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ARTICLE

# Finnish word order: Does comprehension matter?

Pauli Brattico

Research Center for Neurocognition, Epistemology and Theoretical Syntax (NETS), School for Advanced Studies IUSS Pavia, Italy
Email for correspondence: pauli.j.brattico@gmail.com

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**Abstract**

Finnish word order is relatively free, making room for all mathematically possible word orders in many constructions. Because there is no evidence in this language for radical nonconfigurationality, explanations must be sought from syntax. It is argued in this article that morphosyntax and word order represent syntactic structure at the PF-interface. Rich morphosyntax frees word order, poor morphosyntax freezes it. The hypothesis is formalized within the context of a parsing-oriented theory of the human language faculty (UG) combining left-to-right minimalism with the dynamic syntax approach. The analysis was implemented as an algorithm and successfully tested with a corpus of 119,800 unique Finnish word orders.

**Keywords:** adjunction; computational linguistics; dynamic syntax; Finnish; top–down grammar; word order

## 1. Introduction

Finnish, like several other Finno-Ugric languages such as Hungarian (É. Kiss 1987, 2008), exhibits relatively few constraints on word order in a finite clause (e.g. Lindén 1947; Hakulinen 1975, 1976; Hakulinen & Karlsson 1979; Vilkuna 1989; Palander 1991; Holmberg & Nikanne 2002). Often all or nearly all mathematically possible word permutations are attested. Some are illustrated in (1)–(2).[1]

(1) Jari lainasi kirja-n Merjalle. (canonical S–V–O–IO order)
*Jari.NOM loaned book-ACC to.Merja*
'Jari loaned a/the book to Merja.'

(2) a. Kirjan lainasi Jari Merjalle. (O–V–S–IO).
b. Kirjan lainasi Merjalle Jari. (O–V–IO–S)
c. Merjalle lainasi Jari kirjan. (IO–V–S–O)
d. Merjalle lainasi kirjan Jari. (IO–V–O–S)
e. Merjalle Jari lainasi kirjan. (IO–S–V–O).
f. Merjalle kirjan lainasi Jari. (IO–O–V–S)
g. Kirjan Jari lainasi Merjalle. (O–S–V–IO).
h. Kirjan Merjalle lainasi Jari. (O–IO–V–S)

i. Jari kirjan lainasi Merjalle. (S–O–V–IO).
j. Jari Merjalle kirjan lainasi. (S–IO–V–O)
. . .

As there is no independent evidence for radical nonconfigurationality in this language (van Steenbergen 1989, Manninen 2003, Brattico 2019b), most studies have approached the phenomenon by relying on syntactic displacement, often using discourse features as drivers (Hakulinen 1975; Vainikka 1989; Vilkuna 1995; Koskinen 1998; Nelson 1998; Holmberg 2000; Kaiser 2000, 2006; Holmberg & Nikanne 2002; Boef & Dal Pozzo 2012; Huhmarniemi 2012; Brattico 2018). Yet, no analysis exists that accounts for the free word order phenomenon as a whole. This has left many word order phenomena, reviewed in the next section, unaccounted for.

The following analysis of the Finnish free word order phenomenon will be proposed in this article. It will be argued that the human language parser can map both word order and rich morphosyntax into hierarchical order. Thus, in a language such as Finnish in which morphosyntax is rich, case suffixes guide arguments into their canonical positions. In a language with impoverished morphosyntax, canonical positions are recovered from order. A computational theory of the language comprehension, adopting ideas from the left-to-right minimalism (Phillips 1996, 2003; Chesi 2012; Brattico 2019a; Brattico & Chesi 2020) and Dynamic Syntax (Kempson, Meyer-Viol & Gabbay 2001, Cann, Kempson & Marten 2005) is developed that implements these properties (Section 4) and is tested against a corpus of 119,800 Finnish word order combinations by computer simulation (Section 5).

## 2. Finnish word order

The data in (1)−(2) could lead one to believe that all mathematically possible word order permutations are possible in Finnish. Indeed, some authors have proposed that Finnish is (either wholly or partially) nonconfigurational and obeys no or few syntactic constraints (for various proposals, see Välimaa-Blum 1988; Vilkuna 1989; Sammallahti 2002, 2003; Helasvuo 2013). Syntactic explanations are typically substituted with pragmatic ones, as the word order correlates with discourse interpretation. On the other hand, virtually all (or all) studies that have investigated the matter by using evidence outside of word order have concluded that Finnish is configurational (Hakulinen 1975; Vainikka 1989; van Steenbergen 1989; Koskinen 1998; Nelson 1998; Holmberg 2000; Holmberg & Nikanne 2002; Kaiser 2000, 2006; Manninen 2003; Boef & Dal Pozzo 2012). Independent syntactic phenomena, such as binding, morphosyntax, operator movement, topicalization, ellipsis, control and quantifier scoping behave as if the language would exhibit structural asymmetries (Brattico 2019b). Furthermore, free word order is restricted to finite domains, with infinitival constructions operating under much less free regime. I will assume in this article that Finnish is configurational.

If Finnish is configurational, then (1)−(2) must emerge by means of grammatical displacement, and the problem is what the displacement operation is. Certain facts can be regarded as uncontroversial. The Finnish preverbal subject position is preceded by an operator position (glossed here as C/op) that is filled in by operator-like elements, such as interrogative pronouns, relative pronouns or contrastively focused

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phrases, and the filling mechanism is operator/A′-movement (Vainikka 1989, Vilkuna 1995, Huhmarniemi 2012, Huhmarniemi & Brattico 2013). It can also be filled in by T-to-C head movement. Thus, only specifically marked or interpreted elements can occur in this position. It is not a 'free' position.

The operator position is followed by a preverbal subject position that can be filled in by a phrase of almost any type, which tends to receive a topic reading (Vilkuna 1989, Holmberg & Nikanne 2002, Huhmarniemi 2019). The discourse-configurationality of the Finnish preverbal subject position together with the observation that it can be filled in by almost any kind of phrase accounts for some of the Finnish noncanonical word orders. The standard template, based on the evidence discussed in the sources mentioned and first proposed by Vilkuna (1989, 1995), is illustrated in (3).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (3) | Ketä$_2$ | C/op$^0$ | Jari$_1$ | T/fin$^0$ | ihaile-e | ___$_1$ | ___$_2$? |
| | *who.*PAR | | *Jari.*NOM | | *admire-3*SG | | |
| | C/op field | | Topic/subject field | | V-field | Postverbal field | |

Here the consensus ends, however. A mechanical generation and evaluation of all logically possible words orders in basic Finnish finite clauses, performed by the author, revealed a number of phenomena unexplained by (3) or by anything else found in the current literature. These inadequacies constitute the motivation for the present study. I will review them next.

First, Finnish head movement is not restricted to local domains. The fact that head movement is nonlocal creates word order variations that cannot be and have not been accounted for by the standard analysis above. Two examples of nonlocal head movement are provided in (4).

(4) *Nonlocal head movement*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a. | Juoda$_1$-ko | Jari | käski | Merja-n | _$_1$ | vettä? | |
| | *to.drink-Q* | *Jari.*NOM | *asked* | *Merja-*GEN | | *water.*PAR | |
| | 'Was it to drink/drinking that Jari asked Merja to do with water?' | | | | | | |
| b. | Syödä$_2$-ko | Jari | sanoi | että | Merja-n | pitää | _$_2$ |
| | *eat-Q* | *Jari.*NOM | *said* | *that* | *Merja-*GEN | *must.0* | |
| | läävke-i-tä? | | | | | | |
| | *medicine-*PL-PAR | | | | | | |
| | 'Was it by eating that Jari said that Merja must consume the medication?' | | | | | | |

While it is not trivial that these data exhibit long-distance head movement, I refer to them theory-neutrally as 'nonlocal head movement constructions' in this article.[2]

There are also grammatical (if marginal) sentences in which a head has moved over another head into a position that does not exist in the standard model. Example (5) below illustrates this problem. Here the main verb moves over the negation into a position between C and Neg that is not posited by the standard model.

| | | | | | | |
|---|---|---|---|---|---|---|
| (5) | ??Jari | antanut$_1$ | e-i | ___$_1$ | kirja-a | Merjalle. |
| | *Jari.*NOM | *given* | *not-3*SG | | *book-*PAR | *to.Merja* |

'Jari did not give a/the book to Merja.'

Let us consider the properties of this construction more closely. The negation *e-i* 'not-3SG' is either its own Neg head or occurs in a separate finiteness head, both above T. This is justified on the grounds that the negation agrees in ϕ-features with the grammatical subject and occurs above the tensed verb (Holmberg et al. 1993, Holmberg & Nikanne 2002, Thomas 2012). Whatever (e.g. Neg, finiteness head) hosts the negation is selected by C/op, which provides the position for the raised verb in (5). The subject must be in the specifier of C/op, as shown by the analysis (6a). The problem is that if a head moves to C/op, no phrase can fill its specifier (Vilkuna 1989, 1995; Huhmarniemi 2012; Brattico et al. 2013). This general and virtually exceptionless limitation is illustrated in (6b).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (6) | a. ??Jari$_1$ | anta-nut$_2$ | e-i | ___$_1$ | ___$_2$ | kirja-a | Merjalle. |
| | *Jari.*NOM | *gave-*PAST | *not-3*SG | | | *book-*PAR | *to.Merja* |
| | SPEC | C/op | NEG | SPEC | T | | |
| | b. *Jari$_1$ | antoi$_2$-ko | ___$_1$ | ___$_2$ | kirja-n | Merjalle? | |
| | *Jari.*NOM | *gave-Q* | *SPEC* | *T/*FIN | *book-*ACC | *to.Merja* | |
| | SPEC | C/op | | | | | |

In addition, (5) is not interpreted so that 'Jari' constitutes the contrastive/corrective topic or focus, as it should were it located at Spec,C/op (Vilkuna 1989, 1995). Therefore, example (5) is hard to reconcile with the standard analysis.

Let us leave the issue and address other problems of the standard analysis. The number of topics seem not to be limited in any principled way (7a), although an increase in the number of topics seems to correlate (in author's judgment) with an increase in marginality; and much more if the topics are stacked above the negation (7b). To me, (7a) has a natural reading in which Pekka, the book and Merja are known from previous discourse and constitute topics. This phenomenon has been documented in previous literature (see, in particular, Vilkuna 1989), but no systematic analysis exists, to my knowledge.

(7) *Several topics*

| | | | | | | |
|---|---|---|---|---|---|---|
| a. E-i | Pekka | kirja-a | Merjalle | ole | antanut! | |
| *not-*3SG | *Pekka.*NOM | *book-*PAR | *to.Merja* | *had* | *given* | |

'Pekka had NOT given the book to Merja!'

| | | | | | | |
|---|---|---|---|---|---|---|
| b ?*Miksi | Pekka | kirja-a | Merjalle | e-i | ole | antanut? |
| *why* | *Pekka.*NOM | *book-*PAR | *to.Merja* | *not-3*SG | *had* | *given* |

'Why Pekka have not given the book to Merja.'

These topics occupy position(s) that the standard analysis does not project. Notice that they occur above the auxiliary in (7a), so that the position of the lexical verb is irrelevant.

Fourth, it is possible to dislocate arguments towards the end of the clause, a phenomenon first discussed by Vilkuna (1989) and later analyzed in more detail by

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Brattico (2016, 2018), the latter which argues that the operation correlates with informational focus interpretation of the moved constituent. This is illustrated in (8).

(8) *Nonlocal rightward movement*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ?Kirja-n$_2$ | käski | ___$_1$ | Merja-n | lainata | ___$_2$ | kirjastosta | *Pekka*$_1$. |
| *book*-ACC | *asked*.3SG | | *Merja*-GEN | *to.borrow* | | *from.library* | *Pekka*.NOM |

'About the book, Pekka (=information focus) asked Merja to borrow it from the library.'

The operation is limited neither to the grammatical subject nor to the last position of the clause. It remains to be analyzed rigorously. One of the main goals of the present work is to fill in this gap.

Fifth, although the standard model explains how it is possible to topicalize several types of constituents, it does not explain why infinitival topics, such as those illustrated in (9), feel marginal.

(9) a.

| | | | | | |
|---|---|---|---|---|---|
| ??[Syödä | lääkkeitä]$_1$ | Jari | e-i | halun-nut | ___$_1$. |
| *to.eat* | *medicine* | *Jari*.NOM | *not-3*SG | *want*-PAST | |

'Jari did not want to eat MEDICINE.'

b.

| | | | | |
|---|---|---|---|---|
| ?*[Merjan | lainata | kirja-n | kirjastosta]$_1$ | käski |
| *Merja*.GEN | *to.borrow* | *book*-ACC | *from.library* | *asked* |
| Pekka$_1$. | | | | |
| *Pekka*.NOM | | | | |

Fronting of infinitival phrases (if this is indeed how these clauses are derived) creates further distortions in the ordering of the grammatical heads in the sentence. I find these constructions marginal but not ungrammatical.

Another observation, completely unaccounted for, is the fact that genitive arguments are much more resistant to movement than nominative or accusative arguments.[3] The pattern is illustrated by the two examples in (10). I judge (10a) to be ungrammatical; (10b) is marginal or ungrammatical. Compare (10) with (8).

(10) a.

| | | | | | |
|---|---|---|---|---|---|
| *Jari | käski kirja-n | lainata | ___$_1$ | kirjastosta | Merja-n$_1$. |
| *Jari*.NOM | *asked book*-ACC | *to.borrow* | | *from.library* | *Merja*-GEN |

b.

| | | | | | |
|---|---|---|---|---|---|
| ?*Huomenna | pitää | ___$_1$ | syödä | lääkkeitä | Merja-n$_1$. |
| *tomorrow* | *must.0* | | *to.eat* | *medicine* | *Merja*-GEN |

'Merja must eat medicine tomorrow.'

Something prevents genitive arguments from moving into positions that are available for nominative, accusative or partitive arguments. Examination of the whole corpus of all word order permutations of certain basic Finnish construction types shows that the pattern is general. Genitive arguments resist noncanonical positioning, especially to the right, independent of the construction. This will become evident later in this article.

Completely unexplained and/or unexplored is also the fact that infinitival clauses accept multiple topics and/or subjects, at least to some degree:

(11) ??Jari käski [kirja-t$_2$ Merja-n$_1$ palauttaa __$_1$ __$_2$ kirjastoon].
*Jari.NOM asked books-ACC Merja-GEN to.return to.library*
'Jari asked that the books, Merja would return to the library.'

It remains unclear (indeed, unaddressed) if such infinitival phrases contain left peripheral cartographies much like the finite clause. Huhmarniemi (2012) shows that many infinitival phrases contain at least one A′ edge position. The semantic interpretation associated with these word order variations is unclear. They feel felicitous if interpreted as expressing contrastive focus or perhaps also topic, but the intuition is quite weak.

It is possible to combine the properties enumerated above, for example by topicalizing an infinitival clause with two topics (12a), perhaps even in a clause in which a head moves over another head (12b).

(12) a. ??[Lääkkei-tä$_1$ Merja-n syödä __$_1$]$_2$ käski Jari __$_2$
*medicine-PAR Merja-GEN to.eat asked Jari.NOM*
'Jari asked Merja to eat medicine.'

b. ?*[Lääkkei-tä$_1$ Merja-n syödä __$_1$]$_2$ antanut ei __$_2$ Jari.
*medicine-PAR Merja-GEN to.eat give not Jari*
'Jari did not let Merja to eat medicine.'

I judge both sentences to be grammatical (possible and understandable in some context) but quite marginal.[4]

A final problem that I would like to address concerns the graded acceptability of many of the examples reported in the preceding text. The phenomenon is interesting in several ways. First, without a principled way of dealing with marginality it is hard to use marginal sentences as evidence. They come out as 'unclear' evidence, hence their status in any argument can be called into question. The second concern, often neglected, is the fact that marginality must be part of linguistic competence: as much as native speakers know that a sentence is grammatical or ungrammatical, they also know if it is marginal (assuming judgments does not fluctuate randomly, an assumption I will return to later). Finally, this author's experiment with all mathematically possible word orders in Finnish suggests that something systematic is at play. Marginality is not at all uncommon: in a more systematic judgment task with random word order permutations, reported later in this article, I found that ~24% of the sentences were marginal in various ways (~75% ungrammatical). In addition, after examining thousands of scrambled sentences it is hard not to notice that there are patterns. For example, it seems to hold that nominative and accusative arguments produce marginality when they occur in noncanonical positions, if any deviance at all, whereas noncanonical positioning of genitive arguments produce ungrammaticality or extreme marginality. In addition, marginality seems to increase as a function of the number of specifiers and/or topics occurring in association with any given grammatical head. Whatever the source of marginality, it does not seem to constitute mere linguistic noise. Ideally we should try to find some principled way of approaching this phenomenon, too.

I will propose an analysis of Finnish word order in this article that addresses most of these concerns. The basic idea is that scrambled word orders are unnatural for the human parser and confuse language comprehension (see Braze 2002, Hofmeister et al. 2013). To examine this idea rigorously I adopt a parser-friendly top-down approach (Phillips 1996, 2003; Chesi 2012, Brattico 2019a; Brattico & Chesi 2020) that has been further influenced by the dynamic syntax framework (Kempson et al. 2001, Cann et al. 2005), and then apply it to the analysis of Finnish word order.

## 3. The framework

There are several reasons to distinguish grammatical competence, knowledge of language, from its use (Chomsky 1965). One is that while any theory of language use must incorporate a theory of competence, the vice versa is not necessarily true. It is possible to construct a theory of grammatical well-formedness without taking performance factors, such as processing efficiency, accuracy, irrationality, or error recovery, into account. It does not follow from this, however, that performance is irrelevant to competence. As much as the human language faculty must operate within the boundaries set by the human conceptual-intentional system(s), it must also function within the boundaries set by sensory systems involved in comprehension. It could be that such limits are insignificant, but whether they are or are not must be determined by empirical inquiry.[5] One such inquiry is argued for in this article. I will argue that the explanation of free word order benefits from a shift from language production into comprehension.

Let us examine how the core computations of the language faculty might operate within the context of language comprehension. Let us assume that language incorporates an elementary recursive ability, call it Merge. Merge takes two elements $\alpha$, $\beta$ and yields [$\alpha$ $\beta$], a combination of the two (Chomsky 1995:Chapter 4, 2008; Chomsky, Gallego & Ott 2019). This does not predict how $\alpha$ and $\beta$ are selected, which is a matter of free will (Chomsky 1959). What matters for the theory of competence is whether the combination of $\alpha$ and $\beta$ is well-formed, grammatical, or an admissible operation. On the other hand, when the matter is looked from the perspective of language comprehension, Merge must construct phrase structures on the basis of a linear string of words that arrives to the language faculty through the one-dimensional PF-interface. This operation in the comprehension model substitutes 'selection by free will' in the production model. This shift is nontrivial.

Let us assume, following Phillips (1996), that Merge can operate on the basis of a linear string of words. While Phillips assumes that the parsing operation that maps the input string into a phrase structure is also a theory of grammar/competence, hence that parsing = grammar, let us take a weaker position according to which the theory of Merge must be consistent with this scenario. The justification for the weaker thesis is that native speakers can parse sentences they receive through their sensory systems. It follows from this that because the input is linearized from left to right, Merge must be able to operate countercyclically by merging constituents in a top–down/left–right order. Suppose the input contains two words $\alpha + \beta$. Suppose, in addition, that $\alpha + \beta$ arrive to the language faculty through the

PF-interface, linearly ordered, after which they are matched with lexical entries in the lexicon (or surface vocabulary) and are then merged together to yield [$\alpha$ $\beta$]. I will assume, mirroring the standard linearization algorithm, that if $\beta$ follows $\alpha$ at the PF interface, it will be merged to the right edge of the phrase structure (hence the operation could be called, following Phillips, 'Merge Right'). 'Right edge' refers to the top node together with its right daughter, right granddaughter, and so on. To avoid any misunderstanding, I will refer to the Merge operation of this type as Merge$^{-1}$. The superscript −1 refers to the fact that the operation performs an 'inverse' of the bottom-up Merge.

Suppose, to consider a more realistic example, that the input is a Finnish sentence *Pekka käski heidän auttaa Merjaa* 'Pekka asked them to.help Merja'. This would generate (13), given in pseudo-English for simplicity, in which each line represents one step in the derivation.

| | | | | | |
|---|---|---|---|---|---|
| (13) | *Pekka* + | *asked* + | *them* + | *to.help* + | *Merja* |
| | ↓ | ↓ | \| | \| | \| |
| | [Pekka | asked] | ↓ | \| | \| |
| | [Pekka | [asked | them]] | ↓ | \| |
| | [Pekksa | [asked | [them | to.help]]] | ↓ |
| | [Pekka | [asked | [them | [to.help Merja]]]] | |

The derivation proceeds from left to right and from top to bottom, following the incremental parsing process. On the other hand, derivation (13) assumes that each word is merged to the right of the bottom constituent. This assumption is unrealistic. If the subject were itself a complex constituent, the derivation could have a step in it in which the incoming word is merged to the top right node, not to the bottom right node. For example, if a previous derivation had generated [*A man who asked them to help Merja*], the next word could be merged to the top right position (as in 'DP + *laughed*'). As a matter of fact, any merge site at the right edge between the top and bottom nodes must be available in principle. This means that instead of selecting a predetermined syntactic interpretation the model must access several possibilities and explore them in some order. To overcome this problem, I assume here, following Brattico (2019a), that all accessible merge sites are ranked and that the ranking creates a search space that the parser-grammar explores recursively. If it finds a solution that does not work (i.e. encounters a garden path), it backtracks to an earlier point by using the search space generated from these rankings. If all options have been explored without reaching grammatical output, the sentence is categorized as ungrammatical. This operation provides the core of what I will call the 'Phillips cycle' in this article, in which words consumed from the input are merged (recursively, backtracking if needed) to the phrase structure into positions determined by the ranking. The cycle is illustrated in Figure 1.

One possibility is to rank the sites by means of some abstract geometrical property. For example, we could assume that the sites are always ranked and explored in a top–down order. This would be computationally inefficient and psycholinguistically unrealistic. We often know, just by looking at the elements that are about to be merged together, whether the operation is admissible or plausible (or impossible or implausible). For example, the fact that the direct object 'Merja' should be merged

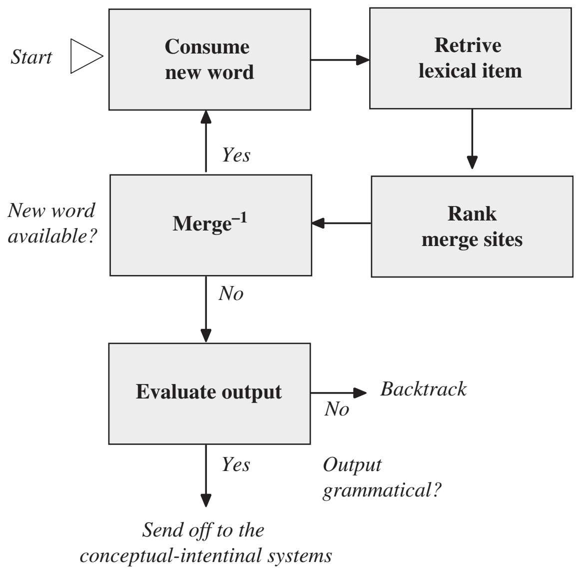


**Figure 1.** Phillips cycle: a new word is consumed, which leads to the retrieval of the corresponding lexical item. Possible merge sites are ranked, after which the highest ranked site is selected, and the cycle begins anew. If there are no more words to be consumed, the output will be evaluated and the algorithm backtracks if the evaluation comes out as negative. If all legitimate branches get explored without a solution, the input is judged as ungrammatical.

to the complement/sister position of the infinitival verb 'to help' in (13) is suggested by the fact that the transitive verb selects for a DP complement. Alternative solutions can be ruled out: finite or infinitival clauses cannot occur in the specifier position of DPs, so these solutions should not be prioritized. Thus, in Brattico (2019a) and Brattico & Chesi (2020) it was assumed, following earlier work by Chesi (2004, 2012), that top–down selectional features are implemented by means of lexical selection features. A transitive verb has a lexical selection feature COMP:D which says that it selects for or 'expects' a DP-complement. Specifier selection was also assumed in the present study: D, for example, does not accept finite tensed clauses or infinitival clauses as its specifier, hence it is endowed with features –SPEC:T/FIN and –SPEC:T. Lexical selection features were used to rank the merge sites: when they match, the solution is ranked higher, and if there is a mismatch, lower. Lexical features are also used to evaluate the output: if the output of the derivation does not satisfy lexical selection features of one or several lexical items, it will be rejected, and the parser will backtrack. Because the initial ranking is based on the satisfaction of selectional features, the output will typically satisfy them as well.[6] The internal operation of the Phillips cycle, as delineated here, will be subjected to a simulation test in Section 5.

Another approach to natural language that has inspired the present approach is the Dynamic Syntax (DS) framework (Kempson et al. 2001, Cann et al. 2005). The DS framework starts from a parsing-oriented perspective similar to Phillips (1996): both competence and performance are based on the ability to process linguistic input from the PF-interface. Accordingly, 'knowing a language is knowing how to parse it' (Cann et al. 2005:1). DS, like the current approach, models language comprehension

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as an incremental, dynamic operation, in which the phrase structure representation is constructed in a step-by-step manner on the basis of incoming words.

## 4. A top–down analysis of free word order

### *4.1 The problem of free word order*

Consider a sentence in Finnish in which the grammatical subject is the last (rightmost) element of the clause. Let us assume (not unrealistically) that the bracketed phrase in (14) is what the parser-grammar has constructed so far, and that the next word to be consumed is *Pekka* 'Pekka.NOM'.

(14) [Kirja-n [käski [$_{vP}$ $\_\_{1}$ [palauttaa Merjalle]]]] + *Pekka*$_1$.
*book-ACC asked to.return to.Merja Pekka.NOM*
'It was Pekka who asked to return the book (=topic) to Merja.'

The correct canonical d-structure position for the subject, according to the widely accepted VP-internal subject hypothesis, is Spec,vP, indicated by '$\_\_{1}$' in the example above. The system elucidated in the previous chapter is not able to process these sentences correctly, as it will generate *Pekka* into a wrong position.

To solve this problem I suggest that the human parser reconstructs such orphan arguments by utilizing two cycles: a FIRST PASS PARSE, which reads and analyzes a chunk of words to create a tentative syntactic analysis by utilizing the Phillips cycle elucidated in the previous section, followed by ADJUNCT RECONSTRUCTION which reconstructs or 'normalizes' arguments to their canonical positions by using morphosyntax. Thus, the orphan argument is first attached to the phrase structure in a 'tentative way' during the first-pass parse and is then reconstructed, by using a grammatical operation, into the canonical position. To implement this idea formally, let us assume that rich case morphology licenses an operation in grammar in which thematic DP arguments are attached to the phrase structure as ADJUNCTS (making them syntactically adverbials, see next section) and are then, by using case morphology as cues, reconstructed into canonical positions by means of adjunct reconstruction that forms adjunct chains.[7] The idea that thematic arguments are (or can be) attached to the structure as adjuncts was originally proposed by Jelinek (1984), Chomsky (1995:Section 4.7.3), Baker (1996) and Cann et al. (2005) and was applied to Finnish by Brattico (2016, 2018). Case features are utilized by the adjunct reconstruction by requiring that they match with the closest functional head of the type determined by the case feature itself. Matching consists of an inverse, top–down version of Agree (for the operation of Agree in the production theory, see Chomsky 2000, 2001, 2008). I call it Agree$^{-1}$. The following condition on Agree$^{-1}$ (15) is used in this study.

(15) *Condition on Agree$^{-1}$*
a. NOM must be checked by a local +FIN head;
b. PAR and ACC must be checked by a local v/ASP head;
c. GEN must be checked by a local −FIN head.

If the parser-grammar detects a case feature that does not satisfy (15), it will promote the argument into an adjunct (i.e. assume that it has been so promoted by the

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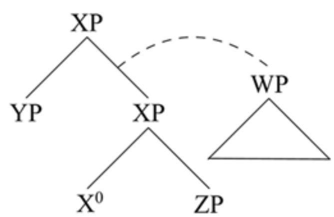
speaker during production) and attempt to reconstruct it into a position that does satisfy (15). Reconstruction is implemented by locating the left edge of the minimal tensed finite clause and by searching downwards for a position that satisfies (15). The first position that satisfies the condition is selected.[8] The adjunct promotion-and-float cycle is then added to the Phillips architecture described in the previous section. The details of the adjunction operation will be elucidated in the next section.

### *4.2 Adjunct and head reconstruction*

If richly case-marked thematic arguments are merged to the phrase structure as adjuncts, then what are adjuncts and adjunction? Manninen (2003), building on the influential analysis of adjuncts by Cinque (1999), assumes that Finnish manner adverbs are attached to the phrase structure as specifiers of expanded vP-projections. Chesi (2013) develops the same idea within the context of the parser-friendly top–down grammar. These theories maintain that adverbials, like arguments, have fixed canonical positions. If, however, we use the theory of adjuncts to explain free word order, we cannot begin from a theory of adjuncts that posits canonical positions.

One analysis of adjuncts that is consistent with the present approach is that of Ernst (2001), who proposes that adjuncts do not have canonical positions. Adjuncts are defined as nonheads that are not sisters to a head (i.e. they are noncomplements), such that they are furthermore not specifically designated as specifiers. I follow this proposal but assume that phrasal (or maximal) noncomplements are adjuncts if they are designated as such; otherwise they are specifiers (both formalizations are of course possible). I follow Chomsky (1995, 2004) and assume that the 'adjunct Merge' is distinguished minimally from argument Merge. Specifically, I assume that adjuncts constitute geometrical constituents of the phrase structure, being merged to the phrase structure as maximal categories, but are excluded from selection and label computations. These assumptions are illustrated in (16), in which WP constitutes the right branch of the node immediately below the highest XP but is not selected and does not project. We can imagine of the adjunct phrase as being 'pulled out' of the main structure and put into a secondary syntactic working space.

(16) $[_{XP}$ YP $[_{XP}$ $[X^0$ ZP] ⟨WP⟩]] (⟨WP⟩ = adjunct)




Canonical adjunct positions are licensed by a formal linking mechanism that ensures that the adjunct can be linked with a suitable functional head (V for VP-adverbials, T for TP-adverbials, and so on).[9] In the case of argument adjuncts, the formal linking mechanism is based on dependencies between case features and features of local functional heads (e.g. ±FIN), as explained earlier.[10]

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It was noted in Section 2 that the distribution of genitive arguments is not as free as that of nominative, accusative or partitive arguments. The simplest possible hypothesis, adopted as a tentative working hypothesis in this work, is to exclude genitive arguments from the adjunct promotion-and-float mechanism. Whether this simple stipulation suffices to capture the notion of possible word order in Finnish will be tested by means of concrete simulation.

The adjunct reconstruction mechanism described in Section 4 does not work correctly in the case of *wh*-interrogatives. They are regulated by A′- movement. I will follow Brattico & Chesi (2020) who propose a theory of A′-reconstruction in connection with a Phillips-style top–down theory. In Finnish, if the phrase in the operator position is morphologically unmarked, it will be interpreted as contrastively focused and is typically stressed prosodically (Vilkuna 1989). I represent prosodic stress by a prosodic feature FOC in the input.[11] The reconstruction algorithm will return the focused phrase to the canonical position by A′-reconstruction (Vilkuna 1995, Huhmarniemi 2012, Brattico & Chesi 2020). If the C field is filled in by head (T-to-C) movement, then the prosodic feature is interpreted as representing the C morpheme itself (17). The parser-grammar will then reconstruct the head to the structure.

(17) Käski$_1$#foc Pekka __$_1$ palauttaa kirja-t Merjalle.
*asked.FOC Pekka.NOM to.return book-PL.ACC to.Merja*
'Pekka DID ask one to return the books to Merja.'

An additional complication is presented by the fact that many words arrive to the PF-interface as multimorphemic units, not as single morphemes. The existing algorithm that was available before this study began extracted complex heads in a process that resembled Matushansky's m-merger approach (Matushansky 2006), but which does not suffice to capture nonlocal head movement. I assume the mechanism proposed in Brattico (2020). Suppose that the input string is *Pekka antoi kirjan Merjalle* 'Pekka gave the book to Merja'. The verb *antoi* 'give' is decomposed in the morphological parser into three separate items, T/fin, v and V, which are fed to Merge one by one. They are first combined into a complex head $(TvV)^0$, which is reconstructed by applying HEAD RECONSTRUCTION, an inverse of head movement. Head reconstruction takes the first/highest morpheme inside the complex head (i.e. vV in the case of $(TvV)^0$) and locates the closest position in downward direction on the projectional spine of the sentence in which it can merge that head without violating lexical selection. Thus, the small verb $(vV)^0$ is reconstructed into the position in which it is selected by T; V is reconstructed from within v into a position in which it is selected by v. The whole sequence creates the required T–v–V chain from the complex head.

#### 4.3 Summary

A proposal to handle Finnish word order phenomenon was developed within the context of Phillips' parsing-friendly minimalist theory (Phillips 1996), dynamic syntax (Cann et al. 2005) and our prior work developing the latter two approaches (Brattico 2019a, Brattico & Chesi 2020). An input string is fed to the model as a linear string of phonological words, after which each word undergoes lexical processing. The result of successful lexical processing is the retrieval of a lexical item that

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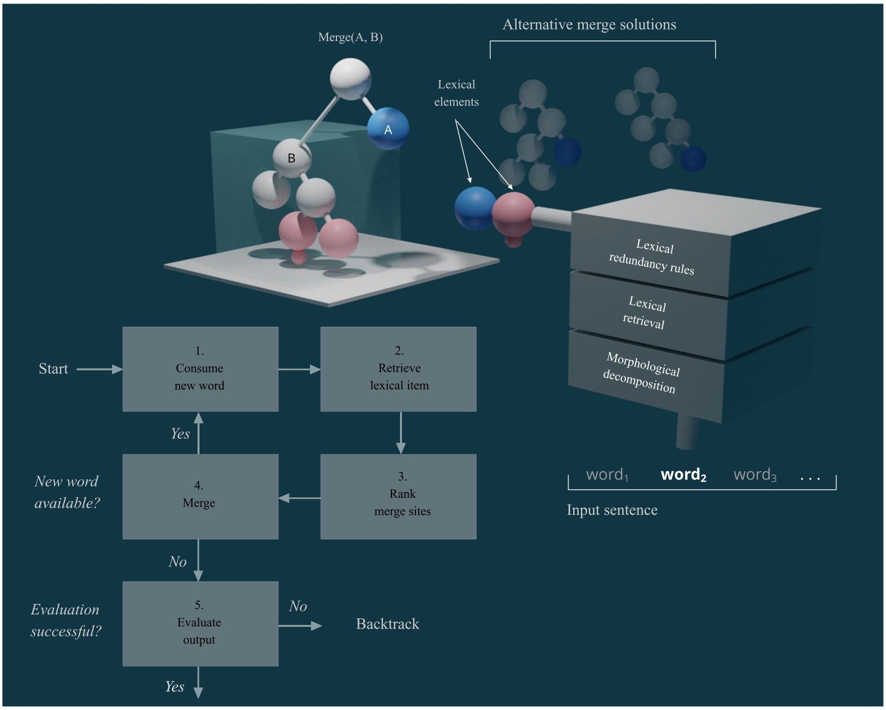


**Figure 2.** Core components of the proposed language comprehension model illustrated in a nontechnical way. See main text for explanation.

is merged to the structure. The string is read from left to right, which means that lexical constituents are merged to the structure in a top–down fashion ('Merge' in Figure 2 below). Because the correct (or intended) position of any lexical constituent is unknown, all solutions are ranked and explored in the ranked order. They are explored only if the highest-ranking solution does not produce a legitimate parse (i.e. the model enters a garden-path). This process creates a tentative first pass structure for the input string, which is normalized by applying a sequence of operations: (i) complex heads are spread out (i.e. $(CTvV)^0$ creates [C ... [T ... [v ... V ... ]]]), (ii) adjuncts are reconstructed into canonical positions and (iii) A′/A-movement is reverse-engineered. The resulting structure is passed on to the LF-interface, which checks that it constitutes a legitimate, semantically interpretable LF-object. Failure at this stage results in recursive backtracking. It is assumed that all case-marked arguments, with the exception of the genitive, can be treated as adjuncts and are floated back into their canonical positions. Case forms are used to locate the canonical position by utilizing $Agree^{-1}$, an inverse of the standard Agree. These assumptions, and the components of the theory, are illustrated in Figure 2.

It remains to be shown that the analysis captures the properties of Finnish word order. The usual method in the natural sciences for justifying a theory is to show by deductive calculation that it derives the observations. To do this, the model was formalized as a computer program that processes Finnish finite clauses. This procedure and the results are reported in Section 5.

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## 5. Simulation experiment

### 5.1 Introduction

The correctness of the proposed hypotheses was assessed by means of computer simulation. Three questions were addressed: (i) whether the comprehension model delineated above is able to parse CANONICAL Finnish finite sentences; (ii) if it is able, whether the same model can parse also NONCANONICAL word orders; and, if it can, (iii) whether marginality, as judged by native speakers, correlates with computational complexity of the parsing process, supporting the notion that marginality emerges from the fact that such sentences are 'unnatural' for the human parser.

### 5.2 The algorithm

The source code embodying the model delineated in the two preceding sections together with technical documentation is available in the public domain and exists as a frozen branch of the master code.[12] The algorithm embodies the assumptions detailed in Sections 3 and 4 together with a few auxiliary conjectures (e.g. concerning morphological parsing, creation of head movement chains). The implementation was written in Python. The algorithm was provided with a lexicon that contains the required words and their lexical features. The lexicon was disambiguated and normalized. Prosodic emphasis was marked as a feature in the input (#foc). The input had no other grammatical annotation and consisted of a linear order of phonological words.

### 5.3 The output of the algorithm and raw data

The algorithm, which read and processed each sentence on a word-by-word basis, provided a parsing solution (structural analysis) for each input together with an overall well-formedness score and a log file documenting the computational steps consumed in the derivation. If no parsing solution was found, the input sentence was judged as ungrammatical. This notion of ungrammaticality was proposed by Cann et al. (2005), who assume that for 'a string to be ungrammatical, there must be no possible sequence of actions whereby a logical form can be constructed' (p. 84).[13] The log and the result files constitute the raw machine-generated data of the present study. Both are available in public domain. All files used in the simulation are organized so that each input sentence is provided with a unique number identifier, and the corresponding items can be then found from the result and log files by searching for that number. Author's judgments, which constitute the gold standard, are available in separate files. The author verified the grammatical analyses provided by the algorithm. Creation of the gold standard is detailed in Section 5.5. The organization of the input/output structure used in this study is illustrated by Figure 3.

### 5.4 Materials and procedure

A small group of grammatical seed sentences (24 sentences in total) was first created which consisted of canonical Finnish finite clauses. These items were created by crossing four syntactic variables: valency (intransitive, transitive, ditransitive),

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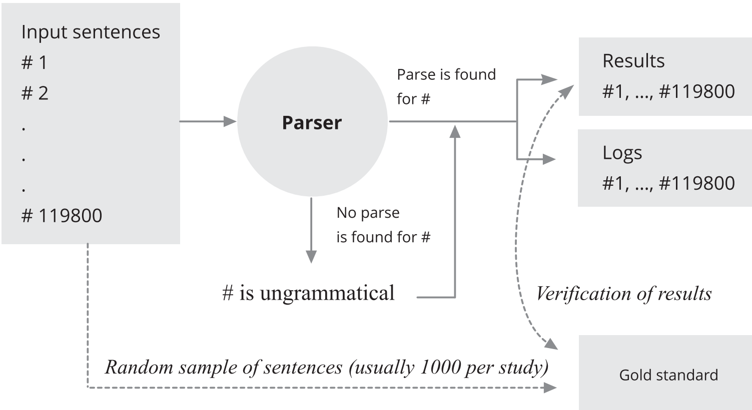


**Figure 3.** Design of the study. The input corpus constitutes a separate text file that is fed to the algorithm sentence by sentence. Each sentence is processed one word at a time. If no parse is found, the input is classified as ungrammatical. Reasons for ungrammaticality are left to the derivational log file. If a solution is found, it is provided with a grammatical analysis. The log file then contains a step-by-step derivation ending up with the accepted solution. Author native speaker judgment is used as a gold standard against which the performance of the model is compared.

polarity (negative, affirmative), embedding (no embedding, infinitival complementation) and the presence of an additional adverbial (yes, no) (a total of $3 \times 2 \times 2 \times 2 = 24$ construction types). The seed sentences are listed in Table 1.

The main corpus was created by generating all mathematically possible and unique word order combinations from the seed sentences. For each sentence in the main corpus, an alternative was created which had the prosodic emphasis on the first word. This must be done because Finnish verb-initial clauses are grammatical if and only if the verb is stressed prosodically and has thus moved to C (with the exception of a few exceptional verb-initial constructions, not included in this study). The main corpus consisted of 119,800 word orders.

### *5.5 Creation of the gold standard*

The output was compared with a gold standard that was based on the author's native speaker judgment. Because of the vast volume of the judgments (approximately 5000 sentences were judged for grammaticality and marginality in this study), and because they required understanding of abstract linguistic features (e.g. FOC), filtering of irrelevant parses and pragmatic anomalies and awareness of implicit contexts that are crucial in assessing the grammaticality of word orders, raw acceptability scores elicited from linguistically untrained participants were considered unreliable. Author's judgments were performed twice, however, once before the algorithm was run (in June 2019) and then six months later (in January 2020).

I used the question 'Could this sentence possibly be used in some context?' as a guide in assessing grammaticality. Grammaticality was a binary choice: grammatical or ungrammatical. I used a four-level system for assessing marginality: 'clear', which

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**Table 1.** Seed sentences covering sentences in different valency (intransitive, transitive, ditransitive), polarity (affirmative, negative), with or without infinitival embedding and with or without an adverbial.

| **Group 1. Declarative clauses** | **Group 5. Negation and adverbial** |
|---|---|
| *Pekka nukkui.* | *Pekka ei nukkunut kuorsaamalla.* |
| 'Pekka slept.' | 'Pekka did not sleep (by) snoring.' |
| *Pekka ihailee Merjaa.* | *Pekka ei häiritse Merjaa kuorsaamalla.* |
| 'Pekka admires Merjaa.' | 'Pekka does not disturb Merja by snoring.' |
| *Pekka antoi kirjan Merjalle.* | *Pekka ei antanut kirjaa Merjalle heittämällä.* |
| 'Pekka gave a book to Merja.' | 'Pekka did not give the book to Merja by throwing.' |
| **Group 2. Negative clauses** | **Group 6. Negated infinitival embedding** |
| *Pekka ei nukkunut.* | *Pekka ei käskenyt heidän nukkua.* |
| 'Pekka did not sleep.' | 'Pekka did not ask them to sleep.' |
| *Pekka ei ihaile Merjaa.* | *Pekka ei käskenyt heidän ihailla Merjaa.* |
| 'Pekka does not admire Merja.' | 'Pekka did not ask them to admire Merja.' |
| *Pekka ei antanut kirjaa Merjalle.* | *Pekka ei käskenyt heidän antaa kirjaa Merjalle.* |
| 'Pekka did not give the book to Merja.' | 'Pekka did not ask them to give the book to Merja.' |
| **Group 3. Embedded infinitivals** | **Group 7. Infinitival embedding with an adverbial** |
| *Pekka käski heidän nukkua.* | *Pekka käski heidän nukkua kuorsaamalla.* |
| 'Pekka asked them to sleep.' | 'Pekka asked them to sleep (by) snoring.' |
| *Pekka käski heidän ihailla Merjaa.* | *Pekka käski heidän häiritä Merjaa kuorsaamalla.* |
| 'Pekka asked them to admire Merja.' | 'Pekka asked them to disturb Merja by snoring.' |
| *Pekka käski heidän antaa kirjan Merjalle.* | *Pekka käski heidän antaa kirjan Merjalle heittämällä.* |
| 'Pekka asked them to give the book to Merja.' | 'Pekka asked them to give the book to Merja by throwing.' |
| **Group 4. Adverbial** | **Group 8. Negated infinitival embedding with an adverbial** |
| *Pekka nukkui kuorsaamalla.* | *Pekka ei käskenyt heidän nukkua kuorsaamalla.* |
| 'Pekka slept while snoring.' | 'Pekka did not ask them to sleep by snoring.' |
| *Pekka häiritsee Merjaa kuorsaamalla.* | *Pekka ei käskenyt heidän häiritä Merjaa kuorsaamalla.* |
| 'Pekka disturbs Merja by snoring.' | 'Pekka did not ask them to disturb Merja by snoring.' |
| *Pekka antoi kirjan Merjalle heittämällä.* | *Pekka ei käskenyt heidän antaa kirjaa Merjalle heittämällä.* |
| 'Pekka gave the book to Merja by throwing.' | 'Pekka did not ask them to give the book to Merja by throwing.' |

meant that the clause was canonical; 'mildly marginal', which referred to sentences that felt noncanonical but otherwise normal and were marked with single question mark; 'clearly marginal', which referred to clauses that felt clumsy, strange or exceptional and were marked with double question mark; and 'extremely marginal',

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which was associated with sentences that were extremely marginal, borderline ungrammatical, or if it was unclear if the sentence was ungrammatical or grammatical. The latter were marked with ?*.[14] The line between extremely marginal and ungrammatical sentences proved to be difficult to draw, so not much significance will be put on this distinction in the analyses. These judgments were converted into a Likert-scale so that 1 = grammatical and clean, 5 = ungrammatical, and the three marginality grades between so that 2 = mildly marginal, 3 = clearly marginal and 4 = extremely marginal, borderline ungrammatical. The algorithm produced the same five-point classification, with 5 corresponding to the situation in which no parse was found. My ratings are provided in separate files associated with this article. Furthermore, my judgments should be interpreted as establishing a rank (not interval or categorical) scale. The point is to compare sentences in the corpus with each other rather than measuring them in some absolute sense.

I compared the machine-generated, predicted output from the model with the gold standard in two ways. All analyses were conducted by taking a representative random sample from the corpus (1000 sentences in most analyses). To check that the parsing solutions were correct, the machine-generated solution was verified by the author. In a second analysis, the author assessed the corpus first independently and the results were compared with the machine-generated output. The sample that was used to verify parsing solutions was different from the one the author used to perform the blind grammaticality and marginality judgments.

Use of mechanical deductive calculations in empirical justification in theoretical linguistics creates challenges due to scalability. Because the number of possible input sentences (here possible word orders) increases exponentially as a function of the number and complexity of the seed sentences, the size of the test corpus increases extremely fast. Addition of one more syntactic parameter into the present dataset would have increased the number of sentences into millions. While a computer can perform almost any number of calculations, the output must still be matched against a gold standard that is produced by native speaker(s). Yet, vast mechanically generated raw test corpora are not suitable targets for linguistically untrained informant judgment. Experimental materials must be carefully curated so that they measure, reliably and consistently, what they are intended to measure. In an ideal case collaborative work between computational modelling, corpus linguistics and experimental work should result in standardized test corpora that are accepted as normative gold standards in the field.

### 5.6 Results

#### 5.6.1 Derivation of the canonical seed sentences: Study 1

A baseline was established by feeding the algorithm with the seed sentences. The model provided correct solutions for all canonical seed sentences, did so without errors, and as efficiently as possible without any garden-pathing (Table 2a and 2b). I use [,] for regular constituent and (,) for adjuncts.

Operator movement was tested by transforming each seed sentence into an interrogative by substituting one of its arguments with an interrogative pronoun and fronting it. The algorithm processed interrogatives correctly. Study 1 confirms that the proposed

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**Table 2a.** Solutions provided by the algorithm for seed sentences in Groups 1–4 in Table 1.

| | |
|---|---|
| 1 | *Pekka nukkui.*<br>[(D *Pekka*):1 [T/fin [(__):1 *nukku*]]]<br>Pekka sleep |
| 2 | *Pekka ihailee Merjaa.*<br>[(D *Pekka*):2 [T/fin [(__):2 [v [*ihailee* [D *Merjaa*]]]]]]<br>Pekka admire Merja |
| 3 | *Pekka antoi kirjan Merjalle.*<br>[(D *Pekka*):4 [T/fin [(__P):4 [v [*antaa* [[D *kirja*] (P(*lle*) [D *Merja*-])]]]]]]<br>Pekka give book to Merja |
| 4 | *Pekka ei nukkunut.*<br>[(D *Pekka*):1 [*ei* [(__):1 [T [(__):1 *nukku*]]]]]<br>Pekka not sleep |
| 5 | *Pekka ei ihaile Merjaa.*<br>[(D *Pekka*):3 [ *ei* [(__):3 [T [(__):3 [v [*ihailee* [D *Merjaa*]]]]]]]<br>Pekka not admire Merja |
| 6 | *Pekka ei antanut kirjaa Merjalle.*<br>(D *Pekka*):7 [*ei* [(__):7 [T [(__):7 [v [*antaa* [[D *kirja*] (P(*lle*) [D *Merja*-])]]]]]]]]<br>Pekka not give book to Merja |
| 7 | *Pekka kaski heidän nukkua.*<br>[(D *Pekka*):4 [T/fin [(__):4 [*käske* [[D *heidän*]:5 [A/inf [(__):5 *nukku*]]]]]]]<br>Pekka ask they sleep |
| 8 | *Pekka käski heidän ihailla Merjaa.*<br>[(D *Pekka*):8 [T/fin [(__):8 [*käske* [[D *heidän*]:9 [A/inf [(__):9 [v [*ihailee* [D *Merjaa*]]]]]]]]]]<br>Pekka ask they admire Merja |
| 9 | *Pekka käski heidän antaa kirjan Merjalle.*<br>[(D *Pekka*):16 [T/fin [(__):16 [*käske* [[D *heidän*]:17 [A/inf [(__):17 [v [*antaa* [[D *kirja*] (P(*lle*)<br>[D *Merja*-])]]]]]<br>Pekka ask they give book to Merja |
| 10 | *Pekka nukkui kuorsaamalla.*<br>[(D *Pekka*):3 [T/fin [(__):3 [*nukku* (*malla kuorsaa*)]]]]<br>Pekka sleep by snoring |
| 11 | *Pekka häiritsee Merjaa kuorsaamalla.*<br>[(D *Pekka*):4 [T/fin [(__):4 [v [*häiritsee* [[D *Merjaa*] (*malla kuorsaa*)]]]]]]<br>Pekka disturb Merja by snoring |
| 12 | *Pekka antoi kirjan Merjalle heittämällä.*<br>[(D *Pekka*):6 [T/fin [(__):6 [v [*antaa* [[D *kirja*] ((P(*lle*) [D *Merja*-])(*malla heittä*))]]]]]]<br>Pekka give book to Merja by throwing |

model produces plausible solutions for all Finnish seed sentences. The parsing process did not involve backtracking or unrealistic search: every solution was found immediately.

### *5.6.2 Noncanonical word orders: Study 2*

The correctness of the model in connection with noncanonical word orders was examined next. A random sample of 1000 sentences were drawn from the whole corpus, which was first judged blindly by the author. The algorithm then processed the same 1000 sentences, after which the output was compared to the blind

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**Table 2b.** Solutions provided by the algorithm for seed sentences in Groups 5–8 in Table 1.

| | |
|---|---|
| 14 | *Pekka ei nukkunut kuorsaamalla.*<br>[(D Pekka):5 [ei [(__):5 [T [(__):5 [nukku (malla kuorsaa)]]]]]]<br>Pekka not sleep by snoring |
| 15 | *Pekka ei häiritse Merjaa kuorsaamalla.*<br>[(D Pekka):7 [ei [(__):7 [T [(__):7 [v [häiritsee [[D Merjaa] (malla kuorsaa)]]]]]]]]<br>Pekka not disturb Merja by snoring |
| 16 | *Pekka ei antanut kirjaa Merjalle heittämällä.*<br>[(D Pekka):11 [ei [(__):11 [T [(__):11 [v [antaa [[D kirja] ((P(lle) [D Merja-]) (malla heitta))]]]]]]]]<br>Pekka not give book to Merja by throwing |
| 17 | *Pekka ei käskenyt heidän nukkua.*<br>[(D Pekka):7 [ei [(__):7 [T [(__):7 [käske [[D heidän]:9 [A/inf [(__):9 nukku]]]]]]]]<br>Pekka not order they.GEN to sleep |
| 18 | *Pekka ei käskenyt heidän ihailla Merjaa.*<br>[(D Pekka):13 [ei [(__):13 [T [(__):13 [käske [[D heidän]:15 [A/inf [(__):15 [v [ihailee [D Merjaa]]]]]]]]]]]]<br>Pekka not order they.GEN to admire Merja |
| 19 | *Pekka ei käskenyt heidän antaa kirjaa Merjalle.*<br>[(D Pekka):25 [ei [(__):25 [T [(__):25 [käske [[D heidän]:27 [A/inf [(__):27 [v [antaa [[D kirja] (P(lle) [D Merja-])]]]]]]]]]]]]<br>Pekka not order they.GEN to give book to Merja |
| 20 | *Pekka käski heidän nukkua kuorsaamalla.*<br>[(D Pekka):12 [T/fin [(__):12 [käske [[D heidän]:13 [A/inf [(__):13 [nukku (malla kuorsaa)]]]]]]]]<br>Pekka order they.GEN to sleep by snoring |
| 21 | *Pekka käski heidän häiritä Merjaa kuorsaamalla.*<br>[(D Pekka):16 [T/fin [(__):16 [käske [[D heidän]:17 [A/inf [(__):17 [v [häiritsee [[D Merjaa] (malla kuorsaa)]]]]]]]]]]<br>Pekka order they.GEN to disturb Merja by snoring |
| 22 | *Pekka käski heidän antaa kirjan Merjalle heittämällä.*<br>[(D Pekka):24 [T/fin [(__):24 [käske [[D heidän]:25 [A/inf [(__):25 [v [antaa [[D kirja] ((P(lle) [D Merja-])(malla heitta))]]]]]]]]]]<br>Pekka order they.GEN to give book to Merja by throwing |
| 23 | *Pekka ei käskenyt heidän nukkua kuorsaamalla.*<br>[(D Pekka):19 [ei [(__):19 [T [(__):19 [käske [[D heidän]:21 [A/inf [(__):21 [nukku (malla kuorsaa)]]]]]]]]]]<br>Pekka not order they.GEN to sleep by snoring |
| 24 | *Pekka ei käskenyt heidän häiritä Merjaa kuorsaamalla.*<br>[(D Pekka):25 [ei [(__):25 [T [(__):25 [käske [[D heidän]:27 [A/inf [(__):27 [v [häiritsee [[D Merjaa] (malla kuorsaa)]]]]]]]]]]]]<br>Pekka not order they.GEN to disturb Merja by snoring |
| 25 | *Pekka ei käskenyt heidän antaa kirjaa Merjalle heittämällä.*<br>[(D Pekka):37 [ei [(__):37 [T [(__):37 [käske [[D heidän]:39 [A/inf [(__):39 [v [antaa [[D kirja] ((P(lle) [D Merja-])(malla heitta))]]]]<br>Pekka not order they.GEN to give book to Merja by throwing |

judgments by the author. Aggregate results from that comparison are provided in Table 3.

Approximately 75% of the judgments produced by the model matched with the author's blind judgment and 100% of the parsing solutions, when they were

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**Table 3.** Prediction error in a sample of 1000 sentences taken from the whole corpus.

| Group | Error category | Number | % |
|---|---|---|---|
| A | Grammatical sentences analyzed wrongly as ungrammatical | 135 | 13.5 |
| | of which judgments were 'extremely marginal' vs. 'ungrammatical' | 95 | 9.5 |
| B | Ungrammatical sentences analyzed wrongly as grammatical | 54 | 5.4 |
| C | Wrong marginality estimation (adjacent categories) | 43 | 4.3 |
| D | Wrong marginality estimation (non-adjacent categories) | 22 | 2.2 |
| E | Wrong parsing output | 0 | 0.0 |

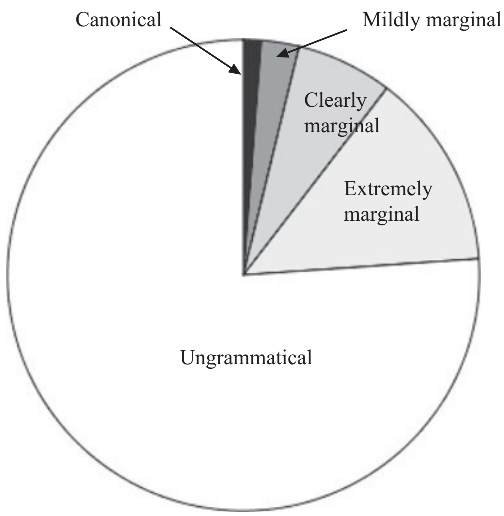


**Figure 4.** Distribution of native speaker grammaticality and marginality judgments. Judgments were generated by including all logically possible word orders from the seed sentences in Table 1 and by evaluating a random sample of 1000 sentences. Evaluation was done by the author. Distinction between adjacent categories should not be regarded as dichotomous or well-defined.

produced, were correct or at least plausible to this author's linguistically informed judgment (based on a sample of 1000 sentences). Notice that most errors in the group A occurred when the algorithm was unable to distinguish 'ungrammatical' from 'extremely marginal', which suggests that the distinction might be difficult to draw or is perhaps unstable or does not exist. If we ignore these, then the prediction error is 15.9%.[15] I will analyze the nature of these errors further below. The distribution of author judgments is provided in Figure 4. This might be taken as an estimate for the freedom in Finnish word order in a corpus of relatively simple constructions (defined by the seed sentences in Table 1).

The log files, written by the algorithm as it processed the test sentences, show that the model's success is based on the components elucidated in Section 4. The algorithm uses the adjunct promotion and the floating technique to reconstruct orphan arguments into their canonical positions by using case morphology. Limited

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distribution of genitive arguments came out correctly when it was assumed that their canonical positions were reconstructed on the basis of order alone. Genitive arguments in Finnish were therefore treated like accusative and nominative arguments in English. Head movement reconstruction was sufficient to reconstruct grammatical heads and was successful in pruning out ungrammatical (i.e. reversed or totally scrambled) head orders. Notice that the head reconstruction was a limited process: it was not able to reconstruct heads into 'upward direction', for example. Verb-initial clauses with prosodic stress were reconstructed correctly, and the same was the case with focused phrases, which were correctly normalized by A′/A-bar reconstruction. Example derivations and analyses are discussed in detail in the supplementary document 'Analysis and derivation of Finnish finite clauses by the algorithm'.

The majority of errors were contributed by sentences in the Group A. Most of them (~70%) consist of word salad sentences that the author judged as extremely marginal (?*) but the model was unable to process and thus classified as ungrammatical. Example (18) illustrates examples from this category. The judgments are mine; the model judged them ungrammatical. Notice the feature #foc that indicates prosodic stress on the first constituent.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (18) | a. | ?*Merjalle#foc | heittämällä | ei | Pekka | heidän | kirja-a |
| | | *to.Merja* | *by.throwing* | *not* | *Pekka* | *they.*GEN | *book-*PAR |
| | | antaa | käskenyt. | | | | |
| | | *to.give* | *order* | | | | |
| | | 'Pekka did not order them to give the book to MERJA by throwing.' | | | | | |
| | b. | ?*Pekka#foc | Merjalle | kirja-a | heidän | ei | käskenyt |
| | | *Pekka* | *to.Merja* | *book-*PAR | *they.*GEN | *not* | *order* |
| | | heittämällä | antaa. | | | | |
| | | *by.throwing* | *to.give* | | | | |
| | | 'PEKKA did not order them to give the book to Merja by throwing.' | | | | | |
| | c. | ?*Pekka#foc | häiritä | kuorsaamalla | ei | käskenyt | heidän |
| | | *Pekka* | *to.disturb* | *by.snoring* | *not* | *order* | *they.*GEN |
| | | Merja-a. | | | | | |
| | | *Merja-*PAR | | | | | |
| | | 'PEKKA did not ask them to disturb Merja by snoring.' | | | | | |

The sentences are extremely odd, perhaps ungrammatical, to a native speaker. Furthermore, the distinction between extremely marginal and ungrammatical is unclear and possibly non-dichotomous. An anonymous *NJL* reviewer, who is a native speaker of Finnish, classified these examples as ungrammatical. If they are ungrammatical, then the model performance is better. On the other hand, to draw any conclusions one has to judge all 1000 sentences. I will return to the nature of these errors at the end of this section.

Category B contained sentences that the model classified wrongly as grammatical. There were a few instances of nonlocal head movement that the model was able to reconstruct but which are not trivial for native speakers. An example of this phenomenon is provided in (19) (#211).

| | | | | | | |
|---|---|---|---|---|---|---|
| (19) ??Käskenyt$_1$#foc | kirja-a | Pekka | ei | _$_1$ | Merjalle | heittämällä |
| *order* | *book*-PAR | *Pekka*.NOM | *not* | | *to.Merja* | *by.throwing* |
| heidän | antaa. | | | | | |
| *they*.GEN | *to.give* | | | | | |

‘Pekka did not ORDER them to give the book to Merja by throwing.’

Are sentences of this type grammatical or ungrammatical? There are no systematic published studies of Finnish nonlocal head movement and thus very little to rely to settle the issue. I leave the problem for future research.

Category C involves prediction errors in marginality estimations that involves adjacent marginality categories. These errors have little or no meaning due to the overlap between the adjacent categories, further quantified below. Category D warrants closer examination. The total number of such errors was negligible, but approximately two thirds of these sentences were ones in which the model underestimated their marginality and was therefore too good in parsing them. This suggests that human comprehension is subject to limitations that the model was not capturing. Table 4 provides a sample of sentences in which the author and the model agreed on marginality, providing an overview of how the model handled marginality and what type of grammaticality–marginality–ungrammaticality continuum it (correctly) predicts to exit.

The relationship between parsing complexity, as predicted by the model, and native speaker marginality judgments was examined next. Because the relevant numbers are meaningful only for sentences which the model judged as grammatical, only such input sentences are included in the analysis. Computational complexity increased linearly as a function of author’s marginality judgments, as shown in Figure 5.

Spearman correlation between parsing complexity (number of computational steps required to provide a solution) and native speaker marginality judgment in sentences that the model judged grammatical was 0.38 ($p < .001$). ‘Number of computational operations’ was the sum of both Merge and Move. Thus, although parsing predicts variation in marginality judgments, it is not the only predicting factor. The hypothesis that one factor affecting marginality could be the number of extra specifiers or topics per grammatical head was also tested. The algorithm computed a DISCOURSE SCORE for each sentence that was a linear function of the extra (>1) specifiers occurring in connection with any head(s) in the output analysis, which was then correlated with the native speaker judgment. The score is recorded as DISCOURSE PLAUSIBILITY in the raw output. A correlation (Spearman correlation 0.57, $p < .001$) was found. Thus, the initial suspicion that marginality could be predicted on the basis of the number of specifiers/topics per head, hence discourse complexity, was verified.

The nature of the errors in the Category A were difficult to discern reliably due to the fact that many of these sentences were excessively complex. To better understand the errors involved with Category A, and hence to examine the problems of the analysis, the model was evaluated by taking a random sample of 1000 sentences from the first four groups (Groups 1–4, Table 1) that were generated by

**Table 4.** A sample of sentences judged similarly by the author and the model, illustrating the grammaticality–marginality–ungrammaticality continuum predicted by the model.

| # | Sentence | Word order | Native | Model |
|---|---|---|---|---|
| 24 | *KUORSAAMALLA häiritsee Merjaa Pekka* | Adv-V-O-S | . | . |
| 25 | *EI Pekka ihaile Merjaa* | n-S-V-O | . | . |
| 32 | *HEIDÄN Pekka käski antaa Merjalle kirjan* | s-S-V-v-IO-O | . | . |
| 48 | *Pekka käski heidän ihailla Merjaa* | S-V-s-v-O | . | . |
| 58 | *HEITTÄMÄLLÄ Pekka antoi kirjan Merjalle* | Adv-S-V-O-IO | . | . |
| 22 | *Pekka käski heidän kirjan antaa Merjalle* | S-V-s-O-v-IO | ? | ? |
| 39 | *MERJALLE käski heidän Pekka antaa kirjan* | IO-V-s-S-v-O | ? | ? |
| 43 | *Kirjan heittämällä Merjalle Pekka antoi* | O-Adv-IO-S-V | ? | ? |
| 64 | *HEITTÄMÄLLÄ Merjalle kirjan antoi Pekka* | Adv-IO-O-V-S | ? | ? |
| 89 | *Pekka heidän Merjalle käski kirjan antaa* | S-s-IO-VO-v | ? | ? |
| 23 | *Kuorsaamalla Pekka Merjaa häiritsee* | Adv-S-O-V | ?? | ?? |
| 49 | *PEKKA kirjan heidän Merjalle käski antaa* | S-O-s-IO-V-v | ?? | ?? |
| 79 | *MERJAA heidän ihailla käski Pekka* | O-s-v-V-S | ?? | ?? |
| 132 | *Heidän Merjalle Pekka kirjan käski antaa* | s-IO-S-O-V-v | ?? | ?? |
| 214 | *Merjalle kirjan Pekka antoi* | IO-O-S-V | ?? | ?? |
| 232 | *ANTAA heidän Pekka Merjalle käski kirjan* | v-s-S-IO-V-O | ?* | ?* |
| 273 | *Heidän kirjan Merjalle antaa käski Pekka* | s-O-IO-v-V-S | ?* | ?* |
| 630 | *ANTANUT kirjaa Pekka Merjalle ei* | V-O-S-IO-n | ?* | ?* |
| 705 | *Heidän Merjaa ihailla Pekka käski* | s-O-v-S-V | ?* | ?* |
| 710 | *Pekka kirjan Merjalle heidän käski antaa* | S-O-IO-s-V-v | ?* | ?* |
| 2 | *KIRJAN Pekka antaa Merjalle käski heidän* | O-S-v-IO-V-s | * | * |
| 5 | *Pekka antaa käski kirjan Merjalle heidän* | S-v-V-O-IO-s | * | * |
| 6 | *Antaa kirjan käski Merjalle Pekka heidän* | v-O-V-IO-S-s | * | * |
| 8 | *HEIDÄN Pekka antaa Merjalle käski kirjan* | s-S-v-IO-V-O | * | * |
| 9 | *PEKKA kirjan Merjalle käski antaa heidän* | S-O-IO-v-s | * | * |

S = main clause subject, V = main clause verb, O = main clause object, IO main clause indirect object, Adv = adverbial, s = infinitival subject, v = infinitival verb, n = negation. Sentence numbers (#) refer to the numbering in the test corpus.

crossing valency (intransitive, transitive and ditransitive) with construction type (simple declarative clauses, negative clauses, clauses with an embedded infinitival, and clauses with an adverbial). This sample contained simpler and shorter sentences. The author judged the sentences blindly and the result were compared with the model output. A summary comparison between author's and model's judgements is provided in Table 5.

Category A could now be broken into three clear subcategories. The first (A1) contained 'V . . . neg' orders that the author judged marginal but the grammar

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**Table 5.** Prediction error in a sample of 1000 sentences constructed from Groups 1–4 in Table 1.

| Group | Error category | Number | % |
|---|---|---|---|
| A | Grammatical sentences analyzed wrongly as ungrammatical | 114 | 11.4 |
| A1 | *V . . . Neg order | 35 | 3.5 |
| A2 | *v . . . V order | 63 | 6.3 |
| A3 | *v . . . s order | 15 | 1.5 |
| A4 | Other | 1 | 0.1 |
| B | Ungrammatical sentences analyzed wrongly as grammatical | 54 | 5.4 |
| C | Wrong marginality estimation (adjacent categories) | 183 | 18.3 |
| D | Wrong marginality estimation (non-adjacent categories) | 55 | 5.5 |
| E | Wrong parsing output | 0 | 0.0 |

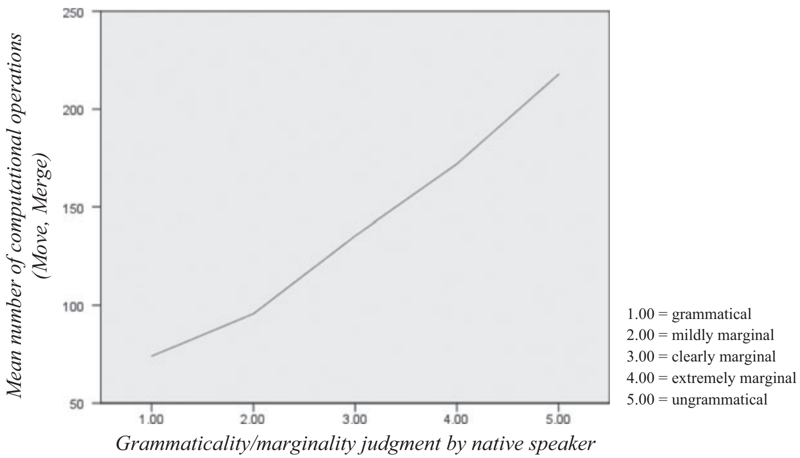


**Figure 5.** Mean value of the total number of computational operations Merge and Move as a function of native speaker judgment (0 = grammatical, 1 = mildly marginal, 2 = clearly marginal, 3 = extremely marginal, 4 = ungrammatical). The main reason for the increase of complexity is due to occurrence of garden paths (parsing decisions that do not lead into a solution) in connection with more marginal sentences.

was unable to parse (20a); the second (A2) contained 'v . . . V' orders (v = infinitival verb, V = main verb) that the author judged marginal but the model was not able to parse (20b); and (A3) contains 'v . . . s' orders some of which the author judged extremely marginal and the model ungrammatical. An example of each category is provided below. Judgments are from author; the model cannot parse them.

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(20) (V = finite verb, Neg = negation, v = infinitival verb, s = infinitival subject)

a. *V...Neg order (correct order is Neg . . . V)*

| | | | |
|---|---|---|---|
| ??Pekka | ihaile | e-i | Merja-a. |
| *Pekka.*NOM | *admire* | *not-3*SG | *Merja-*PAR |

'Pekka does not admired Merja.'

b. *v . . . V order (correct order is V . . . v)*

| | | | | | |
|---|---|---|---|---|---|
| ??HEIDÄN | Merjalle | antaa | käski | Pekka | kirja-n. |
| *they.*GEN | *to.Merja* | *to.give* | *order* | *Pekka.*NOM | *book-*ACC |

'Pekka asked THEM (not me) to give Merja a book.'

c. *v . . . s order (correct order is s . . . v)*

| | | | | | |
|---|---|---|---|---|---|
| ?*KÄSKI | antaa | Pekka | heidän | kirja-n | Merjalle. |
| *order* | *to.give* | *Pekka.*NOM | *they.*GEN | *book-*ACC | *to.Merja* |

'Pekka ORDERED (not asked) them to give the book to Merja.'

Examples (20a, b) illustrate null head movement, in which V or v moves over something and lands in a position whose properties cannot be inferred from anything (i.e. there are no criterial or prosodic features). The algorithm was not allowed to generate null heads or reconstruct head movement from a null head. I rated many sentences of this type as grammatical, however. The required upward head movement reconstruction looks nontrivial. I leave this problem for future research.

Another group of ungrammatical sentences that the model classified wrongly as grammatical (Category B) contained multitopic constructions or very heavy 'head-final constructions' such as (21).

(21)

| | | | | | |
|---|---|---|---|---|---|
| Kirjan | Merjalle | heittämällä | heidän | antaa | Pekka |
| *book.*ACC | *to.Merja* | *by.throwing* | *they.*GEN | *to.give* | *Pekka.*NOM |
| käski. | | | | | |
| *ordered* | | | | | |

'Pekka ordered them to give the book to Merja by throwing.'

I judged (21) to be ungrammatical, while the model predicted extreme marginality.

It remains a possibility that author's judgments reflect linguistic noise rather than a stable grammar. This was examined by evaluating one dataset twice: first before the algorithm was run, as described above, and then for a second time six months later. The Pearson correlation between the two ratings was high, 0.73 ($p < .000$). Figure 6 shows the distribution of the rating changes. Because the changes are evenly distributed into both directions, my overall rating leniency remained the same. *T*-test revealed no difference in the mean ratings between the two measurements ($M_{2019} = 3.578$ and $M_{2020} = 3.573$, $t(999) = 0.142$, $p = .887$).

Normally distributed variation suggests that it represents noise in judging speed, parsing speed, reading speed, focus, attention, shifting judging criteria emphasis and other performance aspects (see Sprouse et al. 2018). Overall, however, my ratings reflect a stable grammar. This concerns both grammaticality

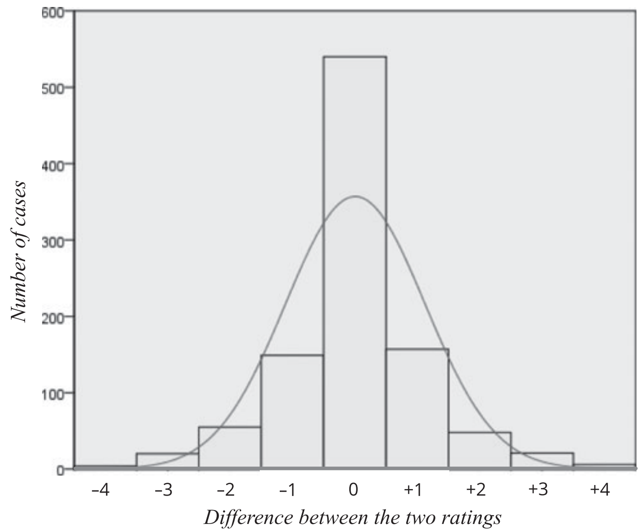


**Figure 6.** Distribution of the differences between the two ratings together with normal distribution. There were 10 examples in the ±4 category, 41 in the ±3, 103 in ±2 and rest were in the range (−1, 0, 1), with more than half in the category of 'no change'.

and marginality, and further supports the notion that marginality is part of grammatical competence.

*5.6.3 Noncanonical word order in English: Study 3*

The model was tested with English sentences to verify that it captured the contrast between a free word order language such as Finnish and a frozen word order language such as English. In English, (most) thematic arguments are not associated with case suffixes; hence adjunct reconstruction is not available. All thematic arguments must be reconstructed by using A′/A-reconstruction. The matter was examined by translating the clauses from Group 1 into English, creating a corpus containing all possible word order permutations from these seeds, and running them through the parser-grammar. The results are summarized in Table 6. Notice that what in Finnish amounts to the OVS order will come out in English as a regular SVO order, but with the reversed thematic roles (e.g. *John likes Mary*, *Mary likes John*).[16]

For comparison, Tables 7a and 7b list the grammaticality/marginality estimations (Table 7a) and output solutions (Table 7b) provided by the model for all possible word order permutations for the basic Finnish intransitive, transitive and ditransitive clauses in the Group 1.

The model captures the distinction between English and Finnish: in English, word order can be said to be frozen, whereas in Finnish, free. If the present hypothesis is correct, then the difference depends on the availability of adjunct reconstruction for arguments, available in Finnish on the basis of rich case suffixes but not in English. I propose that this is what explains the parametric

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**Table 6.** Grammaticality judgments for noncanonical word orders in English, as provided by the model.

| Sentence | Word order | Sentence | Word order |
|---|---|---|---|
| *John sleeps* | SV | **John to Mary the book gave* | S-IO-OV |
| **Sleeps John* | *VS | **Gave John the book to Mary* | VSO-IO |
| *John likes Mary* | SVO | **Gave John to Mary the book* | VS-IO-O |
| **John Mary likes* | *SOV | **Gave the book to Mary John* | VO-IO-S |
| **Likes John Mary* | *VSO | **Gave to Mary John the book* | V-IO-SO |
| **Likes Mary John* | *VOS | **The book John gave to Mary* | OSV-IO |
| **Mary John likes* | *OSV | **To Mary John gave the book* | IO-SVO |
| *Mary likes John* | (OVS) | **To Mary the book John gave* | IO-OSV |
| *John gave the book to Mary* | SVO-IO | **To Mary the book gave John* | IO-OVS |
| **John the book gave to Mary* | *SOV-IO | *Mary gave the book to John* | SVO-IO |
| **John the book to Mary gave* | SO-IO-V | | |

distinction between rigid word order languages and free word order languages. Notice that Finnish genitive arguments were treated as if they were English DPs: only linear order in the input was used in reconstructing them.

## 6. Discussion and conclusions

A computational model of language comprehension, following and developing Phillips (1996, 2003), Cann et al. (2005), Brattico (2019a) and Brattico & Chesi (2020) was proposed, in which language comprehension is incremental and uses the inverse versions of standard computational operations (i.e. Merge$^{-1}$, Move$^{-1}$, Agree$^{-1}$). Words are merged to the phrase structure in tandem with consuming them from the one-dimensional input at the PF-interface. This model was augmented with several novel grammatical operations that were required on independent grounds on the basis of Finnish data. These mechanisms were as follows.

First, it was assumed that rich morphosyntax, and not only order, is used to infer hierarchical relations between words as they occur in the input. This was implemented by merging words into tentative positions during the first pass parse and then reconstructing them into the vicinity of functional heads on the basis of their case suffixes (e.g. NOM = +FIN, GEN = −FIN, ACC/PAR = V/ASP). This uses the operation Agree$^{-1}$, perhaps pointing towards a possible functional motivation for case assignment. Genitive arguments were excluded from the mechanism and treated like arguments in a rigid word order language. Second, a separate head movement reconstruction (Move$^{-1}$) was postulated that extracted constituents from within complex heads, as provided by the morphological parser, and reconstructed them into the first position in which they could be selected by a higher head (e.g. v was reconstructed from within T into a position in which it would be selected by T). Third, the occurrence of more than one specifier per head was used to generate

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**Table 7a.** Word order variations in basic finite clauses in Finnish and the grammatical/marginality estimations provided by the model.

| # | Sentence | # | Sentence |
|---|---|---|---|
| 1 | *Pekka nukkui* (SV) | 17 | **Antoi kirjan Pekka Merjalle* (VOS-IO) |
| 2 | **Nukkui Pekka* (VS) | 18 | **Antoi kirjan Merjalle Pekka* (VO-IO-S) |
| 3 | *Pekka ihailee Merjaa* (SVO) | 19 | **Antoi Merjalle Pekka kirjan* (V-IO-SO) |
| 4 | *?Pekka Merjaa ihailee* (SOV) | 20 | **Antoi Merjalle kirjan Pekka* (V-IO-OS) |
| 5 | **Ihailee Pekka Merjaa* (VSO) | 21 | *?Kirjan Pekka antoi Merjalle* (OSV-IO) |
| 6 | **Ihailee Merjaa Pekka* (VOS) | 22 | *?Kirjan Pekka Merjalle antoi* (OS-IO-V) |
| 7 | *?Merjaa Pekka ihailee* (OSV) | 23 | *Kirjan antoi Pekka Merjalle* (OVS-IO) |
| 8 | *Merjaa ihailee Pekka* (OVS) | 24 | *Kirjan antoi Merjalle Pekka* (OV-IO-S) |
| 9 | *Pekka antoi kirjan Merjalle* (SVO-IO) | 25 | *?Kirjan Merjalle Pekka antoi* (O-IO-SV) |
| 10 | *Pekka antoi Merjalle kirjan* (S-V-IO-O) | 26 | *?Kirjan Merjalla antoi Pekka* (O-IO-VS) |
| 11 | *?Pekka kirjan antoi Merjalle* (SOV-IO) | 27 | *?Merjalle Pekka antoi kirjan* (IO-SVO) |
| 12 | *?Pekka kirjan Merjalle antoi* (SO-IO-V) | 28 | *??Merjalle Pekka kirjan antoi* (IO-SOV) |
| 13 | *?Pekka Merjalle antoi kirjan* (S-IO-VO) | 29 | *Merjalle antoi Pekka kirjan* (IO-VSO) |
| 14 | *?Pekka Merjalle kirjan antoi* (S-IO-OV) | 30 | *Merjalle antoi kirjan Pekka* (IO-VOS) |
| 15 | **Antoi Pekka kirjan Merjalle* (VSO-IO) | 31 | *??Merjalle kirjan Pekka antoi* (IO-OSV) |
| 16 | **Antoi Pekka Merjalle kirjan* (VS-IO-O) | 32 | *?Merjalle kirjan antoi Pekka* (IO-OVS) |

Sentence numbers (#) refer to the numbering in the test corpus.

an extra licensing head between the two phrases (e.g. C(*wh*) in the presence of a *wh*-phrase).

The model was formalized and implemented as a computer program. A corpus of Finnish finite clauses was created by crossing three grammatical variables, valency (intransitive, transitive, ditransitive), polarity (affirmative, negative), infinitival embedding (no, yes), presence of independent adverbial (no, yes), which created $3 \times 2 \times 2 \times 2 = 24$ basic seed sentences. A baseline was established by verifying that the parser-grammar was able to parse these sentences correctly and efficiently, after which it was fed with all mathematically possible word order combinations of the seed sentences (119,800 clauses in total). The proposed mechanisms were sufficient to classify grammatical sentences correctly as such and to provide them a plausible grammatical analysis; it was also able to predict marginality. Therefore, it can be argued that the model provides a useful analysis of the Finnish word order. More specifically, this study supports the notion that rich morphosyntax can substitute for order in inferring hierarchical relations between words, and that the marginality of many noncanonical word order permutations results from the fact that they constitute input strings that are unnatural, hence computationally costly, for the human parser.

**Table 7b.** Analytic solutions provided by the model for sentences in Table 7a.

| # | Parsing solution |
|---|---|
| 1 | [(D *Pekka*):1 [T/fin [(__):1 *nukku*]]] |
| 2 | — |
| 3 | [(D *Pekka*):1 [T/fin [(__):1 [v [*ihailee* [D *Merjaa*]]]]]] |
| 4 | [(D *Pekka*):1 [(D *Merjaa*):2 [T/fin [(__):1 [v [(__):2 *ihailee*]]]]]] |
| 5 | — |
| 6 | — |
| 7 | [(D *Merjaa*):1 [(D *Pekka*):2 [T/fin [(__):2 [v [(__):1 *ihailee*]]]]]] |
| 8 | [(D *Merjaa*):1 [T/fin [(__):2 [v [(__):1 [*ihailee* (D *Pekka*):2]]]]]] |
| 9 | [(D *Pekka*):1 [T/fin [(__):1 [v [*antaa* [[D *kirja*] (P(*lle*) [D *Merja*-])]]]]]] |
| 10 | [(D *Pekka*):1 [T/fin [(__):1 [v [[*antaa* [(P(*lle*) [D *Merja*-]):2 [D *kirja*]]] (__):2]]]]] |
| 11 | [(D *Pekka*):1 [(D *kirja*):2 [T/fin [(__):1 [v [(__):2 [*antaa* (P(*lle*) [D *Merja*-])]]]]]]] |
| 12 | [(D *Pekka*):1 [(D *kirja*):2 [(P(*lle*) [D *Merja*-]):3 [T/fin [(__):1 [v [[(__):2 *antaa*] (__):3]]]]]]] |
| 13 | [(D *Pekka*):1 [(P(*lle*) [D *Merja*-]):2 [T/fin [(DP):1 [v [[*antaa* [D *kirja*]] (__):2]]]]]] |
| 14 | [(D *Pekka*):1 [(P(*lle*) [D *Merja*-]):2 [(D *kirja*):3 [T/fin [(__):1 [v [(__):3 [*antaa* (__):2]]]]]]]] |
| 15 | — |
| 16 | — |
| 17 | — |
| 18 | — |
| 19 | — |
| 20 | — |
| 21 | [(D *kirja*):1 [(D *Pekka*):2 [T/fin [(__):2 [v [(__):1 [*antaa* (P(*lle*) [D *Merja*-])]]]]]]] |
| 22 | [(D *kirja*):1 [(D *Pekka*):2 [(P(*lle*) [D *Merja*-]):3 [T/fin [(__):2 [v [[(__):1 *antaa*] (__):3]]]]]]] |
| 23 | [(D *kirja*):1 [T/fin [(__):2 [v [(__):1 [*antaa* ((D *Pekka*):2 (P(*lle*) [D *Merja*-]))]]]]]] |
| 24 | [(D *kirja*):1 [T/fin [(__):2 [v [(__):1 [*antaa* ((P(*lle*) [D *Merja*-) (D *Pekka*):2)]]]]]] |
| 25 | [(D *kirja*):1 [(P(*lle*) [D *Merja*-]):2 [(D *Pekka*):3 [T/fin [(__):3 [v [[(__):1 *antaa*] (__):2]]]]]]] |
| 26 | [(D *kirja*):1 [(P(*lle*) [D *Merja*-]):2 [T/fin [(__):3 [v [[(__):1 [*antaa* (D *Pekka*):3]] (__):2]]]]]] |
| 27 | [(P(*lle*) [D *Merja*-]):1 [(D *Pekka*):2 [T/fin [(__):2 [v [[*antaa* [D *kirja*]] (__):1]]]]]] |
| 28 | [(P(*lle*) [D *Merja*-]):1 [(D *Pekka*):2 [(D *kirja*):3 [T/fin [(__):2 [v [(__):3 [*antaa* (__):1]]]]]]]] |
| 29 | [(P(*lle*) [D *Merja*-]):1 [T/fin [(__):2 [v [[*antaa* [(D *Pekka*):2 [D *kirja*]]] (__):1]]]]] |
| 30 | [(P(*lle*) [D *Merja*-]):1 [T/fin [(__):2 [v [[*antaa* [[D *kirja*] (D *Pekka*):2]] (__):1]]]]] |
| 31 | [(P(*lle*) [D *Merja*-]):1 [(D *kirja*):2 [(D *Pekka*):3 [T/fin [(__):3 [v [(__):2 [*antaa* (__):1]]]]]]]] |
| 32 | [(P(*lle*) [D *Merja*-]):1 [(D *kirja*):2 [T/fin [(__):3 [v [(__):2 [[*antaa* (D *Pekka*):3] (__):1]]]]]]] |

Sentence numbers (#) refer to the numbering in the test corpus.

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**Supplementary material.** To view supplementary material for this article, please visit https://doi.org/10.1017/S0332586520000098

## Notes

**1** Abbreviations: 0 = zero agreement or default third person agreement; 1, 2, 3 = first, second and third person; ACC = accusative Case; C = complementizer; FIN = finiteness head or finiteness feature; FOC = contrastive focus feature (expressed by means of e.g. prosodic stress); GEN = genitive Case; Neg (or NEG or neg) = negation head; NOM = nominative Case; op = operator hear or feature; PAR = partitive Case; PL = plural; SG = singular; SPEC = specifier position; T = tense; Q = yes/no particle *-kO* (capital letter represents changes due to vowel harmony).

**2** I have collected data from Finnish nonlocal head movement into a currently unpublished manuscript 'Predicate clefting and long head movement in Finnish' (Brattico 2020).

**3** Finnish genitive is assigned to thematic subjects and/or prehead specifier positions of most infinitivals (including deverbal nouns, nouns, and postpositions), to the thematic subject of special modal verbs, and to singular full DP direct objects in narrowly defined syntactic and morphosyntactic contexts. Vainikka (1989, 1993, 2011) has argued, convincingly, that the genitive constitutes a general/default specifier case in Finnish.

**4** Finnish exhibits a strict EPP condition on the preverbal subject: almost every clause must have one (Vainikka 1989, Vainikka & Levy 1999, Holmberg & Nikanne 2002, Huhmarniemi 2019). In my Finnish, this condition seems to be nullified in connection with T-to-C movement: *Antanut*$_1$ *ei* __$_1$ *Pekka Merjalle lääkkei-tä* 'give not.3SG __ Pekka.NOM to. Merja medicine-PAR 'Pekka did not GIVE medicine to Merja' is grammatical to me, but ungrammatical if nonlocal head movement has not taken place. A reviewer disagrees on some of my judgments, however, so the issue must be addressed in a separate study.

**5** An opposite approach would be one in which the syntax–PF mapping constitutes an 'ancillary process' whereas connections between syntax and thought 'enter into principled explanation' (Chomsky 2008:138). See also Chomsky et al. (2019:251–252).

**6** Several ranking principles were used in this study. Each ranking principle weights either in favor or against each solution and the solutions are ranked based on the pooled voting. The function of the system is to guess which solutions are likely to create a useful output in the derivation's future and which are not. For a list of the ranking principles, see Brattico (2019a:Section 3.3.2).

**7** The hypothesis was implemented formally by associating rich case suffixes in Finnish (minus the genitive) with features that license the adjunct attachment operation for thematic arguments and controls their structural position by utilizing Agree$^{-1}$, as explained in the main text. The association is established in the lexicon and is not predicted from a general rule. Morphological richness, as a surface property, plays an indirect role: if two surface forms cannot be distinguished case-wise and therefore map into the same adjunct licensing feature, assuming that such mappings are in the lexicon in the first place, then constituents marked by that form will compete for the same structural (and hence also thematic) position, which often produces wrong interpretations or no output at all. When this happens, word order gains control of the structural-thematic positions. Because the association between case forms and adjunct licensing features was created in the lexicon, it is possible for a language to have both adjunct licensing case features and case features which do not license adjunction (e.g. Finnish genitive vs. other case features).

**8** This assumption replaces or mirrors the locality-economy model of the enumerative minimalist grammar (Chomsky 1995).

**9** Cann et al. (2005) uses two mechanisms for handling unexpected constituents in the input stream that have inspired the adjunct system adopted in the current study. One mechanism is UNDERSPECIFICATION, which allows nodes to remain underspecified during the first pass parse. Their attachment is resolved later when more information is available. Another DS mechanism relies on LINKING, which allows the system to construct two independent phrase structures and 'link' them together. To explain free word order properties of Japanese the authors further use 'local underspecification', whose application is guided by case features. This mechanism explains short scrambling in Japanese but is not sufficient for Finnish, in which argument may float far away from the vicinity of their own predicates. The authors are aware of this limitation and propose that such cases are handled by a grammar-external 'abductive' reasoning process they call 'pragmatic enrichment' (p. 255) that fixes the structure by means of 'grammar-external enrichment step' (p. 257). If the operation relies on general cognition and/or abductive reasoning, however, it will most likely depend on non-modular central cognition that could be difficult to model by using the information processing/computational theory of the mind; see (Fodor 2000).

**10** Technically Agree$^{-1}$ licenses both arguments and adjuncts (adverbs, adjectives) in the algorithm proposed in this work. I do not explore this unification further, however, since I still had to separate adverbial licensing from argument licensing when writing the formal code handling both.

**11** Prosody was otherwise ignored. The feature approach adopted here should be considered as a placeholder for a more realistic approach. How to represent prosody formally at the PF-input and especially inside syntax constitutes a nontrivial problem.

**12** The source code and all associated input/output files can be found at https://github.com/pajubrat/parser-grammar. The term 'branch' refers to an earlier version of the program (current version being the 'master branch'). In the present case, it refers to a version that generated the raw data for this study. The branch is named 'Free-word-order-branch-(Study-2)'.

**13** The authors observe that to 'check a well-formedness prediction then is easy: there merely has to be at least one route through the [parsing derivation] maze. To check that something is excluded is much more laborious: there must be no possible route' (Cann et al. 2005:84).

**14** Special symbol ## was used for a few examples which I could not classify as ungrammatical or extremely marginal. This category was collapsed with 'extremely marginal' in all analyses. The symbol was left into the raw data.

**15** An anonymous reviewer suggests that the data could be analyzed by using less fine-grained partitioning into 'grammatical', 'marginal' and 'ungrammatical'. Mapping the original Likert scale into these three categories (1 = grammatical, 2–3 = marginal, 4–5 = ungrammatical) results in 9.7% prediction error (5.2% model too critical, category A; 4.5% model too lenient, category B).

**16** Two spurious and pragmatically implausible parses were found: *the book to John gave Mary* and *the book to Mary gave John*, both with the interpretation of 'the train to Paris gave (us) great satisfaction'.

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