (the professor) as in (32) to German native speakers and examined the event-related brain potentials (ERP) elicited at the disambiguating sentence final auxiliaries hat (has) and haben (have).

(32) a. Das ist die Professorin, die die Sekretärinnen gesehen this is the professor that the secretaries seen  

hat.  

has  

‘This is the professor that has seen the secretaries.’

b. Das ist die Professorin, die die Sekretärinnen gesehen  

this is the professor that the secretaries seen  

haben.  

have  

‘This is the professor that the secretaries have seen.’
c. Er wußte, daß die Professorin die Sekretärinnen
gesehen hat.
‘He knew that the professor has seen the secretaries.’

d. Er wußte, daß die Professorin die Sekretärinnen
he knew that the professor the secretaries
sehen haben.
‘He knew that the secretaries have seen the professor.’

On the basis of the experimental results, Friederici suggests that two different aspects of ERP, namely, its onset latency and its duration, reflect two subprocesses of reanalysis, that is, the diagnosis of the need for reanalysis and the actual reanalysis itself. This can be an empirical support for Fodor and Inoue’s claim that a reanalysis consists of these two operations.

3. Perceptual Approach: Reanalysis Complexity as a Function of Sentence Token (Frazier and Clifton)

Frazier and Clifton (F&C) claim that revision cost cannot be calculated in purely structural terms. They enumerate two factors that influence the cost of a reanalysis, namely, the length of an ambiguous phrase and the relative frequency of a verb’s subcategorization frames. Further, they propose two principles, Semantic Cost Principle and Minimal Revision governing reanalysis and Visibility Hypothesis for the first analysis and reanalysis.

The lengthening of an ambiguous phrase increases revision cost in some cases and facilitates the comprehension in others. In the comparison in (33) with structurally ambiguous phrases, his horse and his beautiful white horse, (33a) with the shorter ambiguous phrase is easier to comprehend than (33b).

(33) a. Before the king rides his horse is always groomed.
b. Before the king rides his beautiful white horse is always groomed.  (p. 145)

In (34), on the other hand, the longer ambiguous phrase after the operation they need in (34b) eases the possible reanalysis in comparison to (34a) with the shorter ambiguous phrase tomorrow.
(34) a. John will explain to the kids that their grandfather died tomorrow.
b. John will explain to the kids that their grandfather died after the operation they need. (p. 147)

It appears that lengthening the ambiguous phrase, especially after the point of disambiguation, facilitates the comprehension process.

F&C claim that the relative frequency of a verb’s subcategorization frames influences revision cost. In the comparison in (35), (35a) with walk is easier to comprehend than (35b) with read.

(35) a. Which girl did the teacher walk (_) to the principal’s office with _?
b. Which book did the teacher read (_) to the children from _? (p. 154)

In (35a), the parser gives up a lexically unpreferred gap following the preferred intransitive walk, and in (35b), on the other hand, the parser must give up a gap corresponding to the most frequent subcategorization of read. This is the reason for the stronger GP intuition in (36b) than in (36a).

F&C’s proposal concerning semantic effects in reanalyses is Semantic Cost Principle in (36).

(36) Semantic Cost Principle: Revising semantically interpreted (confirmed) decisions is more costly than revising semantically uninterpreted ones. (p. 148)

The strong GP effect in Bever’s (1) is claimed to follow from Semantic Cost Principle. That is, raced, which is first semantically analyzed as the main verb, must be revised as a reduced relative. The example (37) the structure of which is the same with Bever’s (1) is not associated with conscious processing difficulty.

(37) The letter sent on Monday arrived today. (p. 148)

This is because semantic information immediately disconfirms the main verb analysis of sent.

When there are more than one revision at a reanalysis, the parser’s decision is claimed to be governed by Minimal Revision Principle in (38).

(38) Minimal Revision: Don’t make an unnecessary revision. When revision is necessary, make the minimal revision consistent with the error signal, maintaining as much of the already assigned structure and interpretation as possible. (p. 155)
In (39), when the first PP *in the chest* is first analyzed as the locative argument of *put* and then the second PP *in the closet* is encountered, the parser has two alternative revisions. That is, the first PP is revised to modify the preceding NP or the second is to modify *the chest*. A native speaker prefers the latter interpretation.

(39) Brian put the silverware in the chest in the closet. (p. 156)

For the former revision, the predicate-argument relation between *put* and *in the chest* must be cancelled, but in the latter revision that relation is maintained. The latter revision is thus preferred following Minimal Revision Principle.

F&C propose Visibility Hypothesis in (40) as the principle to apply in both first analysis and reanalysis.

(40) **Visibility Hypothesis:** In first analysis and reanalysis, attachment to a visible node is less costly in terms of processing/attentional resources than attachment to a less visible node. (i) Node X is more visible than node Y if X was postulated later than Y. (ii) Nodes within a perceptually-given package (e.g., intermediate phonological phrase) are more visible than nodes outside the package. (p. 163)

In the comparison in (41), the relative clause modifying the subject of the main clause is longer in (41b) with an adjunct clause *after it was built by NASA* than in (41a). It is claimed that, at the point that *had cost* is encountered, the visibility of the main clause in (41b) (either the IP itself or the (predicted) VP) is less than in (41a) since many more recent nodes have been postulated in (41b) than in (41a).

(41) a. Unfortunately, *[the space capsule everyone objected to] had been built by NASA and cost the taxpayers a fortune.*

b. Unfortunately, *[the space capsule everyone objected to after it was built by NASA] had cost the taxpayers a fortune.* (p. 165)

The Visibility Hypothesis thus predicts that the predicate *cost* in (41a) should be easier to process than in (41b).7 Sentence (41b) should be

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7 Note here that the nodes for the adjunct structure *after it was built by NASA* in (41b) are assumed to be "more recent" to the IP (or the VP) than those for *had been built by NASA* in (41a). The reason for this recency judgment is not neces-
particularly complex at the point of *had cost* where the parser must attach the input item relatively high, outside the relative clause. This prediction is supported by an eyetracking experiment. The total reading time for the italicized region was shorter in (41a) than in (41b).

It must be the case that some non-structural factors may affect human sentence processing. According to the standard hypothesis, however, language is one of the input systems (Fodor (1983)). The human parser is thus generally assumed to be a module, which is informationally encapsulated. F&C’s experimental findings and their proposal are impressive indeed, but they do not necessarily shed light on the mechanism of the human parser. Even when we do not presuppose modularity for human parser, unless the details of the interaction between different kinds of information processing are specified, it is difficult to make a prediction for a (re)analysis. F&C’s proposal should thus be said to be descriptively adequate. In the present form, it does not have the sufficient explanatory power.

4. Phonological Approach: Prosodic Constraint on Reanalysis (Bader)

Bader proposes a prosodic explanation of processing difficulty as Prosodic Constraint on Reanalysis in (42).

(42) **Prosodic Constraint on Reanalysis (PCR):** Revising a syntactic structure is difficult if it necessitates a concomitant reanalysis of the associated prosodic structure. (p. 8)

Bader examined his hypothesis by the reading time experiment on German *ihr* ambiguity as in (43).

(43) a. Zu mir hat Maria gesagt, daß man ihr Geld
to me has Maria said that one her money
beschlagnahmt hat.
confiscated has
‘Maria said to me that someone confiscated her money.’

sarily clear. We should rather consider the structural distance between the main clause IP and *NASA*. In (41a), *NASA* is part of the main VP and thus it is structurally close to the IP. In (41b), on the other hand, *NASA* is deep in the relative clause and thus it is structurally far from the IP. The relative recency of *and cost* and *had cost* to the IP should thus be estimated by the immediately preceding input *NASA*.
b. Zu mir hat Maria gesagt, daß man ihr Geld
   to me has Maria said that one her money
   anvertraut hat.
   entrusted has
   ‘Maria said to me that someone entrusted money to
   her.’

c. Zu mir hat Maria gesagt, daß man sogar ihr Geld
   to me has Maria said that one even her money
   beschlagnahmt hat.
   confiscated has
   ‘Maria said to me that someone confiscated even her
   money.’

d. Zu mir hat Maria gesagt, daß man sogar ihr Geld
   to me has Maria said that one even her money
   anvertraut hat.
   entrusted has
   ‘Maria said to me that someone entrusted money even
   to her.’ (pp. 11-19)

The preferred interpretation for ihr is possessive as in (43a). The
default intonation pattern of [NP ihr Geld] is ihr GELD. In (43b), the in-
terpretation of ihr is revised to be dative as [NP ihr] [NP Geld]. The in-
tonation pattern of this dative reading is also ihr GELD. PCR thus
predicts no processing difficulty for this reanalysis. A focus particle
sogar affects the intonation pattern. In (43c), the focused head is
Geld, and thus the intonation pattern is ihr GELD again. In (43d),
however, because of the presence of the focus particle, the intonation
pattern is revised from ihr GELD to IHR Geld. Since this is a viola-
tion of PCR, processing difficulty is predicted only for (43d). The
reading times at the participle anvertraut and the auxiliary hat for (43d)
are significantly longer than those at the corresponding positions for the
other three examples. Bader claims that PCR is applicable to some
English GP sentences like (44). (An intonational phrase is abbreviated
as I.) The possible reanalysis of the answer in (44b) is not associated
with a conscious processing difficulty. This is because both (44a) and
(44b) consist of a single intonational phrase and therefore the prosodic
structure is not altered in the reanalysis.

(44) a. (I Peter knew the answer immediately.)
   b. (I Peter knew the answer would be false.) (p. 8)

In the reanalysis in (45b), on the other hand, the first intonational
phrase must be revised from (I Without her contributions) to (I Without her).

(45) a. (I Without her contributions) (I the funds would be inadequate).
b. (I Without her) (I contributions would be inadequate).

This is a violation of PCR. Hence the GP effect.

The experiments by Bader is strictly controlled and their results are convincing. PCR may be applicable to other languages than German. Here, the applicability of PCR depends on the definition of intonational phrase. An intonational phrase is the domain of an intonational contour found in a given language. The end of an intonational phrase is prosodically marked by boundary tones, and, optionally, by pausing and lengthening phrase-final syllables. Intuitively, many of GP sentences in English and Japanese contain the reanalyses of prosodic structure. If a clause consists of one intonational phrase as in (44a), however, the number of the intonational phrases of GP sentences with lexical categorical ambiguity in (14) and those with PP ambiguity like (23b) is only one. In these cases, PCR is not effective in explaining the GP effect since the reanalyses do not involve the alternation of intonational phrase. Further, if an embedded clause does not construct an independent intonational phrase as in (44b), the GP sentences containing reanalyzed embedded clauses like (23a) are wrongly predicted to be non-GP. Bader proposes PCR as only one of the factors that cause the conscious processing difficulty, and thus PCR is not intended to explain all the GP effects. In any event, the definition of intonational phrase should be more strict for the clear explanation and prediction. Further again, PCR is a constraint on reanalysis, and thus the first parse must be determined by other constraints or principles.

5. Network Approach: Competitive Attachment Parser (Stevenson)

Competitive Attachment Parsing Model proposed by Stevenson is a hybrid of X theory and localist network. The model builds syntactic analyses by activating network processing nodes that directly represent a parse tree structure. The nodes of the network correspond one-to-one to nodes and links in a parse tree. Attachment nodes are established between two phrasal nodes that are potential sisters in the parse tree. Then, attachment nodes with higher activation levels will receive
more of the phrasal node’s output activation. This competition mechanism in the parallel restructuring operations is represented in (46), where Stack is a single phrasal node that can activate multiple attachments and e is Empty Node.

Attachment $a_1-a_4$ were previously activated. To attach the current phrase to the tree on the stack, exactly one of the prior attachment, $a_i$, must become inactive, and the corresponding pair of attachments, $p_i$ must become active.

In this model, GP effect is explained as follows: At the point of disambiguation, the parser cannot activate the set of attachments corresponding to the correct analysis. That is, the set of competing attachment nodes between the current (disambiguating) phrase and the partial parse tree does not include the attachments necessary for the reanalysis. For example, the network at the point of processing *got* in the GP sentence in (47) is represented in (47').

(47) When Kiva left the room got quiet. (p. 353)
For the grammatical analysis, the postverbal NP *the room* needs to break its attachment to the verb and reattach as the specifier of the current IP. To do this, the network must de-activate attachment node $a_1$ and activate node $a_2$. However, $a_2$ is not able to win the competition with $a_1$ for the output activation from the NP. This is because the attachment of the NP to the I' is not strong enough by itself to win the competition with the attachment of the NP to the V. The current I' thus activates the default empty node attachment, leading to a clause with an empty (and unbound) subject. Since the network settles on an irrecoverably ungrammatical analysis, the model correctly predicts the GP effect.

In general, a network model has an advantage to easily utilize contextual information, and the recency effect can be easily realized because the activation decays as time goes. Further, Stevenson's com-
petitive attachment model can explain the unconscious processing difficulty by counting the number of iterations of the network to determine a consistent attachment configuration. Further again, in Stevenson’s model, no mechanism peculiar to reanalyses is necessary for the explanation of processing difficulty, which is desirable from the viewpoint of daily language use.

The possible methodological problem of network model is that the empirical validity of the model can be examined only in computer simulation. Whether an attachment succeeds or not depends on the activation states of the processing units in the network and the timing of an input. Since we cannot exactly reproduce the network at the relevant time by intuition, it is difficult to make a prediction for the attachment by paper and pencil. Here we have a possible danger to make the network a kind of black box. Since the success of computer simulation depends on the details of the simulation program and the architecture of hardware, the validity of the Stevenson’s model should be strictly examined from the computational viewpoint.

6. Concluding Remarks

We can point out the empirical and the theoretical contributions of the book by this review. Let us conclude this article by enumerating these contributions and the remaining problems.

- Reanalysis Cost: GP effect was judged in all-or-nothing way in many of the preceding literature. However, it is recognized in the chapters by Gorrell, Ferreira & Henderson, Fodor & Inoue and Frazier & Clifton that GP effect is graded. This means that the cost of a reanalysis varies among different situations.
- Universality and Specificity: Most of the preceding proposals aimed to explain the relevant processing phenomena in English. In this book, however, the chapter by Sturt & Crocker examined Italian and Japanese examples to motivate their processing model. De Vincenzi examined wh-dependency in Italian. Further, the chapters by Friederici and Bader discussed German syntactic ambiguity. These should be estimated as a significant contribution of the book to examine what principle or constraint is universal and what is peculiar to a specific language in sentence processing.
- Modularity of Parser: The parser is generally assumed to be a
module. However, Frazier & Clifton and Bader presented experimental evidence indicating that phonological, semantic and perceptual (word frequency, recency, etc.) information other than the syntactic affect sentence processing. It should be clarified what kind of information the parser utilizes and how these different processes are organized.

- **Relation between First Parse and Reanalysis**: Gorrell’s Incremental Licensing is the principle for the first parse and his Structural Determinism and Right-Edge Availability are constraints on reanalysis. Lewis assumes two distinct operations, link and snip, for the first parse and reanalysis respectively. Further, Fodor & Inoue propose Attach for the first parse and Adjust for reanalysis. On the other hand, Stevenson assumes a single operation for the two processes. Which is better empirically and theoretically?

- **Relation between Syntax and Parser**: The operations of the parser must be constrained in some way by syntax. However, the relation between the two was implicit in many cases. Gorrell’s Incremental Licensing is an explicit statement for the relation between syntax and parser. Further, Fodor & Inoue’s Grammatical Dependency Principle is a significant attempt to specify the role of syntax in reanalysis. It should be discussed in detail what kind of syntactic information is the driving principle of parser. Moreover, what kind of formalization of syntactic information is proper for sentence processing can be discussed.

- **Serial or Parallel?**: Many of the symbolic processing models presuppose serial processing. On the other hand, one of the main characteristics of Stevenson’s Competitive Attachment Parser is parallel processing. If the parser operates in parallel fashion, the way and the extent of the parallelism should be made explicit.

- **Cognitive Motivation for Parsing Constraint**: It is clear that the parsing operations are constrained in some way in the presence of GP effect. Many constraints have been proposed to explain GP effect. However, the cognitive motivations for the constraints are not necessarily clear through the book. The parsing constraints should be well-motivated by the cognitive grounds.
REFERENCES


