

## REANALYSIS IN SENTENCE PROCESSING

# STUDIES IN THEORETICAL PSYCHOLINGUISTICS

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# REANALYSIS IN SENTENCE PROCESSING

edited by

JANET DEAN FODOR

*CUNY Graduate School and University Center, New York, U.S.A.*

and

FERNANDA FERREIRA

*Michigan State University, East Lansing, U.S.A.*



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# Contents

List of Contributors	ix
----------------------	----

---

Preface	xi
---------	----

---

1 Prosodic influences on reading syntactically ambiguous sentences	1
--------------------------------------------------------------------	---

---

**Markus Bader**

- 1 *Introduction*
- 2 *Phonological coding and syntactic ambiguity resolution*
- 3 *Focus particles and syntactic ambiguity*
- 4 *Experiment 1*
- 5 *Experiment 2*
- 6 *Experiment 3*
- 7 *General discussion*

2 Reanalysis aspects of movements	47
-----------------------------------	----

---

**Marica De Vincenzi**

- 1 *Introduction*
- 2 *Differences between types of wh-dependencies*
- 3 *The Italian processing data*
- 4 *Conclusions from the Italian experiments*
- 5 *Some evidence on processing wh-questions in English*
- 6 *Conclusions*

3 Syntactic reanalysis, thematic processing, and sentence comprehension	73
-------------------------------------------------------------------------	----

---

**Fernanda Ferreira & John M. Henderson**

- 1 *Introduction*
- 2 *General issues of reanalysis*
- 3 *Ferreira & Henderson's (1991a, 1991b) model of reanalysis*
- 4 *Our current model of reanalysis*
- 5 *Summary of the new model*

4 Attach Anyway	101
-----------------	-----

---

**Janet Dean Fodor & Atsu Inoue**

- 1 *Background*
- 2 *Attach Anyway and Adjust*
- 3 *The Grammatical Dependency Principle*
- 4 *The Thematic Overlay Effect*
- 5 *Capture and theft*
- 6 *Conclusion*

---

5 Sentence reanalysis, and visibility 143

---

**Lyn Frazier & Charles Clifton, Jr.**

- 1 *Introduction*
- 2 *Reanalysis cost*
- 3 *Reanalysis preferences*
- 4 *Visibility*
- 5 *Why visibility*
- 6 *Conclusions*

6 Diagnosis and reanalysis: Two processing aspects the brain may differentiate 177

---

**Angela D. Friederici**

- 1 *Introduction*
- 2 *The processing view of revision*
- 3 *Language processing in ERP*
- 4 *Processing subject-first and object-first structures*
- 5 *The data*
- 6 *The late positivity*
- 7 *Conclusion*

7 Syntactic analysis and reanalysis in sentence processing 201

---

**Paul Gorrell**

- 1 *First pass as prelude*
- 2 *Syntax*
- 3 *The parser*
- 4 *Right Association and Locality*
- 5 *Diagnosis and Structural Determinism*
- 6 *Summary*

8 Reanalysis and limited repair parsing: Leaping off the garden path 247

---

**Richard L. Lewis**

- 1 *Introduction*
- 2 *Reanalysis as a functional requirement*
- 3 *Four theories of reanalysis*
- 4 *Limited cue-driven repair*
- 5 *Toward a complete theory of garden path effects*
- 6 *Conclusion*

9 A computational model of recovery 287

---

**Vincenzo Lombardo**

- 1 *Introduction*
  - 2 *The grammar*
  - 3 *Elementary parsing operations*
  - 4 *Ambiguity resolution*
  - 5 *Recovery*
  - 6 *Discussion and conclusions*
- Appendix: Hierarchical Dependency Grammar*

---

**10 Parsing as incremental restructuring** 327

---

**Suzanne Stevenson**

- 1 *Introduction*
- 2 *Competition and restructuring*
- 3 *Modeling reanalysis*
- 4 *Discussion*
- 5 *Conclusions*

---

**11 Generalized monotonicity for reanalysis models** 365

---

**Patrick Sturt & Matthew W. Crocker**

- 1 *Introduction*
- 2 *What is reanalysis?*
- 3 *Accounting for constraints on reanalysis*
- 4 *The monotonicity framework*
- 5 *A general definition of monotonicity*
- 6 *Reflections on the monotonicity framework*
- 7 *Concluding remarks*

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## List of Contributors

**Markus Bader:** Institute of German Linguistics, Friedrich-Schiller-Universität Jena. Philosophische Fakultät; Ernst-Abbe-Platz 4; 07740 Jena; Germany.  
xmk@rz.uni-jena.de

**Charles Clifton, Jr.:** Department of Psychology, University of Massachusetts, Amherst. South College; Box 37130; Amherst, MA 01003-7130.  
cec@psych.umass.edu

**Matthew W. Crocker:** Centre for Cognitive Science, University of Edinburgh. 2 Buccleuch Place; Edinburgh EH8 9LW; Scotland, UK.  
mcw@cogsci.ed.ac.uk

**Marica De Vincenzi:** Institute of Psychology of the National Research Council (CNR). Viale Marx, 15; 00137 Roma; Italy.  
mkdv@kant.irmkant.rm.cnr.it

**Fernanda Ferreira:** Department of Psychology, Michigan State University. East Lansing, MI 48824-1117.  
fernanda@pilot.msu.edu

**Janet Dean Fodor:** Program in Linguistics, CUNY Graduate School and University Center. 33 West 42nd Street; New York, NY 10036.  
jfodor@email.gc.cuny.edu

**Lyn Frazier:** Department of Psychology, University of Massachusetts, Amherst. South College; Box 37130; Amherst, MA 01003-7130.

**Angela D. Friederici:** Max-Planck-Institute of Cognitive Neuroscience, Leipzig. Inselstraße 22-26; 04103 Leipzig; Germany.  
angelafr@cns.mpg.de

**Paul Gorrell:** Max-Planck-Institute of Cognitive Neuroscience, Leipzig. Inselstraße 22-26; 04103 Leipzig; Germany.  
gorrell@cns.mpg.de

**John M. Henderson:** Department of Psychology, Michigan State University.  
East Lansing, MI 48824-1117.  
john@eyelab.msu.edu

**Atsu Inoue:** Department of Economics, Kantogakuin University.  
4834 Mutsuura-Cho; Kanazawa-ku Yokohama 236; Japan.  
71051.3021@compuserve.com

**Richard L. Lewis:** Department of Computer and Information Science, The  
Ohio State University. 2015 Neil Avenue; Columbus, OH 43210-1277.  
rick@cis.ohio-state.edu

**Vincenzo Lombardo:** Dipartimento di Informatica, Centro di Scienza  
Cognitiva, Università di Torino. C.so Svizzera, 185; 10149 Torino; Italy.  
vincenzo@di.unito.it

**Suzanne Stevenson:** Department of Computer Science and Center for Cognitive  
Science (RuCCS), Rutgers University. CoRE Building, Busch Campus; New  
Brunswick, NJ 08903.  
suzanne@ruccs.rutgers.edu

**Patrick Sturt:** Centre for Cognitive Science, University of Edinburgh.  
2 Buccleuch Place; Edinburgh EH8 9LW; Scotland, UK.  
sturt@cogsci.ed.ac.uk

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## Preface

The topic addressed in this volume lies within the study of sentence processing, which is one of the major divisions of psycholinguistics. The goal has been to understand the structure and functioning of the mental mechanisms involved in sentence comprehension. Most of the experimental and theoretical work during the last twenty or thirty years has focused on ‘first-pass parsing’, the process of assigning structure to a sentence as its words are encountered, one at a time, ‘from left to right’.

One important guiding idea has been to delineate the processing mechanisms by studying where they fail. For this purpose we identify types of sentences which perceivers have trouble assigning structure to. An important class of perceptually difficult sentences are those which contain temporary ambiguities. Since the parsing mechanism cannot tell what the intended structure is, it may make an incorrect guess. Then later on in the sentence, the structure assignment process breaks down, because the later words do not fit with the incorrect structural analysis. This is called a ‘garden path’ situation. When it occurs, the parsing mechanism must somehow correct itself, and find a different analysis which is compatible with the incoming words. This reanalysis process is the subject of the research reported here.

What defines the parser’s reanalysis task is the nature of the first-pass analysis for the ambiguous word string, and its relation to the correct analysis. We need to start, then, with a clear view of which analyses are generally favored in the first-pass parse. (Note that we are presupposing here that the parser does not compute *all* analyses of an ambiguous string. Some partial parallel models of the human parsing routines have been proposed, but no current model assumes that the parser copes with ambiguity by pursuing all analyses simultaneously. Thus, at least some choices are made on-line, and reanalysis is sometimes needed.) Generalizations have been formulated to predict which analyses of an

ambiguous sentence are favored by the parser and which are overlooked. The principles that have been proposed include Minimal Attachment, Late Closure, some more recent thematically based principles, and preferences based on the frequency of occurrence of structures in the language.

These models of first-pass processing have had considerable success. Yet relatively little attention has been given to the fact that parsing difficulty is not an all-or-none matter. Many kinds of garden-path occur, but they are not all equally severe. In some cases it is easy for the parser to shift from the initial wrong analysis to the alternative correct analysis. In other cases, it is remarkably difficult. An example of a garden path that is easy to recover from is *Sandra bumped into the busboy and the waiter told her to be careful*. When the phrase *and the waiter* is encountered, it could be part of the object of *bump into*. But when the verb *told* is reached, it shows that *the waiter* must be the subject of a new clause. The structure must therefore be rearranged, yet both experimental results and intuitive judgments confirm that this is not a difficult adjustment to make. By contrast, there are garden paths that are extremely difficult to recover from, as in *The daughter of the king's son admires himself*. Here, the preferred analysis of the subject phrase is [*the daughter of [the king's son]*], which is feminine and equivalent in meaning to *the daughter of the prince*. But this analysis is gender-incompatible with the reflexive pronoun *himself* that is encountered later in the sentence. So the first-pass analysis must be restructured into [[*the daughter of the king's son*], which means the same as *the princess' son*; since it is masculine it is compatible with the reflexive. In this case, very few perceivers arrive at the necessary analysis without explicit help or conscious deliberation.

Difficulty contrasts such as this are the bread and butter of research on reanalysis. They constitute the data base for developing and testing models of how the reanalysis mechanism is designed and how it operates moment by moment. From the data base we try to extract insights about what factors determine whether a misanalysis will persist or can be easily corrected.

Factors that might be relevant include: the semantic plausibility of the analysis that must be relinquished; how great the semantic distance is between the old analysis and the new one; whether or not the prosodic contour computed on the basis of the incorrect structure also needs to be modified; and how severely working memory is already taxed when the analysis breaks down and reanalysis must be undertaken. An important consideration is the distance over which the revision must occur. As Sturt & Crocker's chapter notes, the relevant distance might be between the point at which parsing breaks down and the earlier point

at which the incorrect structure was chosen; or what matters might be the distance a phrase must move across the structural representation in order to correct the error. Structural relationships between these points could be at least as important as mere distance. And distance itself might be variously defined in terms of length in words (or syllables or morphemes), number of structural nodes, or processing time.

The methods used to establish which of these properties influence ease of reanalysis run the gamut from intuitive judgments of sentence difficulty, to high-technology methods such as measuring brain activity. In between, there are standard experimental paradigms for collecting judgments from subjects; for measuring reading times, eye movement patterns, and reaction times in secondary load tasks; and question-answering and sentence completion tasks to assess the interpretations that perceivers impose. Early work used exclusively visually presented materials, but it has become more practicable now to store and manipulate auditory stimuli, and there has been a growing interest in the study of spoken language. As yet, relatively few experimental studies of reanalysis have been conducted; intuitions tend to predominate in the early stages of research on a topic. But the current trend, as evidenced in this volume, is towards development of a pool of broadly accepted facts against which theories can be tested.

For example, one thread running through several chapters is that an adequate theory ought at least to be able to explain the well-established difference in revision difficulty between the constructions illustrated in (1) and (2).

- (1) Mary forgot her husband needed a ride yesterday.
- (2) Although Mary forgot her husband didn't seem very upset.

These particular examples are from the chapter by Lewis, but the same contrast clothed in different words is used as a yardstick by many of the contributors. In both examples, a noun phrase must be shifted from one clause to another one, but this shift is easy in (1) and difficult in (2). Other structures that readers will encounter in more than one chapter that follows include *wh*-movement questions, and subject and object relative clauses in German, as well as the venerable *The horse raced past the barn fell*.

In line with current interest in cross-linguistic comparisons, the work reported here addresses reanalysis in a range of languages: German, Italian, Japanese, and to a lesser extent Dutch, Hebrew, and Mandarin, in addition to English. To

what extent the reanalysis routines are universal, as would be expected if the parsing mechanism is innate, is not known. But certainly the examples continue to have a familiar ring about them as we move from one language to another, and the same principles can often be seen at work.

Once we have some constraining data to work with, we need to devise a model incorporating a set of mechanisms that make sense of these facts. Several kinds of model are under investigation, with very different implications for the nature of the revision process, and hence of the parsing mechanism as a whole. For example, it has to be established whether there exists a special-purpose reanalysis mechanism or whether the first-pass mechanisms are flexible enough to take on this task. One way in which they might do so is to revise an incorrect analysis by returning to the beginning of the sentence and re-parsing it, making a different structural choice at the point of ambiguity. Or it could be that the parser repeats as little of the existing analysis as possible. A parser may backtrack word by word through the current (incorrect) structure, considering alternatives as it goes, leaving earlier decisions intact. A more analytic revision mechanism would try to deduce what error was made on the first pass and how it can be corrected. It would implement the correction by repairing the structure previously assigned, presumably using routines distinct from the first-pass processes.

These are the sorts of issues that have recently taken center stage in current sentence processing research. The contributors to this volume approach the topic from different disciplinary traditions and so are able to bring to it a variety of methodologies and ways of thinking: computational, psychological, linguistic, and neurophysiological. Thus we converge on the theoretical and empirical problems with all the research tools that can be mustered.

We would like to express our thanks to the friends and colleagues who helped to put this volume together. We thank all our fellow authors for the superlative chapters they have contributed, and also for being wonderfully prompt and cooperative about practical matters. Our production editor Eva M. Fernández has earned the gratitude and admiration of everyone concerned with the preparation of the volume. Her fine editorial judgment has added value to the contents, and her calm and graceful efficiency has kept us on track for timely publication so that the ideas represented here will appear in print while they are still new and exciting. There are plans afoot to continue the debate begun in these pages, in a workshop and in further publications. The authors and editors would be pleased to hear from others who are working on this topic—or who are persuaded by this book that it would be good to do so.