On the efficient implementation of German verb placement in HPSG

Berthold Crysmann*
DFKI GmbH
Stuhlsatzenhausweg 3
D-66123 Saarbrücken
Germany
crysmann@dfki.de

Abstract

We report on significant performance gains (factor > 5.5 with ceiling effect, 14.7 without) that can be achieved by a redesign of the implementation of verb-movement in an HPSG for German. We show that the move from uniformly right branching structures to variable left/right branching is not only defensible on linguistic grounds, but also leads to a more general grammar, if the formalism does not permit empty categories.

1 Introduction

Within the context of phrase structure grammar, the proper treatment of free word order and discontinuous constituency has been a matter of much controversial debate over at least the last 15 years. The types of analysis being proposed range from GB-style verb-movement analyses, over essentially flat structures, to entirely novel concepts such as topological accounts within word order domains. Although many HPSG theoreticians nowadays assume linearisation approaches such as (Reape 94; Kathol 95), most current HPSG parsers rely on a context-free backbone for efficiency reasons. A notable exception is the Babel system (Müller 96; Müller 02), which permits direct processing of discontinuity in a way similar to the proposals by (Reape 94) and (Kathol 95).[1] Unfortunately, with respect to performance, the BABEL system cannot really compete with systems such as PET (Callmeier 00).[2] Thus, in the context of grammar implementation for real-world applications, direct processing of discontinuity is but a hypothetical option.

In this paper, I will compare two different ways of representing German clausal phrase structure, a right-branching analysis with verb movement, and a variable-branching analysis. I will argue that most arguments in favour of a uniformly right-branching phrase structure for German are flawed within the context of feature-based formalisms and, furthermore, that their implementation in trace-less grammar formalisms, such as LKB (Copestake 01) or PET is far from elegant. I will then present an alternative implementation in terms of left- and right-branching structures and show that this will not only lead to a significant reduction in grammar rules, but also will give rise to considerable performance gains.

* This work was partially financed by a BMBF grant to the project Whiteboard.

[1] (Reape 91) also reports on an implementation effort for direct parsing of discontinuity. However, the system described there does not use a large-scale grammar.

[2] Comparing the relative performance differences between PET and Babel, (Müller 02) reports that his PET grammar performed around 13 times faster than the Babel grammar, when parsing the Verbmobil corpus.

2 German word order: some basic issues

Verb placement A well-known property of German clausal structure is the variable position assumed by the finite verb: while finite verbs in complementiser-introduced subclauses appear clause-finally (modulo extraposition), their position in matrix clauses can be said to be initial (V1 or V2), typically preceded by a topicalised constituent or a wh-phrase, if any. The alternation between verb first and verb second is a matter of extraneous factors, such as sentence mood (e.g., polarity questions) or topic drop. Topological studies of German(ic) refer to the position of complementisers and matrix finite verbs as the *left sentence bracket*.

The left sentence bracket is highly selective as to the elements which can appear there: apart from complementisers, only finite verbs can be found in this position, while non-finite verbs as well as separable verb particles get "stranded" in the *right sentence bracket*. Thus, in matrix clauses, analytic tense forms such as the perfective, or even lexical items, such as separable prefix verbs, will be realised discontinuously.

Within transformational grammar, the complementary distribution of V1/V2 and overt complementisers has been taken as evidence for a movement analysis, deriving initial placement from an underlyingly head-final position. Before the advent of purely linearisation-based accounts, this perspective on German word order has had some considerable impact on HPSG analyses (Kiss & Wesche 91; Kiss 95; Netter 92; Frank 94; Oliva 92; Netter 98; Müller & Kasper 00).

Scrambling Another salient and well-known feature of German syntax is the relative freedom in which complements can appear in the so-called *Mittelfeld*, the topological field between left and right sentence bracket. Not only can complements of a single verb get easily permuted, subject to factors such as phonological weight, and given/new partitioning (Uszkoreit 87), but they can also be interspersed with all sorts of modifiers. This property has often been taken as evidence against a classical VP constituent for German (Pollard 96; Uszkoreit 87; Nerbonne 94), among others.

Scrambling of complements is not limited to the dependents of a single verb: certain verbs, such as auxiliaries, modals, and aci-verbs are said to construct *coherently*, having their own complements and those of their verbal complements interleaved. In HPSG, coherence is standardly modelled by means of argument composition (see (Hinrichs & Nakazawa 90; Kiss 94), among others). As argued by (Müller 00), probably all control and raising verbs in German permit optional coherence. Furthermore, in the coherent construction, adjuncts are systematically ambigu-

ous in that they may modify either the upstairs or the downstairs verb, subject, of course, to semantics and pragmatics.

2.1 Flat structures vs. binary branching

Starting with (Uszkoreit 87), many researchers within the phrase structure framework have taken the relative freedom of word order in the Mittelfeld as evidence to argue against a classical VP constituent and in favour of entirely flat structures, e.g., (Pollard 96; Nerbonne 94; Kasper 94). Due to the interspersal of complements and modifiers, an analysis in terms of entirely flat structures necessitates the use of relational dependencies or else a type-raising approach along the lines of (Bouma *et al.* 01). These consequences might have led researchers such as (Netter 92; Netter 98; Frank 94), among others, to stick with binary branching.

In the light of current implementations of the HPSG formalism, binary branching does indeed offer some considerable advantages: not only is it possible to formulate the Subcategorisation or Valence Principle without the need for functional or relational constraints, but it also provides a straightforward way to interleave head-complement and head-modifier structures. As demonstrated in (Müller 02), the implementation of flat structures in HPSG formalisms without relational constraints, forces one to either spell out all different permutations in the grammar rules for heads of different valency, giving rise to an unmaintainably high number of phrase structure schemata, or else to permute the valence lists by means of lexical rules. A still unsolved problem is the treatment of modifiers: as adjuncts and complements can be freely interspersed, and because the position of adjuncts in the German Mittelfeld is not fixed, or otherwise predictable, adoption of an entirely flat structure in the Mittelfeld will lead to yet another proliferation of phrase structure schemata. A possible solution to the dilemma might be to assume a type-raising approach along the lines of (Bouma *et al.* 01). However, as argued by (Müller 02), such an approach will lead to termination problems, unless lazy evaluation is used, or the number of adjuncts is artificially restricted in the lexicon. Thus, for grammar implementation targetted at systems such as LKB and PET, which do not offer either relational constraints or lazy evaluation, a binary branching analysis is the only viable option.

2.2 Right branching vs. variable branching

Among the theoretical accounts that assume a binary branching structure there appears to be overwhelming consent that German verbal projections should have a uniformly right-branching structure. While this choice seems to be guided, at least in part by the GB analyses that serve as their model, together with general aesthetic considerations, it is noteworthy, though, that with the exception of (Netter 98), all other proponents of uniform right-branching (Kiss & Wesche 91; Oliva 92; Frank 94) assume a left-branching structure to combine the initial verb with the remainder of the clause. What is common to all these approaches is that the uniformity of VP structures is achieved at the expense of postulating an empty phrase-final head whose valence information is lexically unspecified, "later" to be filled by the initial verb via some percolation mechanism.

An alternative view, discussed in brief in (Netter 98), would be to assume right branching structures if the finite verb is in final position, yet left-branching structures, if it happens to precede the Mittelfeld. As far as I am aware, this position has not been adopted by any HPSG theoretician. Cf., however, the German LS-GRAM grammar documented in (Schmidt *et al.* 96), as well as (Hoeksema 85) for a proposal along these lines in the context of Categorial Grammar.

(1) [[[[Bringt] Peter] morgen] die Ladung]
brings Peter tomorrow the cargo
'Does Peter deliver the cargo tomorrow?'

(2) [Peter [morgen [die Ladung [bringt]]]]

(Netter 98) utterly rejects this solution as linguistically unmotivated, providing the following arguments: first, representation of canonical order would require inversion of the valence lists; second, that left-branching structures would give rise to constituents which cannot otherwise be attested in the syntax of German. This latter point appears rather weak to me, given that there is hardly any evidence for a classical VP constituent in German anyway (Uszkoreit 87; Pollard 96; Nerbonne 94). The third argument Netter provides relates to the reversal of tree-structural c-command relations, which he takes as decisive for determining scope. (Müller 02) essentially replicates this argument, stating that the relative scope of modifiers in German is standardly determined from left to right.

(3) a. Peter kommt oft vergeblich.
Peter comes often in vain
'Peter comes often in vain.'

b. Peter kommt vergeblich oft.
Peter comes in vain often
'It is in vain that Peter comes often.'

Of course, as (Müller 02) adds in a footnote, the validity of this argument depends entirely on what the appropriate representation should be to determine order-sensitive scope, i.e., tree structure or surface order.[3] Within current HPSG theory, however, the notion of c-command does not play any significant role (Pollard & Sag 94). With most implementations of the HPSG formalism traversal of (non-local) tree structure is dispreferred, as it is quite costly. Furthermore, the formalism provides much more flexible tools than bare phrase structure to capture the relevant relations, most notably feature percolation.

On a more general ground we may ask, whether the postulated left-to-right rule is really a hard constraint of the grammar, or merely a performance preference, however strong. Once we provide a proper context, it appears that this "rule" can easily be overridden:

(4) Da muß es schon erhebliche Probleme mit der
there must it already severe problems with the
Ausrüstung gegeben haben, da wegen schlechten
equipment given have since because.of bad
Wetters ein Reinhold Messmer niemals aufgäbe.
weather a R. M. never would give up
'There must have been severe problems with the equipment, since someone like Reinhold Messmer would never give up just because of the bad weather.'

[3] A similar reservation could be formulated for the argument concerning canonical order, even more so, as it is far from evident how the competing factors shaping constituent order in the German Mittelfeld should be amenable to a formal treatment without soft constraints (Uszkoreit 87).

The preferred, and probably only reading regarding the relative scope of *wegen* 'because' and *niemals* 'never' has the former within the scope of the latter, contrary to what linear order or a right-branching tree structure would suggest.

If, however, modifier scope was a direct function of tree-structural position it will be far from trivial, within a monotonic formalism such as HPSG, to overrule the syntactic constraint on scoping by means of contextual factors.

A similar argument can be built up from the attachment properties of intersective modifiers: If we consider the coherent construction, we find that intersective modifiers can modify either of the verbs in the verbal cluster:

(5) daß ohne Regenschirm ein Vater seine Kinder aus
that without umbrella a father his children out
dem Haus gehen ließ
the house go let

'that a father let his children leave the house without umbrellas.'

What is noteworthy about the example above is that the PP *ohne Regenschirm* may, and, given world knowledge, must be interpreted as a modifier of the downstairs verb. However, due to the intervention of the upstairs verb's subject, we cannot provide a binary-branching tree structure where the subject c-commands the upstairs *ließ*, but the PP would only c-command the downstairs *gehen*. If tree structure was indeed the representation where the semantics of modification got read off, we would not be able to derive any narrow scope readings of verbal modifiers, once these get scrambled over an upstairs argument. Thus, following (Kiss 95), some semantic percolation mechanism would be required here, in addition to tree structure, in order to derive the correct modifier attachment.

Thus, if the semantics of modification cannot be determined on the basis of tree structure alone, we can conclude that the only empirical argument against left-branching in German clausal structure finally turns out to be undermotivated.

3 An experiment

Having established so far that the uniformly right-branching analysis is not linguistically superior to one that uses asymmetric left- and right-branching structures, I will now proceed towards an evaluation of these two approaches with respect to their efficiency in the context of a large-scale computational grammar of German. I will show that a variable left- and right-branching approach provides for a more concise grammar specification than the symmetric analysis, and that significant performance gains will ensue, without any loss in linguistic coverage.

3.1 The grammars

3.1.1 Uniform right-branching

The baseline of our experiment is the competence grammar initially developed by (Müller & Kasper 00) in the context of the Verbmobil project. Owing to this background, it is probably safe to say that it is primarily designed for spoken language processing. Thus, no advantage is taken of punctuation marks typically found in written text. Since 2000, Müller has further extended this grammar, both on the lexical and the syntactic level. Furthermore, he ported the Verbmobil grammar, originally written for the PAGE system (Uszkoreit *et al.* 94), to LKB/PET. The specific version of that grammar used in this experiment dates from May 2002.

The grammar consists exclusively of binary and unary rules. Different order of complements in the Mittelfeld is taken care of by permutation of the SUBCAT list, a task carried out by a set of lexical rules. The treatment of verb placement in this grammar differs drastically from Müller's own theoretical workings, as well as from his implemented BABEL grammar; see (Müller 02) for a detailed comparison. In the LKB/PET implementation, he adopts a head movement approach in the vein of (Kiss & Wesche 91; Frank 94; Oliva 92). Due to the ban on traces in LKB/PET, he uses unary rules to simulate a verbal trace in final position. The SUBCAT list of the empty verb so introduced is highly underspecified, minimally containing a restriction on the maximal number of arguments (5), encoded as types. SUBCAT is passed up the tree by means of the head feature v1, which gets identified with the local value of the initial verb after all complements have been saturated.

The implementation of a trace by means of a unary projection makes it necessary to spell out every possible relation a sentence-final constituent, a complement, a modifier, or the verb cluster, could bear w.r.t. the initial verb. As German is a free word order language it is actually hard to predict what kind of element will appear finally, in case there is no right sentence bracket, i.e., a verb cluster. Thus, we observe a proliferation of very specialised epsilon-rules, e.g. for complements, for adjuncts, several rules for the verb-cluster (which perform, inter alia, the interleaving of SUBCAT lists) etc.[4]

Given that, under a uniformly right-branching analysis, the eps-rules must be able to apply to non-verbal material, during parsing, these rules also apply to non-final constituents, filling the chart with mostly useless hypotheses. Worse, as subcategorisation information of the hypothesised empty verb is completely underspecified, they can combine with other constituents to their left (and right).

Turning to the issue of order-sensitive scope, note that Müller's LKB/PET implementation does not exploit this for semantics construction. Thus, irrespective of linear order, or rather: c-command relations, both scopings are always available. If adjunct extraction is involved, i.e. if a modifier appears in the *Vorfeld*, a topic position, the grammar assigns two different syntactic analyses: one where the modifier in the Mittelfeld takes syntactic scope over the trace of the extracted adjunct, and one where the trace takes scope over the modifier in the Mittelfeld. Again, the MRS representations associated with these tree structures are completely identical. From the point of view of the semantic representations obtained, one may call this a spurious ambiguity.

To conclude, the implemented version of a uniformly head-final analysis is neither particularly elegant, nor does it appear restrictive enough to warrant efficient processing. Furthermore, the potential gain that uniform right-branching might bear in terms of modifier scope, is only

[4] In formalisms that do not permit empty terminals (=traces) the effect of trace insertion can be simulated by means of unary non-headed productions applying to a constituent adjacent to the hypothesised position of the empty element. These rules must be differentiated as to the syntacto-semantic relation the daughter bears w.r.t. the simulated verb trace.

hypothetical, as it does not have an impact on the semantic representations derived. A similar observation can be made regarding canonical order, owing to the fact that his LKB/PET grammar does not specify any restriction on the relative order of complements and/or adjuncts in the Mittelfeld.

3.1.2 Variable left- and right-branching

The revised grammar, which I will briefly describe here, was derived from Müller's original LKB/PET grammar during the second half of 2002. Thus, apart from the changes reported on here, both grammars share a considerable code base.

As to the linguistic analysis, I have chosen to stick with the "movement" analysis whenever this was necessary to relate discontinuous elements of the cluster, and the domain of application for the eps-rule could be restricted. Thus, stranded verb particles and overt final verb-cluster are still related to the initial finite verb via the original percolation mechanism. For verb-initial structures without a right sentence bracket, however, I assume a left branching structure, permitting direct local saturation of the finite verb's arguments. Thus, the current implementation removes the percolation mechanism in exactly those cases where it is both unnecessary, and highly costly. As a side effect, this reduces the number of rules for verb movement from 24 to 6.

3.2 Experimental setup

All test runs reported here were performed on the same hardware platform, a 2.2 GHz Pentium 4 machine, running Linux v2.4.20. In order to be able to carry out the experiments on comparatively large corpora, it was necessary to restrict overall parsing times: therefore an upper bound of 70,000 was set regarding the number of passive edges used during each individual parse. If this upper bound is reached, the PET parser flags that the search space could not be explored exhaustively, but nevertheless delivers any results obtained so far. The performance on each test run was recorded with the [incr tsdb()] tool (Oepen & Flickinger 98).

Both grammars have been set up to use the same optimisations in the PET parser, most notably quick check (Kiefer *et al.* 99; Callmeier 00): For the present experiment, quick check paths were established for each grammar individually, using the same set of 290 sentences from an unrelated domain (tourist information).

Although the revised variable-branching grammar derives genetically from the Müller LKB/PET grammar, the changes involved are nevertheless considerable. Thus, to ensure that performance gains are not simply due to a loss in restrictiveness and/or the set of phenomena being covered, we conducted a regression test on the manually constructed TSNLP test suite, measuring lexical ambiguity, coverage and overgeneration. With respect to the regression test, both grammars displayed the same degree of lexical ambiguity (3.26 readings per lexical item). Similarly, the figures for coverage and overgeneration are comparable, giving identical values for overgeneration (7.3%), as well as a slight improvement with respect to coverage (old: 73.8%; revised: 74%).

As test corpus for measuring the performance gains, we have chosen a subset of the Verbmobil corpus, viz. VM CD-15, a test suite of moderate complexity, with an average sentence length of 5.18 words. The Verbmobil corpus is a spoken language corpus for which the original grammar had been optimised.

3.3 Results

The results of the experiment are summarised in Tables 1 and 2.

	Cov (%)	>70000 (%)	Time (s)	Tasks
Old	78.0	16.1	2.41	47512
Rev	85.2	2.5	0.45	8548
Factor			5.29	5.56

Table 1: Verbmobil CD 15 (all parses)

The first table presents the coverage and performance measures achieved by the individual grammars on the entire set of 2233 sentences, regardless of whether the search space could be fully explored within the given limit of 70000 passive edges, or not. On this direct comparison, the revised grammar not only yields a speed-up by a factor greater than 5, both in parse time and the number of tasks, but it also clearly achieves better coverage. This is probably partly related to a better use of available resources: in only 2.5% of the test items was it the case that the search space could not be fully explored within the given limit, whereas with the original grammar, this percentage went up to 16.1%. Accordingly the average sentence length of exhaustively parsed sentences is significantly higher with the revised grammar (4.9 vs. 5.18 words), when compared to that of the original (3.9 words on average).

Although the relative performance gains are already quite good on this direct comparison, it is clear that the original grammar benefits quite strongly from a ceiling effect here: on 16.1% of the entire test suite, performance measures with this grammar cannot possibly get any worse than the time it takes to build 70000 passive edges.

	Time (s)	Tasks
Old	0.67	12988
Rev	0.04	884
Factor	16.4	14.7

Table 2: Verbmobil CD 15 (exhaustive parses)

Thus, in order to neutralise this ceiling effect, we can restrict the comparison to exactly those sentences which could be fully analysed by both of the grammars involved. Under this condition, the performance factor increases from about 5.5 to 14.7 (tasks).

3.4 Conclusion

I have argued in this paper that the adoption of an asymmetric left- and right-branching analysis of German clausal structure is to be preferred over a seemingly more elegant uniformly right-branching one. I have argued that the asymmetric treatment is not only defensible on linguistic grounds, but that it also provides for a more concise specification and much more efficient use of resources during run-time.

We believe that the signicant reduction of local ambiguity during parsing will make it feasible to apply approximation techniques (Kiefer & Krieger 00) to the grammar, a perspective to be explored in the near future.

The promising results reported here have also been confirmed on Verbmobil test suites of increased complexity (VM-CD1, 9 words/sentence). It appears though that the inefficiency of the original grammar defines an upper bound on the sentence length beyond which no meaningful results can be obtained, due to space exhaustion. We therefore plan to make use of ambiguity packing (Oepen & Carroll 00), which makes more efficient use of the parse chart, to investigate how each of the two grammars will scale up, once average sentence length is increased.

References

(Bouma *et al.* 01) Gosse Bouma, Rob Malouf, and Ivan A. Sag. Satisfying constraints on extraction and adjunction. *Natural Language and Linguistic Theory*, 19(1):1–65, 2001.

(Callmeier 00) Ulrich Callmeier. PET — a platform for experimentation with efficient HPSG processing techniques. *Journal of Natural Language Engineering*, 6(1):99–108, 2000.

(Copestake 01) Ann Copestake. *Implementing Typed Feature Structure Grammars*. CSLI Publications, Stanford, 2001.

(Frank 94) Annette Frank. Verb second by lexical rule or by underspecification. Arbeitsberichte des Sonderforschungsbereichs 340 43, IMS, Stuttgart, 1994.

(Hinrichs & Nakazawa 90) E. Hinrichs and T. Nakazawa. Subcategorization and VP structure in German. In Hughes, Shaun, and Salmons, editors, *Proceedings of the Third Symposium on Germanic Linguistics*, Amsterdam, 1990. Benjamins.

(Hoeksema 85) Jack Hoeksema. Wazdat? — contracted forms and verb second in Dutch. In J. Farlund, editor, *Germanic Linguistics*, pages 112–124. IULC, 1985.

(Kasper 94) Robert T. Kasper. Adjuncts in the mittelfeld. In John Nerbonne, Klaus Netter, and Carl Pollard, editors, *German in Head-Driven Phrase Structure Grammar*, number 46 in Lecture Notes, pages 39–69. CSLI Publications, Stanford University, 1994.

(Kathol 95) Andreas Kathol. *Linearization-Based German Syntax*. Unpublished PhD thesis, Ohio State University, 1995.

(Kiefer & Krieger 00) Bernd Kiefer and Hans-Ulrich Krieger. A context-free approximation of Head-Driven Phrase Structure Grammar. In *Proceedings of the 6th International Workshop on Parsing Technologies (IWPT 2000)*, pages 135–146, 2000.

(Kiefer *et al.* 99) Bernd Kiefer, Hans-Ulrich Krieger, John Carroll, and Rob Malouf. A bag of useful techniques for efficient and robust parsing. In *Proceedings of the 37th Annual Meeting of the Association for Computational Linguistics (ACL-99)*, pages 473–480, 1999.

(Kiss & Wesche 91) Tibor Kiss and Birgit Wesche. Verb order and head movement. In Otthein Herzog and Claus-Rolf Rollinger, editors, *Text Understanding in LILOG*, number 546 in Lecture Notes in Artificial Intelligence, pages 216–240. Springer-Verlag, Berlin, 1991.

(Kiss 94) Tibor Kiss. Obligatory coherence: The structure of german modal verb constructions. In John Nerbonne, Klaus Netter, and Carl Pollard, editors, *German in Head-Driven Phrase Structure Grammar*, number 46 in Lecture Notes, pages 71–107. CSLI Publications, Stanford University, 1994.

(Kiss 95) Tibor Kiss. *Infinite Komplementation. Neue Studien zum deutschen Verbum infinitum*. Linguistische Arbeiten. Niemeyer, Tübingen, 1995.

(Müller & Kasper 00) Stefan Müller and Walter Kasper. HPSG analysis of German. In Wolfgang Wahlster, editor, *Verbmobil: Foundations of Speech-to-Speech Translation*, pages 238–253. Springer, Berlin, 2000.

(Müller 96) Stefan Müller. The babel-system: An HPSG Prolog implementation. In *Proceedings of the 4th International Conference on the Practical Application of Prolog*, pages 263–277, London, 1996.

(Müller 00) Stefan Müller. *Complex Predicates: Verbal Complexes, Resultative Constructions, and Particle Verbs in German*. Habilitationsschrift, University of the Saarland, Saarbrücken, 2000.

(Müller 02) Stefan Müller. Continuous or discontinuous constituents? A comparison between syntactic analyses for constituent order and their processing systems. to appear in *Research on Language and Computation*, 2002.

(Nerbonne 94) John Nerbonne. Partial verb phrases and spurious ambiguities. In John Nerbonne, Klaus Netter, and Carl Pollard, editors, *German in Head-Driven Phrase Structure Grammar*, number 46 in Lecture Notes, pages 109–150. CSLI Publications, Stanford University, 1994.

(Netter 92) Klaus Netter. On non-head non-movement. In Günter Görz, editor, *KONVENS '92*, Reihe Informatik aktuell, pages 218–227. Springer-Verlag, Berlin, 1992.

(Netter 98) Klaus Netter. *Functional Categories in an HPSG for German*. Number 3 in Saarbrücken Dissertations in Computational Linguistics and Language Technology. DFKI & Universität des Saarlandes, Saarbrücken, 1998.

(Oepen & Carroll 00) Stephan Oepen and John Carroll. Ambiguity packing in constraint-based parsing - practical results. In *Proceedings of the 1st Conference of the North American Chapter of the Association for Computational Linguistics*, pages 162–169, Seattle, WA, 2000.

(Oepen & Flickinger 98) Stephan Oepen and Dan Flickinger. Towards systematic grammar profiling. test suite technology ten years after. *Journal of Computer Speech and Language*, 12:411–436, 1998.

(Oliva 92) Karel Oliva. The proper treatment of word order in HPSG. In *Proceedings of Coling 92*, pages 184–190, Nantes, 1992.

(Pollard & Sag 94) Carl Pollard and Ivan Sag. *Head–Driven Phrase Structure Grammar*. CSLI and University of Chicago Press, Stanford, 1994.

(Pollard 96) Carl Pollard. On head non-movement. In Harry Bunt and Arthur van Horck, editors, *Discontinuous Constituency*, pages 279–305. Mouton de Gruyter, Berlin, 1996.

(Reape 91) Mike Reape. Word order variation in Germanic and parsing. Technical report, DYANA, 1991.

(Reape 94) Mike Reape. Domain union and word order variation in German. In John Nerbonne, Klaus Netter, and Carl Pollard, editors, *German in Head-Driven Phrase Structure Grammar*, number 46 in Lecture Notes, pages 151–197. CSLI Publications, Stanford University, 1994.

(Schmidt *et al.* 96) P. Schmidt, S. Rieder, and A. Theofilidis. Final documentation of the German LSGRAM lingware. Technical report, IAI, Saarbrücken, 1996.

(Uszkoreit 87) Hans Uszkoreit. *Word Order and Constituent Structure in German*. CSLI Publications, Stanford, 1987.

(Uszkoreit *et al.* 94) Hans Uszkoreit, Rolf Backofen, Stephan Busemann, Abdel Kader Diagne, Elizabeth Hinkelman, Walter Kasper, Bernd Kiefer, Hans-Ulrich Krieger, Klaus Netter, Günter Neumann, Stephan Oepen, and Stephen P. Spackman. Disco - an hpsg-based nlp system and its application for appointment scheduling. In *Proceedings of the 15th International Conference on Computational Linguistics (COLING'94), August 5-9*, volume 1, pages 436–440, Kyoto, Japan, 1994.