We will start with a review of some facts about Finnish.

The conventional wisdom about Finnish word order is that it is free because the language has a rich inflectional system. The syntactic role that a given constituent plays in the sentence is often uniquely determined by its form. It is not necessary for comprehension to mark it with position. The standard reference book on Finnish gives only one general directive concerning word order: "One should avoid ordering words in a way that may lead to a misunderstanding or give rise to distracting associations in the mind of the hearer or the reader" (Ikola, 1968:301). This conversational maxim suggests that syntax itself places no constraints on word order. This is seemingly true for major constituents at sentence level. For example, all the six possible permutations of the three words *Esa* (Sg Nom), *luki* 'read' (Past Sg 3rd), and *kirjan* 'book' (Sg Gen) are grammatical sentences in Finnish. Only the last of the six sounds a bit strange in isolation, but one can imagine contexts where it might fit.

(1) *Esa luki kirjan.*  *Kirjan Esa luki.*  *Luki Esa kirjan.*

*Esa kirjan luki.*  *Kirjan luki Esa.*  *?Luki Kirjan Esa.*

Esa read a/the book.

The looseness of ordering constraints on sentence level does not extend to all syntactic categories. The order of constituents in a noun phrase, for example, is almost as fixed in Finnish as it is in English. There are constraints on sentence level as well. They just happen not to rule out any of the permutations in a case as simple as (1). The fact that one can distinguish the subject from the object in these examples by looking at the case endings is certainly not unrelated to the fact that the language allows the order to vary, but the two properties do not always go together.

It would be a mistake to conclude from this data that the order does not matter. In fact it matters a great deal. Although the examples in (1) are equivalent in the sense that they express the same proposition, it is obvious to anyone who speaks the language that these sentences are generally not interchangeable. In particular discourse situations some sound
more natural than others. There are also intonational differences. We leave out the last example because we are not sure of its status. The remaining five seem to fall naturally into two groups. We have tried to find translations that have roughly the same conversational function in English as their counterparts in Finnish.

(2)  NEUTRAL:  (a)  Esa luki kirjan.  
(b)  Kirjan luki Esa.  

CONTRASTIVE:  (c)  ESA kirjan luki.  
(d)  KIRJAN Esa luki.  
(e)  LUKI Esa kirjan.  

Esa read a book.  The book was read by Esa.  
It was ESA who read the book.  It was a BOOK that Esa read.  
Esa DID read a book.

The capitals here indicate that the contrastive sentences seem to require an emphatic stress and intonation peak on their first constituent. The presence and the location of emphasis in (2c–e) is made obligatory by word order. These sentences sound distinctly un-Finnish if one emphasizes some noninitial constituent:  ?Esa KIRJAN luki.  ?Esa kirjan LUKI. (Heinämäki, 1980). In that respect (2a,b) are different. They allow optional emphasis on any constituent: e.g.,  ESA luki kirjan, Kirjan LUKI Esa, Esa luki KIRJAN, etc.

There are also subtler differences. Although the examples in (2a,b) are synonymous, and in some intuitive sense neutral, they address different topics. Sentence (2a) would be a natural answer to the question What did Esa read?; (2b) would sound right only as an answer to Who read the book? In contexts where there is no recent mention of either Esa or the book, for example, in answering a question like What happened?, (2a) sounds more natural.

In Finnish word order and emphasis obviously encode distinctions that in English are associated with other sorts of structural differences. The alternation between the SVO and OVS orders in (2a) and (2b) has intuitively very much the same feel to it as the difference between active and passive in English. The two sentences express the same fact but differ with respect to how that fact is viewed, whether it is seen as a fact about Esa or as a fact about the book. We use the term topic to describe the discourse function of the first constituent in (2a,b). Another word for the same concept is theme.1

The conclusion that we draw from examples of this sort is that it would not be very interesting to write a grammar for Finnish that postulates some fixed underlying order from which various surface orders are generated by means of an uninterpreted scrambling transformation. It would be equally unilluminating to account for the variation by means of numerous phrase structure rules even if they are derived from a small set
of basic rules in a systematic way. In either case one is left with the task of indicating how the ultimate surface configurations differ from one another with regard to topic, emphasis, and other such matters. It is not difficult to produce a grammar that generates all the possible orders. It is more challenging to try to explain what the different configurations express.

Discourse functions like topic are notoriously fuzzy, but they are more relevant for word order in Finnish than structural categories, such as NP, V, VP, or traditional syntactic functions, subject and object and the like. The observations we have made here are hardly new, but we are not familiar with any grammars of Finnish that successfully integrate the description of word order phenomena with the rest of syntax. The problem is particularly difficult in standard transformational grammar. In that framework basic syntactic functions are associated with fixed positions in the underlying phrase structure trees. There is no natural way to assign discourse roles, because they depend not on the application of particular transformations but on the resulting surface configuration.

It seems to us that an adequate solution should have two features. First of all, it should have a system of syntactic representation that does not assign syntactic roles exclusively on the basis of structural configurations. Second, it should provide a way to constrain configuration variation by statements that mention discourse roles in addition to principles that refer to syntactic functions and categorial properties of constituents. The framework we use has been described in a number of papers by Martin Kay under the label functional grammar. We refer to it here as functional unification grammar in order to avoid confusion with other uses of the old term and because unification plays a central role in our grammar.

The organization of this paper is as follows. First, we present some data from Finnish with an informal account of word order phenomena. Then comes a formal grammar for the same data written in the style and notation discussed in Kay’s paper “Parsing in functional unification grammar” (in this volume). We illustrate the workings of the grammar by showing some output from a generator that takes as input a functional description of a sentence and produces from it every realization of the sentence that the grammar allows. Finally, we describe briefly how one turns the generator into a parser that does the reverse operation, that is, a machine that produces for any input sentence all and only the functional descriptions allowed by the grammar.

8.1. Data

Let us start by looking at the data more closely. We concentrate here on simple transitive sentences and discuss the positioning of subject and
object, adverbs, and auxiliary verbs. There are of course many other types of sentences in Finnish, but the principles that determine word order do not vary significantly from one type to another.

8.1.1. Topic

The data in (2) seem to pattern as follows. Each sentence has a topic: some nominal constituent that is located immediately in front of the finite verb. In a simple transitive sentence the subject and the object noun phrase are equally eligible to serve as topics. Because it is more common in Finnish for subjects to be topics than for objects, the SVO order

(2a) *Esa luki kirjan.* Esa read the book

is statistically more frequent than the OVS order²

(2b) *Kirjan luki Esa.* The book was read by Esa.

We see no reason to assume that either one of the two sentences should be syntactically derived from the other or from some canonical underlying configuration by changing the order. It would certainly be mistaken to argue that the OVS order must be transformationally derived from SVO because it is less frequent. This would be analogous to saying that there must be a passive transformation in English because active sentences are more common than passive.

Nevertheless, a grammar of Finnish would be incomplete if it did not in some manner give preference to the SVO order. We do this by designating subject as the default topic of this construction. There are obviously many discourse contexts that are neutral with regard to the choice of topic. For example, if one is using the sentence *Esa read the book* to answer the question *What happened yesterday?*, there need not be any reason at all to take Esa as topic except a bias in the language itself. It is in such cases where default assignments play a role in determining word order. By making subject be the default topic, we give the SVO order preference over OVS whenever the context allows it. We do not assume that there is a single underlying order or an underlying pairing of syntactic and discourse roles.

It is important to recognize in this context that the assignment of default topic depends on particular constructions. For example, in existential sentences (e.g., *There are books on the table*) the subject is not the default topic in Finnish (or English) and its natural place is at the end of the sentence rather than in the beginning.

8.1.2. Contrast

In addition to a topic, a sentence may have an initial emphatic constituent that plays a different role. For the lack of a better term, we call it contrast.
Contrasted focus (Chafe, 1976) and initial focus are other names for the same function.

(2) (c) *ESA kirjan luki.* It was ESA who read the book.
(d) *KIRJAN Esa luki.* It was the BOOK that Esa read.
(e) *LUKI Esa kirjan.* Esa DID read the book.

In some contexts it might be better to translate the first two sentences in English as *topicalized* constructions: ‘By ESA the book was read’, ‘The BOOK Esa read’. The initial constituents in these sentences play a conversational role that is very similar to the focus NP in the cleft construction.

Like the corresponding English sentences, (2c) and (2d) implicate that the contrasted NP picks out one individual from some contextually determined set of alternatives. It does not introduce a new individual to the discourse. There is an implication that the referent and the set of other possible choices are already part of the context of discourse. By saying that the sentence is true of the particular individual, (2c) and (2d) imply it is not true of the others. For example, (2c) implicates that, of the people under consideration, only Esa read the book. (2d) suggests that Esa read the book and not any of the other things.

It is not clear how this account should be extended to cover (2e), where the emphasis is on the verb.3 The alternatives here consist of Esa either reading or not reading the book. Sentence (2e) is an emphatic way of saying that the former is the true one. The appearance of the finite verb in the contrast position is always a mark of disagreement. It implies that the addressee holds the opposite view.

Because of the implied contrast, sentences of this sort are commonly used in rebuttals. For example, (2d) could be uttered to deny a preceding assertion that Esa read something other than the book. It could also be used to continue a sentence like *Esa had a magazine and a book*, with the implication that Esa did not read the magazine.

Note that in a framework that postulates SVO as the underlying word order for Finnish, it would not be possible to attribute the parallel contrastive interpretations of (2c) and (2d) to any particular transformation. The SOV order in (2c) would have to be generated by a rule that moves the verb to the end of the sentence, the OSV order of (2d) by a rule that moves the object to the beginning. This is essentially what is proposed by Hakulinen and Karlsson (1979:308–9). They use the term *Topicalization* for the preposing rule and *Verb Movement* for the postponing rule. We regard this as an unfortunate choice of terminology, because it doesn’t indicate that the discourse role associated with the first position in these cases is one of contrast. What intuitively is the topic (theme) of the sentence is designated not by the initial constituent but by the immediately following one. We will discuss the question of verb placement shortly.
It is interesting in this connection that the contrasted constituent can also take on a number of clitics that occur only in sentence-initial position. Of these the most important one is the question clitic-ko shown in (3).

(3) (a) ESAKO kirjan luki? Was it ESA who read the book?
(b) KIRJANKO Esa luki? Was it a BOOK that Esa read?
(c) LUKIKO Esa kirjan? Did Esa read a book?

Only the last one is a neutral yes/no question; the others carry the same implication as their declarative counterparts. They present the referent of the initial NP as a member of some contextually determined range of alternatives and implicate the sentence is true only of one of them. Because the same order of constituents exists even without the question particle, there is no reason to assume that there is a special fronting rule for yes/no questions in Finnish. This also applies to wh-questions:

(4) (a) KUKO luki kirjan? Who read a book?
(b) KUKA kirjan luki? Who was it who read the book?
(c) MINKÄ Esa luki? What did Esa read?

In all of these cases the same word order can be found in noninterrogative sentences.

8.1.3. Nonemphatic contrast

Sentential adverbs, such as eilen “yesterday” and kotona “at home,” and sangyssa “in bed,” can occur anywhere except between the verb and topic.

(5) (a) Esa luki kirjan eilen. Esa read the book yesterday.
(b) Esa luki eilen kirjan. Esa read the book yesterday.
(c) ??Esa eilen luki kirjan.
(d) Eilen Esa luki kirjan. Yesterday Esa read a book.

As the last example indicates, they can also occur in contrast position preceding topic without necessarily being emphatic. In principle a sentence can contain any number of such adverbs and they can occur alone scattered in allowable adverb positions or in groups of two or more, as in (6).

(6) (a) Eilen Esa luki kotona kirjan sangyssa. Yesterday Esa read at home a book in bed.
(b) Esa luki eilen kotona sangyssa kirjan.

The prosodic pattern in sentences like (5d) and (6a) is sensitive to the position of the verb. If the verb is nonfinal, as in these examples, the contrasted adverb need not carry any special emphasis. But if the verb is moved to the end of the sentence, the adverb becomes emphatic and the prosodic pattern changes accordingly.

(7) EILEN Esa kirjan luki. It was YESTERDAY that Esa read the book.
Emphatic contrast signals that (7) is a rebuttal of a preceding contrary statement. Emphasis on the contrasted constituent and the final position of the verb are a sign of disagreement.

The question now arises whether examples like (2c) and (2d) have initial emphasis because they begin with a contrasted element or because they end with the verb. If it is the latter, then the sentences in (8) should be just as good as those in (9).

(8) (a) Kirjan Esa luki eilen. The BOOK Esa read yesterday.
    (b) ?Esa kirjan luki eilen. It was Esa who read the book yesterday.

(9) (a) KIRJAN Esa eilen luki. The BOOK Esa read yesterday.
    (b) ESA kirjan eilen luki. It was ESA who read the book yesterday.

The contrasted element clearly carries obligatory emphasis in (9), where the verb is final. All of the verb-final cases, (9a), (9b), and (7), are sentences that one would say only to contradict another speaker. Of the two examples in (8), where the verb is nonfinal, at least the former could be uttered without special emphasis on the first noun phrase, and it need not be a case of disagreement. It seems that the difference between emphatic and nonemphatic contrast is a matter of degree. The more emphasis there is, the stronger the suggestion that the statement would become false if the contrasted term were replaced by something else, say the term just mentioned by the other speaker.

8.1.4. Final position

There is a tendency in Finnish as well as English for heavy constituents to gravitate to the end of the sentence.

(10) Esa luki eilen Chomskyn uuden kirjan Hallitsemisesta ja Sitomisesta.
    Esa read yesterday Chomsky’s new book about Government and Binding.

The end is also the unmarked position for constituents that introduce some new individual or put some already mentioned character to a surprising new relation. Heavy phrases that contain a lot of descriptive material typically also introduce new things to the discourse. They could be expected to come at the end for that reason alone.

Although final noun phrases do not necessarily designate novel individuals, that is a clear preference for new things to be introduced last. This tendency is exploited in Finnish to make up for the lack of definite and indefinite articles. Because a reference to a new entity would appear in the final position, one way to mark something as old is not to mention it there. Although the two sentences in (11) are actually both ambiguous from the point of view of English, it is likely that ‘the book’ is the correct translation in (11a) and ‘a book’ in (11b).

(11) (a) Esa luki kirjan eilen. Esa read the book yesterday.
    (b) Esa luki eilen kirjan. Esa read a book yesterday.
8.1.5. Order of verbs

There are two auxiliaries in Finnish: the negative verb *ei*, which is inflected for person and number but not for tense, and the verb *ole* for perfect tense. The latter is similar to *have* in English. *Ei* and *ole* control the form of the next element in the verbal chain very much as English auxiliaries do. The negative verb requires that next verb to be either a present negated form or a past participle. The choice depends on whether the tense of the sentence is present or past. The perfect auxiliary requires that the main verb be a past participle. A sentence may thus have three inflected verbs.

(12) *Esa ei ole lukenut kirja.* Esa hasn’t read the book.

The order is fixed: Negative < Perfect < Main Verb, but the elements do not have to be contiguous. The chain may be broken by intervening adverbs or noun phrases as in (13).

(13) *Ei Esa ole kirjaa lukenut.* No, Esa hasn’t read the book.

Except for the fact that *ei* and *ole* often do occur next to each other, there does not seem to be any motivation in Finnish to regard the string *ei ole* as a constituent analogous to Aux in English. There also does not seem to be any evidence for a structure involving stacked VPs or VVs. There is no phenomenon in Finnish similar to VP-deletion in English. Other elements in the sentence can freely intervene between *ei ole* and *lukenut* as long as their order remains the same. We assume that the structure is flat and consists maximally of three elements: FiniteVerb, TensedVerb, and MainVerb. The negative verb can only be FiniteVerb. If that role is played by *ole*, it is also TensedVerb at the same time, but it is never MainVerb. Anything that can serve as MainVerb can also play the other two roles. Thus in a simple sentence the same verb is simultaneously FiniteVerb, TensedVerb, and MainVerb.

It is interesting to note that it is the main verb rather than the negative or perfect auxiliary that has to appear in the final position in sentences such as (14) that show emphatic contrast.

(14) (a) *EILEN Esa oli kirjan lukenut.* It was YESTERDAY that Esa had read the book.

(b) *KIRJAA Esa ei eilen lukenut.* It was the BOOK that Esa didn’t read yesterday.

8.1.6. Focus of negation

One important feature of negative sentences is that the focus of the negation may be marked by emphasis. This is the case also when the negative verb itself is in the initial contrasted position, as in (15). In that position
it carries emphasis only in the absence of any marked focus, as in (15a). If the sentence contains an emphasis peak to mark the focus of negation (15b–d), the negative verb itself is unstressed regardless of its position. The data here suggest that the focus peak can be anywhere in the sentence, but actually there are restrictions.4

(15) (a) El Esa kirjaa lukenu. No, Esa DIDN’t read a book.
(b) Ei ESA kirjaa lukenu. No, ESA didn’t read the book.
(c) Ei Esa KIRJAA lukenu. No, Esa didn’t read the BOOK.
(d) Ei Esa kirjaa LUKENUT. No, Esa didn’t READ the book.

It is important for the semantics to distinguish the cases in (15) from those in (16), where the sentence does contain negation but the contrast is on some other constituent.

(16) (a) ESA kirjaa ei lukenu. ESA is the one who didn’t read the book.
(b) KIRJAA Esa ei lukenu. The BOOK Esa didn’t read.

One indication of the difference is that (16b) could be used in a dialogue like (17), where (15c) could not appear.

(17) Speaker A: Esa ei lukenu lehtea. Esa didn’t read the paper.
Speaker B: KIRJAA Esa ei lukenu. The BOOK Esa didn’t read.
(*Ei Esa KIRJAA lukenu.) (No, Esa didn’t read the BOOK.)

In this context (15c) would be out of place. Sentences with contrasted negation are appropriate responses only to affirmative statements. Sentence (15c) could be used as a partial denial of (18); so could (16b).

(18) Esa luki kirjan ja lehden. Esa read the book and the paper.

In a context like this one, (15c) and (16b) are equally appropriate. They both entail that (18) is false, but only the former signals that it is in direct conflict with the preceding statement.

Because initial negation is in many ways a special case, it may be a mistake to view it as contrast. A better analysis remains to be worked out.

8.1.7. Crossing clause boundaries

Objects and adverbs from infinitival and participial clauses can also appear in the beginning of the main sentence as topics or in the contrast position, but they do not play any syntactic role in the main clause. For example, cases like (19b) and (19c) show that the object of the infinitive
can be the topic or the contrast of the entire sentence. (There is no good English translation for sentence (19b)).

(19) (a) *Esä halusi lukea kirjan.* Esa wanted to read the book.
(b) *Kirjan halusi lukea Esa.* The one who wanted to read the book was Esa.
(c) *KIRJAN Esä lukea halusi.* The BOOK Esa wanted to read.

More than one element can be outside of the rest of the infinitival clause, at least as long as they occupy designated positions (contrast, topic) in the main sentence. However, it does not seem possible to freely interleave constituents from infinitival clauses with elements of the main clause. Examples such as (20b) sound very marginal if not completely unacceptable.

(20) (a) *Esä halusi lukea kirjan kotona.* Esa wanted to read the book at home.
(b) *?Kirjan halusi kotona Esa lukea.*

If it is true that the mixing of elements from different clauses is possible only in cases like (19b) and (19c), which can be described in the same way as long-distance dependencies in English, then configurational variation in Finnish is clause-bound and affects only sister constituents. It would obviously be much harder to account for examples such as (20b), where the elements of the infinitival clause *lukea kirjan kotona* "to read the book at home" are scattered all over the main sentence. We leave the matter open for the time being.

8.1.8. Other sentence types

So far we have discussed only simple transitive sentences, because they are sufficient to illustrate all the word order phenomena that we are trying to account for in our sample grammar. There are of course many other sentence types in Finnish. The most important are as follows:

(21) Simple intransitive  
Impersonal transitive  
Impersonal intransitive  
Existential  
Possessive  
Necessary  

<table>
<thead>
<tr>
<th>Sentence Type</th>
<th>Example 1</th>
<th>Example 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple intransitive</td>
<td><em>Esä nukkuu kotona.</em></td>
<td><em>Esa sleeps at home.</em></td>
</tr>
<tr>
<td>Impersonal transitive</td>
<td><em>Kirja luettiin.</em></td>
<td><em>The book was read.</em></td>
</tr>
<tr>
<td>Impersonal intransitive</td>
<td><em>Talla tanssi</em>tna.*</td>
<td><em>There is dancing here.</em></td>
</tr>
<tr>
<td>Existential</td>
<td><em>Pihalla juoksee poikia.</em></td>
<td><em>There are boys running in the yard.</em></td>
</tr>
<tr>
<td>Possessive</td>
<td><em>Esällä on rahaa.</em></td>
<td><em>Esa has money.</em></td>
</tr>
<tr>
<td>Necessary</td>
<td><em>Esaan taytyy mukkua.</em></td>
<td><em>Esa must sleep.</em></td>
</tr>
</tbody>
</table>

Each of these sentence types shows just as much variation in word order as simple transitive sentences do in accordance with the same principles. The differences arise from the fact that in some cases the default topic of the construction is something other than the subject. For example,
in possessive sentences the possessor, which syntactically is an adverbial, usually plays the role of the topic. In existential sentences it is most often the locative phrase, although the subject is in principle just as eligible. Because the subjects of existential sentences typically introduce new individuals to the discourse, they tend to occur in the last position leaving the topic slot for the locative phrase. The default order for There are boys running in the yard, composed of poikia "boys" (Pl Partitive), juoksee "run" (Pres Sg 3rd), and pihalla "in the yard," is LOC V S, as shown in (21). However, the S V LOC order in (22a) and LOC S V in (22b) orders are just as grammatical.

(22) Poikia juoksee pihalla. As for boys, there are some running in the yard.

PIHALLA poikia juoksee. It is in the YARD where there are some boys running.

In both cases the topic is boys, in the latter case the adverb is contrasted. We expect that our grammar of simple transitive sentences could easily be extended to include these types of constructions.

8.1.9. Summary

From the foregoing discussion of Finnish it is possible to disengage four propositions that are important to our present concerns.

1. There are languages whose word order is substantially free, if, by that, we mean that once it has been established that a certain sequence of phrases constitutes a sentence, it is also known that most of their permutations have the same status.

2. Finnish and other free word order languages also have a strong permutation property in that the members of a set of permutations are equivalent in more than simple well-formedness. In particular, they are logically equivalent, although they may differ with respect to the preferred resolution of quantifier scope ambiguities and other such matters we have not discussed here.

3. In Finnish, and, as far as we know, in other free word order languages, the members of a set of permutations are rarely if ever equivalent in all respects. In particular, there are important functional properties relating to topic, contrast, and the distinction between given and new which distinguish them.\(^5\) In that respect, Finnish is a configurational language.

4. The placement of constituents may be constrained by a mixed set of criteria. Some may refer to discourse roles, others to syntactic roles or just to grammatical categories. It seems unlikely that one can make sense of the configurational variation in a language like Finnish except as an interplay of many different principles.

We distinguish two discourse roles: topic and contrast. We interpret Topic in the traditional way. An expression in that role serves to identify an individual or individuals that is to be tagged with the proposition ex-
pressed by the sentence. It indicates what the sentence is about. The underlying intuition is that, whenever possible, we tend to associate a proposition with some individual that it involves and view it as a fact about Theme, which is often used in the same sense.

There is no standard term corresponding to our Contrast, but similar characterizations have been given elsewhere for the role itself. There is a suggestion that the expression in that role designates one of several mutually exclusive alternatives. These may but need not be explicitly given in the discourse. By referring to only one of them, the sentence creates an implication that the others lack whatever the relevant property happens to be.

The same two discourse roles, topic and contrast, are of course just as relevant for English as they are for Finnish. Topic is one of the differences between active and passive. Contrast is needed, for example, to explain the fact that The BOOK John read can be used as a correction but not as a continuation to John read the magazine. The difference is that surface configurations in English encode syntactic relations as well as discourse functions, whereas in Finnish they are for the most part only used for the latter purpose.

Our findings about constituent order in Finnish can be summarized as follows:

(23)  
(a) Topic immediately precedes FiniteVerb.  
(b) Contrast (if any) is first and immediately precedes Topic.  
(c) Contrast is more emphatic if MainVerb comes last.  
(d) Only final NPs introduce new discourse referents.  
(e) FiniteVerb precedes TensedVerb, if they are distinct.  
(f) TensedVerb precedes MainVerb, if they are distinct.  
(g) Adverbs can occur in any position not ruled out by other constraints.

These principles account for the data we have considered, but we are aware that some of them need to be refined further and there are other constraints we are not going to pursue here. Instead, we will show how ordering constraints of this sort are integrated with the rest of syntax in functional unification grammar.

8.2. A unification grammar for Finnish

We use the notation described in Kay's paper in this book. In functional unification grammar, each grammatical phrase of a language has a functional representation or description (FD) consisting of attribute-value pairs. The set of possible attributes ranges from phonological to semantic
properties. Here are some of the properties that appear in our grammar for Finnish.

(24) Phonological: Emphasis
Morphological: Case, Number, Person, Tense, Voice
Semantic: Positive, Aspect, Quantity
Structural: Cat(egory), Pattern (alias $), Branching
Syntactic: Subject, Object, Adverb
Pragmatic: Topic, Contrast, New

The values can be either atomic designators (Yes, No, Nom, Sg, Past, NP, etc.) or functional descriptions. They can be designated indirectly by specifying paths that lead to them. For example, the FD of FiniteVerb might contain the pair [Number = Sg]. If the grammar requires Subject to agree with FiniteVerb in Number, then the FD of Subject may contain the pair [Number = (FiniteVerb Number)] (pronounced: "Number is FiniteVerb's Number"). Alternatively, Subject might be specified with [Number = Sg] and FiniteVerb with [Number = (Subject Number)]. These are equivalent ways expressing the fact that the two constituents have been unified with respect to Number.

The values of syntactic and functional attributes are typically FDs. For example, the FD of the sentence John read the book would contain the pair

(25) \[
\text{SUBJECT} = \left[ \begin{array}{c}
\text{CAT} = \text{NP} \\
\text{LEX} = \text{JOHN}
\end{array} \right]
\]

The similarities between our framework and lexical functional grammar (Kaplan and Bresnan, 1980) are obvious. One important difference is that in functional unification grammar the information about constituent structure is not expressed by means of phrase structure rules in the grammar. The dominance hierarchy of mother and daughter nodes is represented separately from the left-to-right order of sister nodes. The latter is encoded as the value of a special pattern attribute ($). This results in a deliberate blurring of the distinction between constituents and properties. It is not important as far as phrases are concerned, because it is a trivial matter to recover a unique phrase structure tree from a fully specified functional representation. It does make a difference in the grammar. Since patterns can be arbitrarily loose or strict with respect to order, it is easy to allow configurational variation. In that respect unification grammar is similar to the immediate-dominance/linear-precedence (ID/LP) variant of generalized phrase structure grammar (Gazdar and Pullum, 1982).

The complete functional description for Esa slept is given in (26).
(26)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Non Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat</td>
<td>S</td>
</tr>
<tr>
<td>$</td>
<td>((Subject) (MainVerb))</td>
</tr>
<tr>
<td>Tense</td>
<td>Past</td>
</tr>
<tr>
<td>Perfect</td>
<td>No</td>
</tr>
<tr>
<td>Positive</td>
<td>Yes</td>
</tr>
<tr>
<td>Polarity</td>
<td>Positive</td>
</tr>
<tr>
<td>Contrast</td>
<td>NONE</td>
</tr>
<tr>
<td>Topic</td>
<td>⟨Subject⟩</td>
</tr>
</tbody>
</table>

```
[TYPE            = Terminal
Cat              = NP
Quantity          = All
Nominal           = NONE
Determiner        = NONE
Branching         = No
Subject           = No
Emphasis          = No
ProDrop           = No
Person            = ⟨MainVerb Person⟩
Number            = ⟨MainVerb Number⟩
Case              = Nom
LEX               = Esa

FiniteVerb       = ⟨TensedVerb⟩
TensedVerb       = ⟨MainVerb⟩
```

```
[TYPE            = Terminal
Cat              = Verb
Tense            = Past
Positive         = Yes
Polarity         = Positive
Subject          = ⟨Subject⟩
TenseMood        = Past
Branching        = No
Person           = 3rd
Number           = Sg
Emphasis         = No
Subcat           = Intransitive
Voice            = Active
Object           = ⟨Object⟩
LEX              = sleep

Abverb           = NONE
Branching        = Yes
Emphasis         = No
LEX              = NONE
Object           = NONE
```
The functional description in (26) is fully specified in the sense that it specifies a single sentence. An important feature of unification grammar is that removing parts of such specifications results in FDs that describe sets of sentences. For example, if the properties [Perfect = NO], [Positive = Yes] are left out, the resulting FD describes a set of sentences containing *Esa slept, Esa didn’t sleep, Esa has slept, Esa hasn’t slept.* Another way to loosen up a description is to introduce alternations. If we change (246) by replacing [Contrast = NONE] with the alternation

(27) \[ \{ \text{Contrast = NONE} \} \]

we get an FD representing the set *Esa slept, Esa DID sleep.*

Loosely specified patterns that do not prescribe a unique order or constituents have the same effect as explicit alternations. For example, the pattern (*... FiniteVerb ... TensedVerb ... MainVerb...*) specifies that the three constituents it mentions have to occur in the given order, but they need not be contiguous. The ellipses marked by three dots match any sequence of constituents. Thus the pattern actually matches a large set of possible sequences.

One can think of a grammar as a very loose functional description that simultaneously describes all the phrases of the language. There is no formal distinction in this theory between a grammar and an FD for a single unambiguous phrase except that the latter by definition contains no alternations.

A section of our Finnish grammar is given in (28). It deals for the most part with verb inflection and subject-verb agreement. The top of the description, [Cat = S], indicates that it pertains to sentences. The first alternation says in effect that a sentence either has the property [Tense = Present] or [Tense = Past]. The second alternation forces a choice between two clusters of properties, one headed by [Positive = Yes], the second by [Positive = No]. In the former case FiniteVerb and TensedVerb are the same, in the latter case FiniteVerb is the tenseless negative verb. The last alternation in the diagram involves a choice between person (active) and impersonal (passive) voice. In the active, the sentence must have a grammatical subject with certain agreement properties. In the passive, there is no such requirement. The pattern ((#[New = No]) #1) in the middle of (28) incorporates the idea that NPs introduce new discourse referents only in the last position. It attributes the property [New = No] to all but the last immediate constituent. This is not a satisfactory solution, but it serves us here as example of a nontrivial pattern.

One way to test the correctness of a grammar of this sort is to take a partial description of a sentence and to produce from it all realizations that the grammar allows. We have used such a generator extensively in
\[(28)\]

\[
\text{Cat} = S
\]

\[
\begin{cases}
\text{Present} \\
\quad \text{[Tense} = \text{Present}] \\
\text{Past} \\
\quad \text{[Tense} = \text{Past}] \\
\end{cases}
\]

\[S = (\ldots \text{FiniteVerb} \ldots \text{TensedVerb} \ldots \text{MainVerb} \ldots)\]

\[
\begin{array}{l}
\text{Positive} \\
\quad \text{Positive} = \text{Yes} \\
\quad \text{Polarity} = \text{Positive} \\
\quad \text{FiniteVerb} = \text{TensedVerb} \\
\end{array}
\]

\[
\begin{array}{l}
\text{Negative} \\
\quad \text{Positive} = \text{No} \\
\quad \text{Polarity} = \text{Negative} \\
\quad \text{FiniteVerb} = \begin{bmatrix}
\text{LEX} & = \text{not} \\
\text{Tense} & = \text{NONE}
\end{bmatrix}
\end{array}
\]

\[
\begin{array}{l}
\text{NonPerfect} \\
\quad \text{Perfect} = \text{No} \\
\quad \text{TensedVerb} = \text{MainVerb}
\end{array}
\]

\[
\begin{array}{l}
\text{Perfect} \\
\quad \text{Perfect} = \text{Yes} \\
\quad \text{TensedVerb} = \text{[LEX} = \text{have]} \\
\quad \text{MainVerb} = \begin{bmatrix}
\text{Tense} & = \text{NONE} \\
\text{TenseMood} & = \text{PastPart} \\
\text{Number} & = \langle\text{TensedVerb Number}\rangle
\end{bmatrix}
\end{array}
\]

\[S = (((\#\text{New} = \text{No}) \#1))\]

\[
\begin{array}{l}
\text{FiniteVerb} = \begin{bmatrix}
\text{Cat} & = \text{Verb} \\
\text{Positive} & = \langle\text{Positive}\rangle
\end{bmatrix}
\end{array}
\]

\[
\begin{array}{l}
\text{TensedVerb} = \begin{bmatrix}
\text{Cat} & = \text{Verb} \\
\text{Tense} & = \langle\text{Tense}\rangle \\
\text{Positive} & = \langle\text{Positive}\rangle \\
\text{Number} & = \langle\text{FiniteVerb Number}\rangle
\end{bmatrix}
\end{array}
\]

\[
\begin{array}{l}
\text{MainVerb} = \begin{bmatrix}
\text{Cat} & = \text{Verb} \\
\text{Subject} & = \langle\text{Subject}\rangle \\
\text{Object} & = \langle\text{Object}\rangle
\end{bmatrix}
\end{array}
\]
the course of our investigation. The generator takes as input an incomplete FD and systematically explores every admissible way of expanding it. It produces a sequence of fully specified FDs from which one can extract a constituent structure tree or just a list of FDs that represent the words, as our generator does. These are turned over to another generator, which augments the stem with appropriate morphological suffixes and prints out the actual Finnish word. Our syntactic generator was written by Martin Kay; the morphological generator for Finnish is the work of Lauri Karttunen, Rebecca Root, and Hans Uszkoreit (1981).

A sample of output from the generator is given in (29). It shows (to a Finn) that the subject-verb agreement part of the grammar in (28) is descriptively adequate. The input description for the generator leaves the

(29) Input description:

\[
\begin{align*}
\text{Cat} &= S \\
\text{Tense} &= \text{Past} \\
\text{Contrast} &= \text{NONE} \\
\text{Topic} &= \langle \text{Subject} \rangle \\
\text{Subject} &= \text{Nominal} = \left[ \begin{array}{c}
\text{Nominal} = [\text{LEX} = \text{child}] \\
\text{Attribute} = [\text{LEX} = \text{small}] \\
\text{Determiner} = \text{NONE}
\end{array} \right] \\
\text{Main Verb} &= [\text{LEX} = \text{sleep}] \\
\text{Object} &= \text{NONE} \\
\text{Adverb} &= \text{NONE}
\end{align*}
\]
values of Positive, Perfect, and Subject's Number unspecified. Since these three attributes are required by the grammar and each has two possible values, the generator produces eight sentences: The small child sleeps. The small children sleep. The small child doesn't sleep, etc. The most striking feature of the example is that the two auxiliary verbs, ei and ole that are not mentioned in the input FD at all, appear in the output where they should with the right inflectional endings.

The FD in (30) contains the part of the grammar that deals with Topic and Contrast. Except for the given/new distinction, discussed previously, it incorporates all the ordering principles listed in (23).

The section of grammar displayed in (30) consists of two alternations, one for Topic, the other for Comment. The first part says that a sentence either has a topic or it does not. The latter alternative is for constructions we have not discussed here, for example, imperatives. If there is a Topic, it can be either Subject, Object, or Adverb. The preferred choice is listed first; it is the one that the generator tries out first. (In that sense, Subject is the default selection for Topic.) Furthermore, the choice of Object or Adverb for that role is limited by an additional requirement. Either there is no Subject, or Subject serves as Contrast, or Subject introduces a new individual to the discourse. The position of Topic depends on whether FiniteVerb serves as Contrast. If it does, then FiniteVerb comes first and Topic immediately behind it. Otherwise they come in the opposite order.

The second alternation in (30) pertains to Contrast. If there is Contrast, either FiniteVerb, Subject, Object, or Adverb serves in that role. If the verb is selected, it is always emphasized. Otherwise emphasis depends on the position of the MainVerb. If MainVerb comes last, Contrast carries emphasis. The position of Contrast is immediately in front of Topic. The expression “PART(Topic NIL)(Contrast NIL)” at the end means that Contrast and Topic have to be distinct, unlike FiniteVerb, TensedVerb, and MainVerb.

As one can see by comparing the two sections of the grammar in (28) and (30), the information of the left-to-right order of constituents comes from several places in the grammar. The value of the pattern attribute typically is a list of patterns, such as (. . . MainVerb . . .), (. . . FiniteVerb . . . TensedVerb . . . MainVerb . . .), (Subject . . .), each of which
(30)

\[
\text{Topic} = \begin{cases} 
\text{Subject} = \text{NONE} \\
\text{Subject} = \text{Contrast} \\
\text{Subject} = [\text{New} = \text{Yes}] \\
\end{cases} \]

\[
\text{No VerbContrast} \\
[\$ = (. . . \text{Topic} \text{ FiniteVerb} \ . . .)] \\
\text{VerbContrast} \\
[\$ = (\text{FiniteVerb} \text{ Topic} \ . . .)] \\
\]

\[
\text{NoTopic} \\
\text{Topic} = \text{NONE} \\
[\$ = (\text{FiniteVerb} \ . . .)] \\
\]

\[
\text{NoContrast} \\
\text{Contrast} = \text{NONE} \\
\text{Emphasis} = \text{No} \\
[\$ = (\text{Topic} \ . . .)] \\
\]

\[
\text{Contrast} \begin{cases} 
\text{VerbContrast} \\
\text{OtherContrast} \\
\end{cases} \\
\]

\[
\text{VerbContrast} \\
\text{Contrast} = \text{FiniteVerb} = [\text{Emphasis} = \text{Yes}] \\
\text{Emphasis} = \text{Under} \\
\]

\[
\text{OtherContrast} \begin{cases} 
\text{Contrast} = \text{Subject} \\
\text{Contrast} = \text{Object} \\
\text{Contrast} = \text{Adverb} \\
\end{cases} \\
\]

\[
\text{NoEmphasis} \begin{cases} 
\text{Emphasis} = \text{No} \\
[\$ = (. . . \text{MainVerb} \ #1)] \\
\end{cases} \\
\]

\[
\text{Emphasis} \begin{cases} 
\text{Contrast} = [\text{Emphasis} = \text{Yes}] \\
\text{Emphasis} = \text{Under} \\
[\$ = (. . . \text{MainVerb})] \\
\end{cases} \\
\]

\[
[\$ = (\text{Contrast} \text{ Topic} \ . . .)] \\
\text{PART} (\text{Topic} \text{ NIL})(\text{Contrast} \text{ NIL}) \\
\]
expresses some ordering constraint. These need to be checked for consistency and merged into a single pattern in order to extract a phrase structure tree for the sentence. In our system this is done by the generator as the phrase is produced. If the patterns are inconsistent, the merge fails and nothing is generated. Sometimes the merge produces alternatives. If the position of some constituent is not uniquely determined, the generator tries out all possibilities and produces multiple output.

The first part of (31) contains an FD for *Esa read the book* which leaves Topic and Contrast unspecified. The second part shows the output from the generator, which contains all the six possible permutations. (The morphological analyzer prints words that have the feature [Emphasis = Yes] in capitals.)

(31) Input Description:

\[
\begin{align*}
\text{Cat} &= S \\
\text{Tense} &= \text{Past} \\
\text{Perfect} &= \text{No} \\
\text{Positive} &= \text{Yes} \\
\text{Subject} &= [\text{LEX} = \text{Esa}] \\
\text{MainVerb} &= \begin{bmatrix} \text{LEX} &= \text{read} \\
\text{Aspect} &= \text{Perfective} \end{bmatrix} \\
\text{Adverb} &= \text{NONE} \\
\text{Object} &= \begin{bmatrix} \text{Cat} &= \text{NP} \\
\text{Nominal} &= [\text{LEX} = \text{book}] \\
\text{Determiner} &= \text{NONE} \\
\text{Quantity} &= \text{All} \\
\text{Number} &= \text{Sg} \end{bmatrix}
\end{align*}
\]

Output:

- Esa luki kirjan
- LUKI Esa kirjan
- LUKI kirjan Esa
- KIRJAN Esa luki
- ESA kirjan luki
- Kirjan luki Esa

One useful aspect of the grammar we have sketched is its modularity. Although the grammar can be represented as a single FD with many alternations, the parts are relatively independent from one another and can be constructed separately.

8.3. Parser

We now turn to the question of what provisions, if any, a parser must make in order to accommodate a language like Finnish. We begin by
considering this question from the point of view of context-free phrase structure grammar without arguing the merits of this kind of grammar for these or any other languages. We are interested in it because it is the simplest and best understood kind of grammar, and one for which a great variety of parsing strategies have been proposed. Functional unification grammar, while it is not context free, does belong to the class of phrase structure grammars in the sense that sentences are assigned recursive constituent structures directly, and these are not modified in the course of the generation process as they would be in, for example, transformational grammar. The daughters of a given node are determined by the label of the parent node without reference to context. The formalism fails to be context free because node labels are not taken from a closed set. As we shall see, the parsing strategies devised for context-free grammar can therefore be carried over virtually unchanged to grammars of this new kind.

At the heart of any context-free parsing algorithm is a step in which it must be decided of a particular string of words and phrases, or of a prefix of such a string, whether or not it matches the right-hand side of a rule in the grammar. Let us call this the matching step. Parsers differ considerably in how the many matching steps that must be taken are scheduled relative to one another and in the schemes used for representing the strings of words and phrases. Matching steps, however, differ only in minor details such as the number of rules considered at a time and possible special treatment for sets of rules whose right-hand sides begin the same way, thus allowing for some economy in the matching process.

If free word order languages present a special problem in the design of parsing strategies, it is clearly in the matching step that the problem arises. But it is not difficult to see that what these languages present is in fact more of an opportunity than a fundamental problem because, in the last analysis, it is always possible to provide a separate rule for each possible order of constituents. The opportunity is to work with a much smaller grammar by embodying the permutation property in the algorithm itself. This also provides no fundamental problem.

Let us assume that the parser gains access to the grammar through the intermediary of a set of functions that obtain rules with particular properties on demand. Thus, if a rule is required to match a string beginning with a determiner or to expand a node labeled NP, these requirements are supplied as arguments to the proper function and any rules meeting them are returned as the value. This much is standard practice. It is clearly a straightforward matter to arrange for the function to manufacture ordered context-free rules of the familiar kind from a data base containing rules whose right-hand sides are not completely specified as to order. There is no reason why a parser should be restricted to a single way of
accessing the rules in its grammatical data base. A rule that allows one constituent ordering can be represented in the usual way, while the set that would result from generating all permutations of unordered rules could be stored in the more compact form and expanded only as required. The artifice of access functions serves to dissociate these essentially administrative concerns from the body of the parsing program.

The fact that the permutations of a given sequence of constituents generally are not equivalent in all respects seems to support the view that the grammar of free word order languages should not be treated in any special way in parsing. Although permuting the constituents of a sentence leaves its logical form unchanged, it does affect other semantic or pragmatic properties so that the rules for the different permutations would have to differ otherwise than in their order. This is not an entirely convincing argument, because the semantic and pragmatic distinctions do not necessarily have to be associated with individual rules of grammar but can be assigned to an interpretive component that works on the resulting constituent structures. This point was well made in respect of lexical functional grammar by P-K. Halvorsen (1983).

Functional unification grammar has the property – which some will consider an advantage and some a liability – of leaving open a large number of different approaches to the parsing of free word order languages. As we have seen, it is convenient within this formalism to separate a grammar into a number of components. The categorial component can be separated from the logical component, and both of these can be distinct from a functional component. Compositional semantics can be described within the formalism, and this can constitute a separate component of the grammar. In this last case, the advantages of keeping the components separate are particularly clear because we should expect the semantic component to be largely universal, allowing itself to be combined through unification with categorial and other components from the grammars of particular languages.

The designer of a parsing strategy for functional unification grammar has the option of obtaining initial structures for sentences using only one of the components and of obtaining more complete descriptions by later unifying these with other components of the grammar. The only requirement is that the component, or components, used in the first stage of the analysis should contain information on constituent sets because, without these, it is impossible to tell which functional roles are filled by distinct constituents. Notice that the components incorporated in the first-order parser need not contain the ordering information represented in patterns even if the word order of the language concerned is narrowly specified. The result of putting these patterns in a component of the grammar with which structures are unified later is that the initial parsing will be con-
ducted as though there were no constraints on word order, and analysis in which the constraints were violated would be eliminated in later steps. This would almost certainly not be the recommended strategy because of the large number of pseudo-ambiguities that would remain after the end of the first stage. Generally speaking, the parser that incorporates only one component will be less constrained and will therefore recognize a greater number of spurious structures, which will fail to unify with other components of the grammar. On the other hand, these structures will be simpler and more easily identified than if the grammar were of the more highly constrained variety resulting from the unification in advance of several components.

A context-free rule has the form \( A \rightarrow B_1 \cdots B_n \), where \( A \) is a nonterminal category label and \( B_1 \cdots B_n \) are arbitrary category labels. A functional unification grammar is not made up of rules, but it is possible to extract a set of rules from it which are very similar to that of context-free rules. These rules have the form \( F \rightarrow P_1 \cdots P_n \), where \( F \) is a functional description and \( P_1 \cdots P_n \) are paths identifying parts of that description. For example, the following would be a possible rule.

\[
(32) \quad \begin{align*}
\text{Cat} & = S \\
\text{Subject} & = [\text{Cat} = \text{NP}] \\
\text{Verb} & = \left[ \begin{array}{l}
\text{Cat} = V \\
\text{Number} = \langle \text{Subject Number} \rangle \\
\text{Person} = \langle \text{Subject Person} \rangle
\end{array} \right]
\end{align*}
\rightarrow \langle \text{Subject} \rangle \langle \text{Verb} \rangle
\]

This says that any phrase whose description can be unified with the one given can be accommodated in the constituent structure in such a way as to dominate a pair of other constituents, the first of which is its subject and the second of which is its verb. Each of these can, of course, have a description of arbitrary complexity, which will also be part of the description of the dominating node. There are therefore indefinitely many labels that a phrase could have while still meeting the conditions required for the application of this rule. Notice that this rule provides for agreement in person and number between the subjects and the verb. Although this does not require essentially non-context-free devices, it does suggest a way in which the formalism might incorporate them. The reader may wish to verify, for example, that the following grammar generates the well-known non-context-free language \( a^n b^n c^n \). In this case the essential property is the Daughter feature, which must have the same value for all nodes at the same level in the structure of any sentence, but a different one for each level. The description of a node dominating three terminals, for example, must have the feature \([\text{Daughter} = [\text{Daughter} = [\text{Daughter} = \text{NONE}]]]\).
Although the form of these rules is not identical to that of a context-free rule and although grammars can be written with them that have more generative power, they can clearly be incorporated in a parser of essentially the same design as would be used with a context-free grammar. It is perhaps worth noting an implication of this, namely that functional unification grammar has less generative power than context-sensitive grammar because it is well known that the same parsing strategies are not applicable to these. The question we now briefly address is that of
8. Parsing in a free word order language

deriving a set of rules of the kind just suggested, with or without ordered right-hand sides, from a grammar expressed in the standard way.

It turns out that an algorithm that will produce rules from a functional unification grammar is a minor variant of the unification algorithm itself. The simplest kind of unification algorithm produces a result in disjunctive normal form. To produce a result in a more compact form would require the use of complex algebraic simplification techniques. However, as a model of human sentence production, a generator of descriptions in disjunctive normal form may be particularly apt because we assume that the speaker will abandon the process as soon as the first term has been produced. While the grammar will generally allow a variety of ways of expressing a given idea, the speaker is interested in finding only one of them, which is to say that he is only interested in one term of the expression. This assumes, of course, that a careful speaker controls the quality of his linguistic output by providing more complete descriptions to the linguistic generator and not by generating several alternatives among which he then makes a choice.

For the present purposes, in any case, a generator of disjunctive normal forms will be ideal and we shall indeed need all the terms in the expressions that it produces. However, the essentially recursive step in which the grammar is unified with constituents below the top-level node is disabled: The result is a device that does nothing more than reduce the grammar itself to disjunctive normal form, providing a separate description of each possible phrase type. These descriptions can be made into the rules we require by simply extracting their patterns and making them the right-hand sides of the rules. Unordered rules are obtained by curtailing the normal unification process so as not to include the patterns. In this case the right-hand sides of the rules are provided by the constituent sets.

The details of the process by which a functional description is reduced to disjunctive normal form need not concern us here. They are part of the stock in trade of computer scientists, especially in artificial intelligence. The following broad outline will be sufficient. The functional description has the structure of a tree with attribute-value pairs labeling terminal nodes and either “and” or “or” labeling the nonterminal nodes. Each term in the disjunctive normal form also has such a tree structure, but since all the nonterminals are labeled “and,” it would be possible to replace them all with a single nonterminal node. Each tree that represents one of these terms can be derived from the tree for the original expression by simply selecting certain arcs and nodes from it. The top node must be included. If a node labeled “and” is included, then the arcs extending downward from it, and the nodes to which these lead, must also be included. If a node labeled “or” is included, then exactly one of the arcs
leading downward from it, and the node to which this leads, must be included. Arcs and nodes must be included only if they satisfy these requirements. It emerges that the terms of the resulting expression, and therefore the rules of the parsing grammar, differ from one another with respect to the choice of a downward arc from at least one "or" node.

What, then, is the appropriate strategy for a "mildly configurative" language like Finnish, where many, but not all, of the orderings of a constituent set are generally allowable? We have outlined straightforward procedures for automatically constructing more or less traditional rules spelling out each possible order individually. Such rules can then be compiled into a transition network that can be made the basis of very efficient analysis procedures. However, the number of such rules that would have to be generated, and the storage space they would consume, would make this an attractive alternative only if all the rules were very short. But we have seen that Finnish has largely flat structures at the sentence level where word order is least constrained; the rules would therefore be long and the size of the corresponding set of ordered rules unthinkably large.

The preferred analysis strategy for a language like Finnish would therefore make use of unordered rules, each annotated with the corresponding patterns taken from the functional unification grammar. Those patterns are then brought into play by the parser at the time the rule is matched against a segment on the string. Let us suppose that each of the patterns associated with a rule is converted into the form of a finite-state machine. Since patterns are written in the language of regular expressions, we know that automata theory has standard techniques for doing this. These are now used in the parser's matching step as follows. The first item in the string to be matched is first compared with the members of the constituent set for the rule to verify that, considerations of order aside, it could belong to a phrase sanctioned by this rule. If it is found, the matching member of the constituent set is removed so that it will not also be allowed to match against subsequent items. Needless to say, this is done in a non-deterministic manner so that what is done in this matching step does not affect others. It is next verified that each of the finite-state machines produced from the patterns associated with the rule can be advanced to a new state over this item. If this can be done for each of the machines, the matching step proceeds to the next character with the reduced constituent set and new states for each of the pattern machines. A string meeting the specifications of the rule has been identified when the constituent set is empty and each of the finite-state machines is in a final state.

What is in fact being done in this procedure is that that particular part of the fully expanded set of rules required for the particular case on hand is computed on demand and the string to be matched is used to direct the
computation in a straightforward way so that it can proceed quite efficiently. In fact, in all but the most perverse situations, which must be especially constructed to make a point, this version of the matching step required very little more computation than one that worked from a grammar containing the fully expanded set of ordered rules. The number of patterns associated with a given rule is quite small and each of them can be made deterministic using algorithms that are a standard part of automata theory. On occasion, it may even be possible to combine some of the finite-state machines associated with a rule into a single machine without encountering much of a combinatorial explosion. In short, the overall strategy leaves room for space versus time trade-offs of several kinds so that it is readily adapted to a variety of practical needs.

We conclude that formalisms like that of functional unificational grammar justify two of the principal claims made for them, namely that they enable a perspicuous account to be given of the so-called functional aspects of language and that they provide a firm basis for performance models and computational procedures. Free word order languages like Finnish cannot be described in a revealing way within a framework that contains only ordered rules or that does not allow separate statements to be made about logical and functional aspects of the language that nevertheless interact so that each constrains the other in a well-defined way. In addition to this, we have shown that a framework in which revealing descriptions of the languages are possible does not lead to intractable parsing problems.

Notes
Most of the research for this paper was conducted while the first author was a fellow at the Center for Advanced Study in the Behavioral Sciences.

1. Preposed constituents in English sentences such as The BOOK Esa read are not topics in this sense of the term, although the preposing rule is commonly known as Topicalization (Chafe 1976; Prince 1981).
3. Heinamaki (1980) and Hakulinen and Karlsson (1981) do not mention finite verbs among constituents that can be contrasted (focused on) but we are inclined to think that they should be included here.
4. As Heinamaki (1980) points out, negation cannot focus on the topic in cases like *Ei KIRJAA Esa lukenuit ‘No, the BOOK Esa didn’t read’, although (15b) and (15c) are both grammatical. The initial placement of negation is irrelevant here because the judgments remain the same even if ‘ei’ comes after the topic: *KIRJAA ei lukenuit Esa versus ESA ei lukenuit kirjaa Esa ei lukenuit KIRJAA. Similar asymmetries in the assignment of negative focus show up in other constructions, for example in existential clauses: Ei TAI OSSA kissoja ole ‘There are no cats in the HOUSE’ verses Ei KISSOJA talossa ole ‘There are no CATS in
the house'. The latter proposition can only be expressed by changing the order to *Ei talossa KISSOJA ole*. It appears that negation cannot focus on the topic unless it is the unmarked default topic — that is, the subject in transitive sentences, locative in existential sentences. This is an interesting problem for future research.

5. The distinction between logical and functional aspects of meaning can be nicely drawn in *situation semantics* — see Barwise and Perry, 1982. The basic idea is that meanings are relations between types of situations. In particular, the meaning of a declarative sentence S is a relation between situations that are assertions of S and situations that are described by them. In Finnish, changes of word order typically affect only the domain but not the range of this relation. The set of situations described by a sentence is unaffected by configurational changes, but the set of discourse situations varies.

6. The feature Char assures that only a appears as a terminal under A, similarly for B and C. All lower level constituents agree with their dominating node with respect to this feature except for terminal nodes, which pick it up as their lexical realization. Every nonterminal node has a Daughter property whose value is a list that in effect encodes the length of the longest branch it dominates. Thus a node that dominates only a terminal symbol has the feature [Daughter = NONE]; the node immediately above has the feature [Daughter = [Daughter = NONE]], and so on.

References


