Binding at the edge of language

Manuscript, January 2022

Abstract. Is binding part of language or cognition? This article argues that it is both. A mathematical formula for computing binding dependencies in Finnish and English is developed which relies on the language-cognition interface. It is assumed that binding regulates assignment management at the language-cognition interface by blanking out portions of the transient discourse available for coreference computations at the hearer's end. Assignments that are marked for filtering are not deleted, however, but downgraded so that they may get resurrected downstream by global cognition under pragmatic conditions. The hypothesis was implemented in Python (a general-purpose programming language) and tested and justified by calculation.

Keywords: binding theory; English; Finnish; language comprehension; reflexives

1 INTRODUCTION

Successful linguistic communication presupposes that both the speaker and hearer construct mutually consistent inventories of semantic objects corresponding to the subject matter under discussion. This allows the interlocutors to position themselves inside a common discourse space and share an implicit notion of what the conversation "is about." The framework presupposes a cognitive mechanism at the hearer's end for deciding whether an incoming expression denotes object(s) that already exist(s) in the shared discourse space or whether the speaker requested a new object to be assumed. For example, the first use of a proper name or an indefinite article typically invites the hearer to assume a new object, whereas an unstressed pronoun or the use of a definite article signals that the reference is discourse old. These restrictions can also be structure-dependent. Sentences (1-3) illustrate structure-dependent coreference patterns for reflexives (1), pronouns (2) and proper names (3) in English.

(1) a. John$_1$ admires himself$_{1,*2}$.

b. *John's$_1$ sister admires himself$_1$.

(2) a. John$_1$ admires him$_{*1,2}$.

b. John's$_1$ sister admires him$_{1,2}$.

(3) a. He$_1$ admires John$_{*1,2}$.

b. His$_{1,2}$ sister hates John$_1$.

The reflexive *himself* must denote the same thing as the subject of its own clause (1), as shown by the shared subscript; *him* cannot denote the same object as the subject of its own clause (2); and a proper name like *John* must introduce a new semantic object (3). These restrictions are known as the *Binding Conditions* in the literature (Chomsky, 1981). Their ultimate nature is controversial, although the phenomenon has received considerable attention in linguistics (Büring, 2005; Chomsky, 1980, 1981, 1982; Chomsky & Lasnik, 1977; Lebeaux, 2009; Reinhart, 1983; Reinhart & Reuland, 1993; Reuland, 2001) and psycholinguistics (Aoshima, Yoshida, & Phillips, 2009; Cunnings & Felser, 2013; Cunnings & Sturt, 2014; Sturt, 2003).[1] I will argue, by considering data from Finnish and English, that the effects of the binding theory can be calculated from a cognitive information processing model where a language-external cognitive module responds to lexical assignment management features that (possibly accidentally) hijack the system for linguistic purposes and thus "blanks out large portions of the discourse" (Hankamer & Sag, 1976, p. 425).[2] I will formulate the hypothesis as a Python program that will calculate the empirical data from the theory.

2 Language Comprehension and Discourse

Before formulating the binding principles we need few background assumptions. Let us assume that the language faculty maps linguistic inputs through a lexico-morphological component into syntactic parses that are interpreted semantically (e.g., Nicol & Swinney, 2003). For example, the input string *the * horse * raced * past * the * barn* is mapped into a syntactic parse, such as [$_S$[$_{DP}$ *the horse*] [$_{VP}$ *raced* [$_{PP}$ *past* [$_{DP}$ *the barn*]]]], that feeds semantic interpretation and generates the reading 'the horse raced past the barn'. To establish a connection between referential expressions in the parsed input and their meanings, we posit a *global discourse inventory* that holds all semantic objects and their known properties that have been mentioned during the ongoing conversation (Heim, 1982; Kamp, 1981).[3] In the case of *the horse raced past the barn*, the inventory holds two spatiotemporal objects, the horse and the barn.

Suppose the next sentence is *it was very fast*. The most likely interpretation for this continuation is one where the inanimate pronoun *it* refers to the horse, but it could also refer to the barn, a third entity, or to the whole event. When all referential expressions are provided with a denotation, we say that the sentence is provided with an *assignment*. Thus, under any particular assignment all referential expressions are assigned some denotation, as shown in Figure 1. Because expressions can often denote several semantic objects, each sentence will typically have several possible assignments.

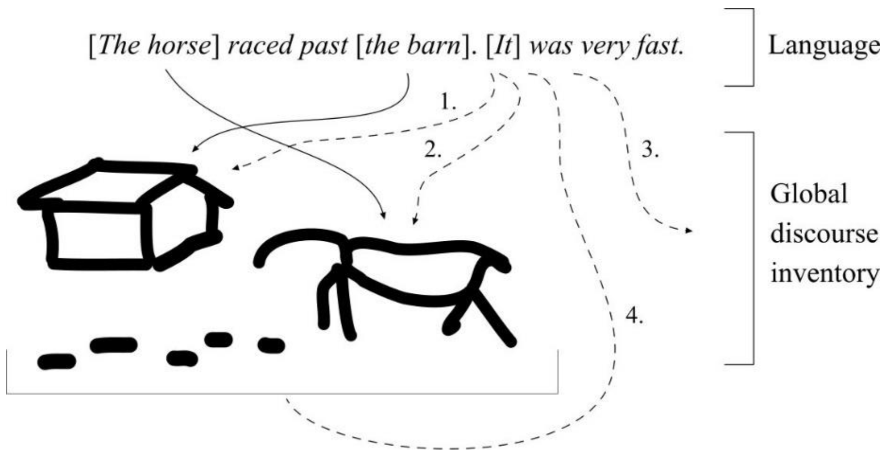


Figure 1. An inanimate pronoun *it* can refer to four entities: the barn (1), the horse (2), a third unknown entity (3) or the whole event (4). When each referential expression is provided with a possible denotation, we say that the whole sentence is associated with an assignment. Most sentences will have several assignments.

This presupposes two cognitive systems, one which (i) constructs or at the very least provides cognitive access to possible denotations and assignments for any referential expression in the input sentence and another which (ii) evaluates them for plausibility. I assume that the first component (i), called *narrow semantics*, bleeds the syntax-semantic interface (LF interface in generative theory) and mediates communication between language and cognition. It operates in a modular way and is constrained by structure-dependent linguistic properties it sees in the parsed phrase structure input. It can be thought of as an “extension” of the linguistic processing pathway. The second component (ii) will be based on extralinguistic global cognition that draws information from multiple sources and evaluates the situation holistically against communicative context. This component makes decisions concerning plausibility. The overall system is illustrated in Figure 2.

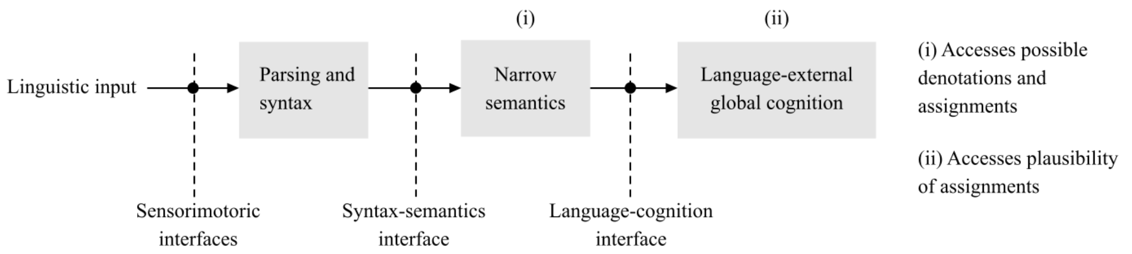


Figure 2. Linguistic architecture assumed in this study. Linguistic input is processed through a sensorimotoric interface and parsed syntactically. The endpoint of syntactic parsing is the syntax-semantics interface, or LF interface, which feeds narrow semantics (i). Narrow semantics interfaces with global cognition (ii).

To illustrate how the architecture works, consider again the conversation *the horse raced past the barn*; *it was very fast*. Both referential expressions *the horse* and *the barn* project corresponding semantic objects ‘the horse’$_1$ and ‘the barn’$_2$ to the global discourse inventory. The pronoun *it* projects an inanimate third person object ‘it’$_3$. When the whole expression is interpreted, narrow semantics, component (i) in Figure 2, provides each referential expression with a set of possible denotations, for example, *it* will be linked with {‘the horse’$_1$, ‘the barn’$_2$, ‘it, thing’$_3$ and ‘it, event’$_4$}, which generates assignments ‘the horse$_1$ raced past the barn$_2$; it$_{1,2,3,4}$ was very fast’.[4] Global cognitive processes (ii) will then rank these assignments and select the most plausible one(s) for consideration by drawing information from multiple sources (e.g., Asher & Wada, 1988; Badecker & Straub, 2002; Garrod & Sanford, 1994; Kaiser, 2011). Ranking is implemented technically by providing each assignment a *weight* that determines its plausibility ranging from 0 (almost impossible) to 1 (possible/very likely).[5]

In this case, the most plausible interpretation is one where *it* refers to the horse. An interpretation where *it* refers to the barn is also possible but very unlikely.

One final assumption is required before discussing binding. This system presupposes a mechanism for separating referential expressions like *the horse* from the nonreferential ones such as *raced* or *past*, since otherwise the algorithm will attempt to link every lexical item with objects in the semantic inventory and subjects them to the binding principles. I use phi-features (e.g., number, person) as reference-anchoring devices. Referential phi-features were further correlated with feature [REF] for 'referential', which excludes nonreferential phi-marking such as concord or DP predicates from the mechanism. This assumption need not be correct; it functions to prevent the algorithm from projecting 'thing objects' for verbs, prepositions, mood, tense, complementizers, conjunctions and in general for any elements we do not want to include into the binding calculations. This assumption is stipulative, but perhaps not completely implausible.

3 BINDING

The framework elucidated above allows us to formulate a set of elementary binding mechanisms. I propose a system where the range of possible denotations accessible to narrow semantics is modulated by lexical features. The mechanism operates at the language-cognition interface.

Let us first assume that global cognition contains a function EVAL which evaluates whether a cognitive object X is new or old in relation to a *reference set* of other cognitive objects. Since the operation is part of global cognition, we assume that it operates with general cognitive objects, in this case with things like 'the horse' and 'the barn'. EVAL could perhaps be depicted as a basic attention mechanism that allows the cognitive system to focus selectively on some mental objects by excluding others. Next, we assume that narrow semantics determines the reference set for EVAL on the basis of phrase structure objects it accesses at the syntax-semantics interface. More formally, suppose EXP_i is a referential expression in a phrase structure object α denoting object *i* in the global discourse inventory, then

(4) *Reference set*

The *reference set* for EXP_i is a set of cognitive objects accessed by narrow semantics from EXP_i in α by using an upward path (5);

(5) *Upward path*

The *upward path* from EXP_i contains all and only the nodes dominating EXP_i in α and the heads of their daughters (excluding EXP_i itself) that can be reached from EXP_i without encountering a head with an *intervention feature*.

I assume that the intervention feature, which is essentially a reformulation of the lexical opacity factor of (Manzini & Wexler, 1987) and creates locality domains for binding, can be anything.[6] The upward path mechanism owes much to Kayne's path approach (Kayne, 1984: Ch. 7, 8): EXP has unambiguous access to nodes in the phrase structure that it reaches through dominance.[7] We will now posit the following lexical features which provide instructions for EVAL. These features will come to mimic standard binding conditions:

(6) *Binding features*

a. [OLD:REF] ('must be locally old, existing object', for reflexives, local anaphors, (1)),

b. [NEW:REF] ('must be locally new object', for regular pronouns, (2)),

c. [NEW:_] ('must be new object', for R-expressions, (3));

d. [OLD:_] ('must be old object', for the demonstrative anaphora, excluded here[8]).

The label NEW/OLD tells whether the object X must be new or old in relation to a reference set and [REF] is the lexical opacity factor, a feature that any referential constituent has, as elucidated in the previous section. These features, when used in the context of the background theory (Section 2) and other postulates of the hypothesis (4-5), will limit possible denotations of referential expressions. To see how, consider (7a-b).

(7) a. John_1 admires $\text{him}_{*1,2}$.

b. John_1 admires $\text{himself}_{1,*2}$

The parser maps both sentences into [$_{S}$ [$_{DP}$ *John*] [$_{VP}$ *admires* [$_{DP}$ *him/himself*]]] and links *John* and *him/himself* with semantic objects 'John'$_1$ and 'he'$_2$ (=*him*/*himself*) in the global discourse inventory.[9] Since the discourse inventory holds two objects [1] and [2], accessible denotations will be *John*$_{\{1,2\}}$ *admires him/himself*$_{\{1,2\}}$. If the sentence was part of a larger conversation, then many more possible denotations would emerge. Next we generate assignments *John*$_1$ *admires him*$_1$, *John*$_1$ *admires him*$_2$, *John*$_2$ *admires him*$_1$ and *John*$_2$ *admires him*$_2$, which are ranked. The proper name *John*$_1$ is associated with an empty reference set. It has feature [NEW:_] which requires *John*$_1$ to refer to objects *not* in that set, hence *John* can denote any object in the global discourse inventory which matches with its lexical features (same name, masculine, singular etc.). The pronoun *him* has feature [NEW:REF] and can be assigned to an object that is not in the reference set {'John'$_i$} as defined by the upward path. Therefore, under any possible assignment, *John* and *him* cannot refer to the same object. The opposite result is calculated for *himself*.

Since the operation takes place inside narrow semantics, the weights can be adjusted downstream. This will explain situations where binding restrictions are ameliorated by pragmatic context (Section 4.4.3). On the other hand, there is no syntactic coindexing or syntactic binding mechanisms (contra Chomsky, 1981; Fiengo & May, 1994; Hicks, 2008; Reuland, 2001, 2006; Rooryck & Wyngaerd, 2011). I follow the style of analysis in (Chomsky, 1995; Culicover & Jackendoff, 1995; Schlenker, 2005) where binding regulates semantic interpretation at the outer edge of language. I will discuss the syntactic alternative in Section 5. Structure-dependency is captured by assuming that narrow semantics accesses phrase structure objects arriving from the parser.[10] The overall hypothesis is summarized in Figure 3.

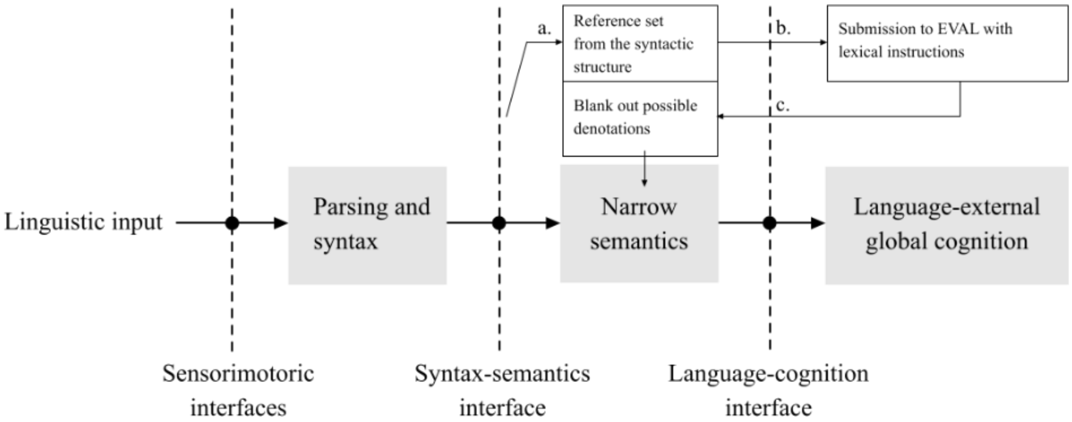


Figure 3. Binding at the outer edge of language. Reference sets are computed on the basis of the phrase structure input arriving from the parser to narrow semantics (a). They are submitted to EVAL together with lexical instructions (b), which determines accessible assignments (c). The mechanism is part of a larger system which interprets referential expressions within local discourse.

4 SIMULATION EXPERIMENT

4.1 Design

Scientific hypotheses must be tested and justified by calculation. To this end, a test corpus containing Finnish and English binding constructions was fed to an algorithm implementing the hypothesis. A Python-based minimalist sentence processor (Brattico, 2019a) was used for parsing and was endowed with the post-syntactic interpretation mechanism elucidated in the previous sections, also implemented in Python.[11] The narrow semantics/global discourse inventory nexus was attached to the output from syntax, which provided input for assignment computations.

The algorithm calculates several types of outputs. The most important is the overall results file, part of which is shown in Figure 4.

```
816 19.  John admires Mary
817
818      [[D John]:1 [T [__:1 [v [admire [D Mary]]]]]]
819
820      Semantics:
821      Recovery: ['Agent of T(John)', 'Agent of v(John)', 'Patient of admire(Mary)']
822      Aspect: []
823      DIS-features: []
824      Operator bindings: []
825      Semantic space:
826      Speaker attitude: ['Declarative']
827      Assignments:
828      [D John] ~ 2, [D Mary] ~ 12, Weight 1
829      [D John] ~ 6, [D Mary] ~ 12, Weight 1
830      Information structure: {'Marked topics': [], 'Neutral gradient': ['[D John]', '[D Mary]'], 'Marked focus': []}
831      spellout structure: [[D John] [T(v,V) D(N)]]
832      surface structure: [[D John] [T [v [admire [D Mary]]]]]
833      s-structure: [[D John] [T [v [admire [D Mary]]]]]
834      LF structure: [[D John]:2 [T [__:2 [v [admire [D Mary]]]]]]
835
836      Discourse inventory:
837      Object 2 in GLOBAL: [D John]
838      Object 6 in GLOBAL: [D John]
839      Object 12 in GLOBAL: [D Mary]
840
841      Resources:
842      Total Time:1120, Garden Paths:0, Memory Reactivation:0, Steps:13, Merge:6, Move Head:2, Move Phrase:2,
843      A-Move Phrase:2, A-bar Move Phrase:0, Move Adjunct:0, Agree:2, Phi:5, Transfer:3, Item streamed into syntax:7,
844      Feature Processing:0, Extraposition:0, Inflection:12, Failed Transfer:2, LF recovery:3,
845      LF test:5, Filter solution:5, Rank solution:3, Lexical retrieval:19, Morphological decomposition:3,
846      Mean time per word:373, Asymmetric Merge:36, Sink:9, External Tail Test:13,
```

Figure 4. Screenshot from the results file generated by the algorithm showing the calculated results for the input sentence *John admires Mary*.

The entry contains a calculated syntactic analysis (line 818 in this example), semantic interpretation (lines 820-839), assignments with weights (line 828-829), abbreviated contents of the discourse inventory (lines 836-839), and computational resources consumed (lines 841-846). Each input sentence that the model judges grammatical is provided with same information, all generated by the model. In addition, the algorithm generates a file showing semantic computations in more detail, including complete contents of the discourse inventory; complete derivational log containing a record of all linguistically meaningful computational steps for each input sentence performed during the simulation; grammatical judgments associated with all input sentences; and phrase structure tree images, used for illustration in the results section of the present article, for each grammatical input sentence. These items constitute the raw data of this study. Detailed contents, names, locations and links for the raw output files are provided in Appendix A. The author verified that the syntactic analyses calculated by the model were plausible in the light of a linguistic theory; that the model judged ungrammatical input sentences ungrammatical; that assignments and their weights were correct and matched with semantic intuitions of a native speaker; that the rest of the semantic interpretation was correct and did not contradict native speaker intuition. All calculation errors that were found during verification are reported below. Since verification must be done by hand, errors may of course remain. Therefore, all the output files are available online, linked from this article, and can be verified independently. I will occasionally refer to the example and line numbers of the output files to make independent verification easier.

4.2 Stimuli (test corpus)

The hypothesis was tested against a test corpus that contained binding constructions, both grammatical and ungrammatical, and both in Finnish and English. Some test sentences formed conversations, others were isolated. The test sentences were selected to cover the core of the whole binding theory, including special constructions exhibits null subjects, DP-internal syntax, picture nouns, noncanonical word orders and embedded infinitivals. Test sentences were written into one file, normalized and organized hierarchically. No morphosyntactic tagging was used apart from few cases where the input item was disambiguated to make analysis easier. When two or more sentences were assumed to be part of the same conversation, they were separated by semicolon; otherwise, no special punctuation was used. The contents of the test corpus are summarized in Table 1.

Table 1. Structure and contents of the test corpus.

#	Category (sentence numbers)	Examples and/or explanation
0	**Core sentences from the article**	
0.1	Binding conditions (1-19)	Sentences (8, 12-14, 17, 18, 21, 28, 29) from this article
0.2	Null pro subjects (20-25)	Sentences (33-36) from this article
0.3	DP-internal syntax (27-31)	Sentences (38, 40, 42, 43) from this article
0.4	Embedded infinitivals (32-37)	Sentences (47, 48, 49) from this article

1	**Proper names (R-expressions)**	
1.1	Grammatical, assignment possible (38-45)	*John sleeps.* *John admires Mary.* *Pekka nukku-u.* 'Pekka.NOM sleep-PRS.3SG' *Pekka ihaile-e Merja-a.* 'Pekka.NOM admire-PRS.3SG Merja-PAR'
1.2	Proper names inside that-clauses (46-47)	*John said that Mary admires Bill.* *Pekka sanoi että Merja ihaile-e Jukka-a.* 'Pekka.NOM said that Merja.NOM admire-3SG.PRS Jukka-PAR'
1.3	Proper names inside embedded infinitival (48-49)	*John wants Mary to admire Bill.* *Pekka sanoo Merja-n ihaile-van Jukka-a.* 'Pekka.NOM says.PRS.3SG Merja-GEN admire-VA/INF Jukka-PAR'
1.4	Condition C (50-58)	*He admires John.* *She admires John.* *He admires Mary.* *She admires Mary.* *He said that John admires Mary.* *He wants John to admire Mary.* *Hän ihaile-e Merja-a.* 'He.NOM admire-3SG.PRS Merja-PAR' *Hän sanoo että Pekka ihaile-e Merja-a.* 'He.NOM says that Pekka.NOM admire-3SG.PRS Merja-PAR' *Hänen siskonsa sanoo että Pekka ihaile-e Merja-a.* 'His/her sister says that Pekka.NOM admire-3SG.PRS Merja-PAR'
1.5	Conversations (59-62)	*John sleeps; John admires Mary.* *John sleeps; Mary sleeps.*
1.6	Pro-drop sentences (63)	*Ihaile-n Merja-a.* 'admire-PRS.1SG Merja-PAR'
2	**Regular pronouns**	
2.1	Pronouns and proper names (64-83)	*John admires him.* *John admires her.* *He admires Mary.* *She admires John.* *It admires John.*

		It admires Mary. *It admires him.* *It admires her.* *John admires it.* *Mary admires it.* *He admires it.* *She admires it.* *It admires it.* *John admires his sister.* *John admires her sister.* *Pekka ihaile-e hän-tä.* 'Pekka.NOM admire-3SG.PRS he-PAR' *Pekka ihaile-e sitä.* 'Pekka.NOM admire-.3SG.PRS it.PAR' *Se ihaile-e Pekka-a.* 'it.NOM admire-3SG.PRS Pekka-PAR' *Se ihaile-e sitä.* 'It.NOM admire-3SG.PRS it.PAR' *Pekka ihaile-e hän-en sisko-a-an.* 'Pekka.NOM admire-3SG.PRS he-GEN sister-PAR(Px/3sg)'
2.2	Only pronouns (84-89)	*He admires him.* *She admires her.* *He admires her.* *She admires him.* *Hän ihailee häntä.* 'He.NOM admire.3SG.PRS he.PAR' *Se ihaile-e sitä.* 'it.NOM admire-3SG.PRS it.PAR'
2.3	*Pronouns with wrong case forms (90-97)	**Him admires he.* **Him admires she.* **Him admires him.* **Him admires her.* **Her admires he.* **Her admires she.* **Her admires him.* **Her admires her.* Not applicable to Finnish due to free word order profile
2.4	Pronouns inside that-clauses (98-107)	*John said that Mary admires Bill.* *John said that Mary admires him.* *John said that he admires Mary.* *John said that he admires him.* *He said that he admires him.* *He said that John admires Mary.*

		Pekka sanoo että Merja ihaile-e Jukka-a. ‘Pekka.NOM says that Merja.NOM admire-3SG.PRS Jukka-PAR’ *Pekka sanoo että Merja ihaile-e hän-tä.* ‘Pekka.NOM says that Merja.NOM admire-3SG.PRS he-PAR’ *Pekka sanoo että hän ihaile-e Jukka-a.* ‘Pekka.NOM says that he.NOM admire-3SG.PRS Jukka-PAR’ *Pekka sanoo että hän ihaile-e hän-tä.* ‘Pekka.NOM says that he.NOM admire-3SG.PRS he-PAR’
2.5	Pronouns inside infinitivals (108-121)	*John wants Mary to admire him.* *Mary wants John to admire her.* *John wants John to admire him.* *Mary wants Mary to admire her.* *John wants Mary to admire it.* *Mary wants John to admire it.* *John wants him to admire Mary.* *John wants her to admire Mary.* *Mary wants him to admire Mary.* *Mary wants her to admire Mary.*
2.6	Possessive pronouns (122-124)	*His sister sleeps.* *Her sister sleeps.* *Hänen siskonsa nukku-u.* His/her sister sleep-PRS.3SG
2.7	Pronouns inside conversations (125-136)	*John sleeps; he admires Mary.* *John admires Mary; he admires her.* *John admires Mary; his sister sleeps.* *It sleeps; he admires Mary.* *It sleeps; he admires her.* *It sleeps; it admires her.*
2.8	Human vs. nonhuman pronouns (137-144)	*John admires Mary; it sleeps.* *John admires Mary; he sleeps.* *Pekka ihaile-e Merja-a; se nukkuu.* ‘Pekka.NOM admire-PRS.3SG Merja-PAR; it sleeps’ *Pekka ihaile-e Merja-a; hän nukkuu.* ‘Pekka.NOM admire-PRS.3SG Merja-PAR; he sleeps’
2.9	C-command tests (145-146)	*John’s sister admires him.* *Peka-n sisko ihaile-e hän-tä.* ‘Pekka-GEN sister admire-PRS.3SG he.PAR’
2.10	Pronouns and null subject sentences (147-150)	*Pekka sanoo että ihaile-e hän-tä.* 'Pekka says that admire.3SG.PRS he-PAR' *Pekka sanoo että ihaile-n hän-tä.*

		'Pekka says that admire.1SG.PRS he-PAR' *Hän sanoo että ihaile-e hän-tä.* 'He says that admire.3SG.PRS he-PAR' *Hän sanoo että ihaile-n hän-tä* 'He says that admire.1SG.PRS h.e-PAR'
3	**Reflexive pronouns, anaphors**	
3.1	Grammatical, assignment possible (151-155)	*John admires himself.* *Mary admires herself.* *he admires himself.* *she admires herself.* *Pekka ihaile-e itse-ä-än.* 'Pekka.NOM admire-3SG.PRS self-PAR-Px/3sg' *Hän ihaile-e itse-ä-än.* 'He.NOM admire-3SG.PRS self-PAR-Px/3sg'
3.2	*Gender mismatch (157-160)	*John admires herself.* *Mary admires himself.* *He admires herself.* *She admires himself.*
3.3	*Human mismatches (161-162)	*It admires herself.* *It admires himself.*
3.4	*Subject reflexives (163-176)	*Himself admires John.* *Himself admires Mary.* *Himself admires he.* *Himself admires him.* *Himself admires she.* *Himself admires her.* *Himself admires it.* *Herself admires John.* *Herself admires Mary.* *Herself admires he.* *Herself admires him.* *Herself admires she.* *Herself admires her.* *Herself admires it.*
3.5	Reflexives in conversations (177-182)	*John admires Bill; he admires himself.* *John admires himself; he sleeps.* *John admires Mary; Bill admires himself.*
3.6	C-command condition (183-184)	*John's sister admires himself.* *Peka-n sisko ihaile-e itse-ä-än.* 'Pekka-GEN sister.NOM admire-3SG.PRS self-PAR-Px/3sg'

3.7	Reflexives and control (185-201)	*John wants Mary to admire herself.* **John wants Mary to admire himself.* *John wants to admire himself.* *He wants to admire himself.* *Mary wants to admire herself.* *She wants to admire herself.* **John wants to admire herself.* **He wants to admire herself.* *John wants himself to admire Mary.* **John wants herself to admire John.* **Mary wants himself to admire John.* *Pekka halua-a Merja-n ihailevan itse-ä-än.* 'Pekka.NOM want-3SG.PRS Merja-GEN admire.VA/inf self-PAR-Px/3SG' *Pekka halu-si Merja-n ihaile-van itse-ä-än.* 'Pekka.NOM want-3SG.PRS Merja-GEN admire-VA/inf self-PAR-Px/3SG' *Pekka halua-a ihail-la itse-ä-än.* 'Pekka.NOM want-3SG.PRS admire-A/inf self-PAR-Px/3SG' *Hän halua-a ihail-la itse-ä-än.* 'He.NOM want-3SG.PRD admire-A/inf self-PAR-Px/3sg' *Pekka halua-a itse-nsä ihaile-van Merja-a.* 'Pekka.NOM want-3SG.PRS self-GEN.Px/3SG admire-VA/inf Merja-PAR'
3.8	Ungrammatical reflexive inside that-clause (202-203)	*John said that Mary admires himself.* *Mary said that John admires herself.*
3.8	Reflexives and null subjects (204-207)	*Pekka sanoo että ihaile-e itse-ä-än.* 'Pekka says that admire-3SG.PRS self-PAR-.PX/3SG' *Pekka sanoo että ihaile-n itse-ä-ni.* 'Pekka says that admire-1SG.PRS self-PAR-PX/1SG'

The test corpus is smaller than what is typical in other studies of this kind. This is due to the detailed and voluminous binding data (accessible denotations, possible assignments, weights) generated by the algorithm that must be verified after each simulation trial.

4.3 Methods and procedure

The algorithm read and processed each sentence, produced the output, and moved to the next sentence until all sentences were processed. Once the trial was complete, the author verified the output for correctness. The output, which is voluminous and linguistically nontrivial, requires linguistic expertise to verify. We will examine the output and its verification below.

4.4 Results

4.4.1 Observational adequacy

Observational adequacy was verified by comparing native speaker judgments against the output generated by the model. Comparison was done by mechanical file-comparison tool. The model reached 100% accuracy. Note that this number concerns only grammaticality judgments; correctness of binding for grammatical input sentences must be verified by looking inside the output files generated by the model (see, e.g., Figure 4).

4.4.2 Binding conditions

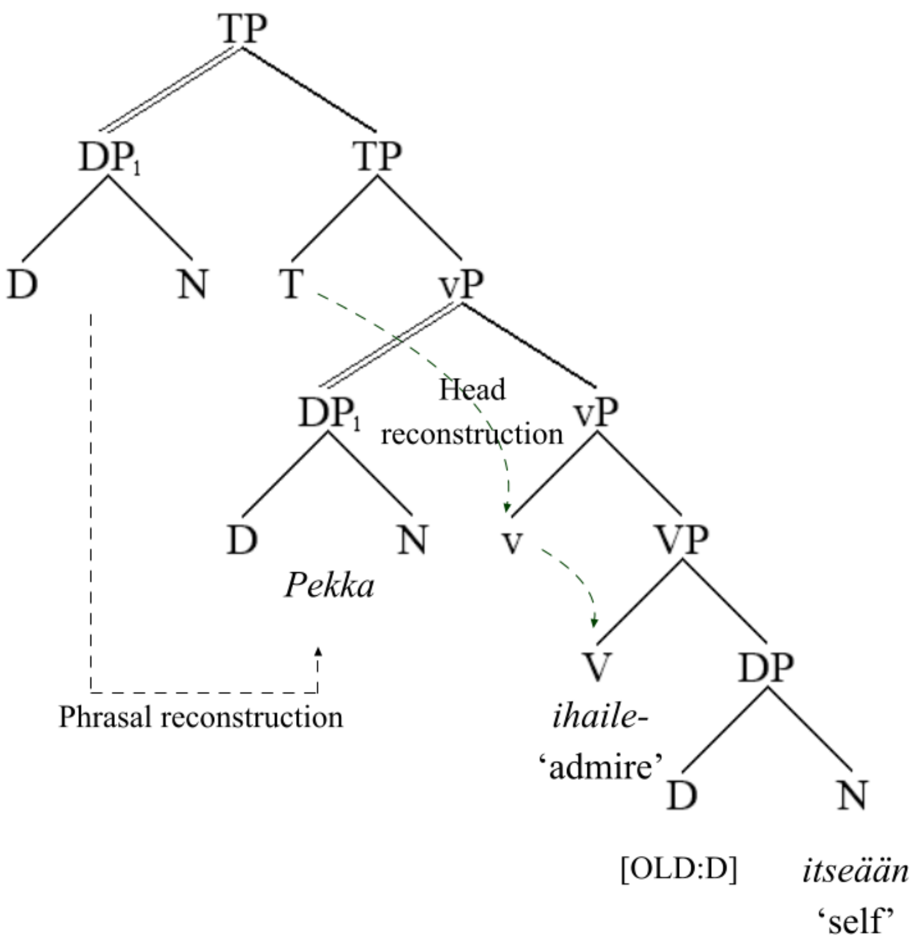
Binding condition A, illustrated by example (1), requires reflexives to be bound locally. The default Finnish reflexive construction uses the SELF-pronoun *itse* ‘self’ typically (but not necessarily) suffixed with an infinitival agreement marker, also called the possessive suffix glossed as PX, that must match with the antecedent in person and number (8)(gender is not grammaticalized in Finnish). In the examples below and in the rest of this article symbol # refers to the same or equivalent sentence in the raw data (Table 1). Line numbers refer to the results file unless otherwise stated.

(8)	a.	Pekka$_1$	ihaile-e	itse-ä(-än)$_{1,*2}$/	*itse-ä(-ni). (#1, 2)
		Pekka.NOM	admire-3SG.PRS	self-PAR(-PX/3SG)	self-PAR(-PX/1SG)
		‘Pekka admires himself/ *myself.’			
	b.	Minä$_1$	ihaile-n	*itse-ä(-än)/	itse-ä(-ni)$_{1,*2}$ (#3, 4)
		I.NOM	admire-1SG.PRS	self-PAR(-PX/3SG)	self-PAR(-PX/1SG)
		‘I admire *himself/myself.’			

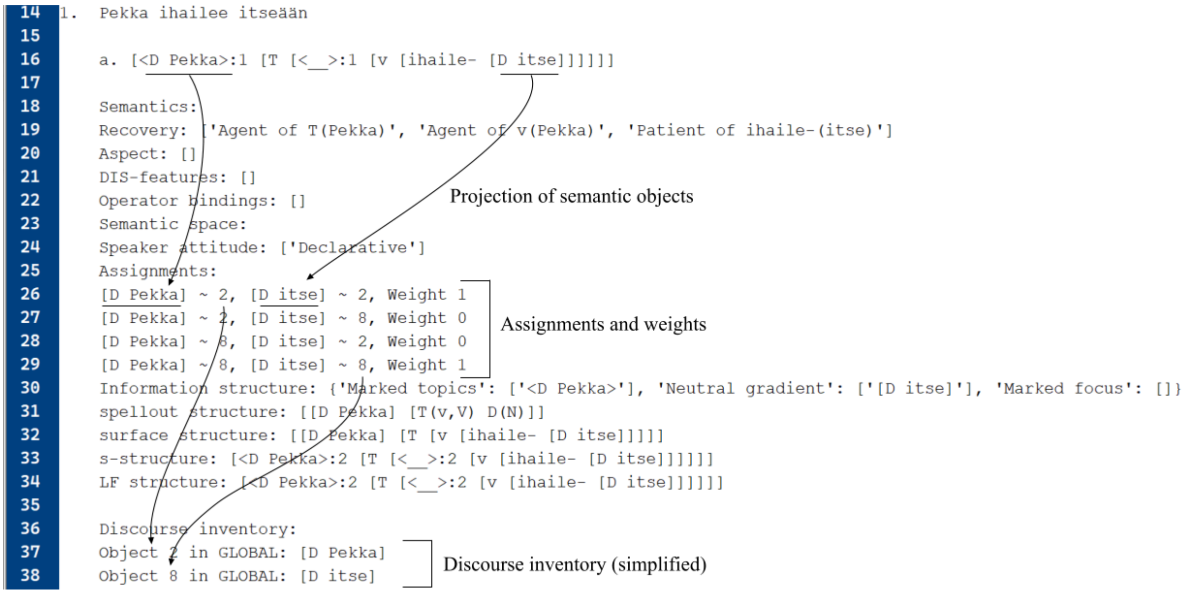
In (8a), the binding mechanism filters out assignments where *Pekka* and *itseään* ‘self.PX/3SG’ do not refer to same entity in the discourse space (lines 26-29 in the results file). If the reflexive is marked for the first person singular, this solution is filtered out by narrow semantics on the basis of the mismatching phi-features, and therefore no solutions are found (line 63). Example (8b) is calculated in the same way (lines 85-154). Below we examine these facts in more detail.

First, there is some controversy over the syntactic nature of the Finnish possessive suffix *-ni*/*-än* glossed as PX in the above and other examples below (Huhmarniemi & Brattico, 2015; Kaiser, 2003; Kanerva, 1987; Toivonen, 2000; Trosterud, 1990, 1993; Vainikka, 1989; van Steenbergen, 1987, 1991). Because it is optional in these contexts and has a wide variety of other uses,[12] I did not attempt to include it explicitly into the calculations as a separate morpheme. The binding possibilities for the SELF + PX construction and for the possessive suffix PX alone are not the same (Trosterud, 1990: 2.1.2; Vainikka, 1989, pp. 196–197, 213–216). Thus, *itseä-än* 'self-PX/3SG' is analysed as a reflexive pronoun with lexical entry 'itse-#D#3p#sg#def#[-par]#reflexive' corresponding to a DP = [$_{\text{DP}}$ D N] where D is a third person singular definite D-element that has the feature 'reflexive' = [OLD:REF] and is marked for the partitive case, and N = *itse*- 'self'. The syntactic analysis calculated by the model for (8) is (9).

(9)



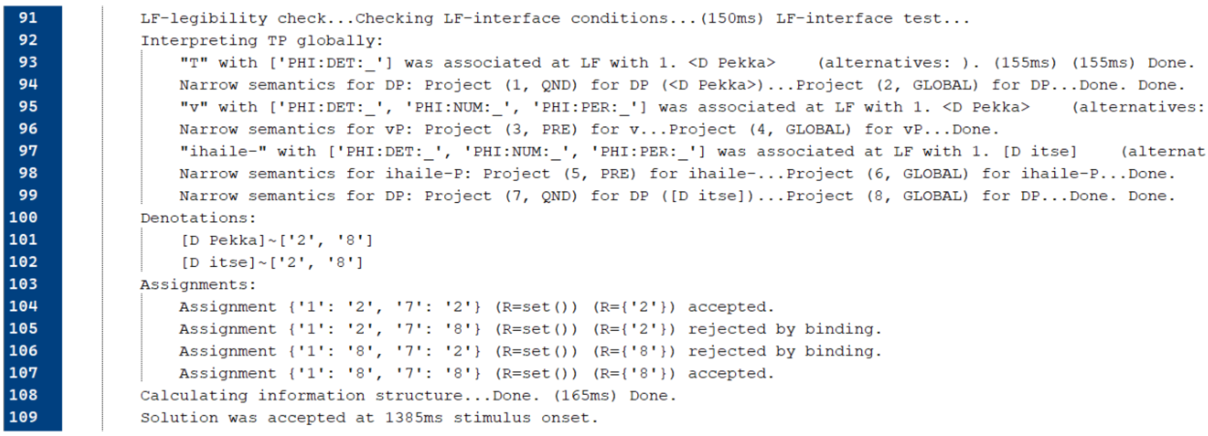
Using this representation, provided by the parser, as a starting point, narrow semantics generates two semantic objects into the global discourse space, 'Pekka'$_2$ and 'self'$_8$, with indexes 2, 8 corresponding to arbitrary number identifiers generated by the algorithm and found from the output files (lines 26-29). Figure 5 shows part of the results file, with added comments and illustrations by author.



```
14 1.   Pekka ihailee itseään
15
16      a. [<D Pekka>:1 [T [<__>:1 [v [ihaile- [D itse]]]]]]
17
18      Semantics:
19      Recovery: ['Agent of T(Pekka)', 'Agent of v(Pekka)', 'Patient of ihaile-(itse)']
20      Aspect: []
21      DIS-features: []
22      Operator bindings: []
23      Semantic space:
24      Speaker attitude: ['Declarative']
25      Assignments:
26      [D Pekka] ~ 2, [D itse] ~ 2, Weight 1
27      [D Pekka] ~ 2, [D itse] ~ 8, Weight 0
28      [D Pekka] ~ 8, [D itse] ~ 2, Weight 0
29      [D Pekka] ~ 8, [D itse] ~ 8, Weight 1
30      Information structure: {'Marked topics': ['<D Pekka>'], 'Neutral gradient': ['[D itse]'], 'Marked focus': []}
31      spellout structure: [[D Pekka] [T(v,V) D(N)]]
32      surface structure: [[D Pekka] [T [v [ihaile- [D itse]]]]]
33      s-structure: [<D Pekka>:2 [T [<__>:2 [v [ihaile- [D itse]]]]]]
34      LF structure: [<D Pekka>:2 [T [<__>:2 [v [ihaile- [D itse]]]]]]
35
36      Discourse inventory:
37      Object 2 in GLOBAL: [D Pekka]
38      Object 8 in GLOBAL: [D itse]
```


Figure 5. Screenshot from the output of the algorithm for the input sentence (8a), in which the syntactic structure (line 16) contains two referential expressions. These generate four possible assignments (lines 26-29), of which two reflexive interpretations are accepted (line 26, 29). Weight 0 means that the solution was supressed, 1 that it was accepted.

Four possible assignments were considered: ‘Pekka$_{\{2,8\}}$ admires himself$_{\{2,8\}}$’, and of these four, two are accepted: ‘Pekka$_2$ admires himself$_2$’ and ‘Pekka$_8$ admires himself$_8$’. More detailed information of these operations is available in the derivational log file, part of which is shown in Figure 6.

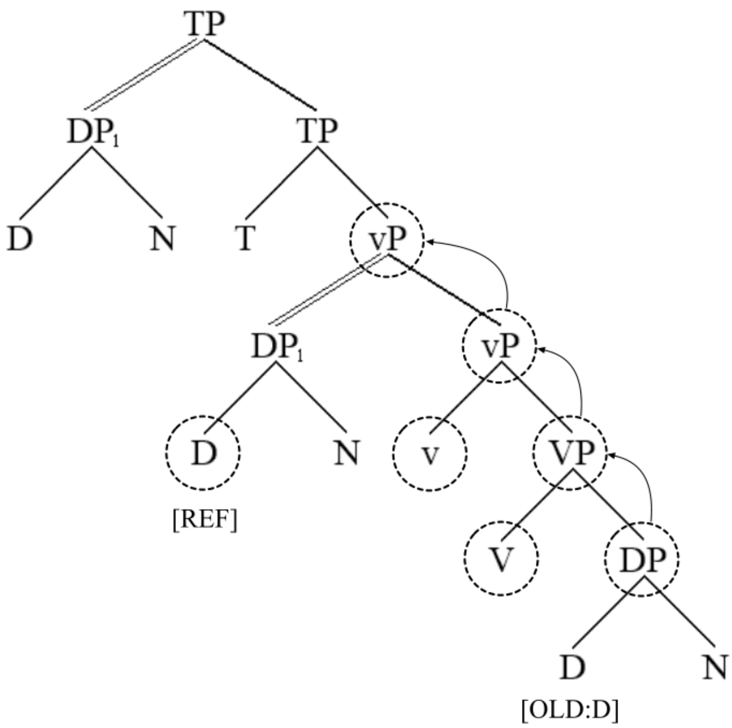


```
91   LF-legibility check...Checking LF-interface conditions...(150ms) LF-interface test...
92   Interpreting TP globally:
93       "T" with ['PHI:DET:_'] was associated at LF with 1. <D Pekka>    (alternatives: ). (155ms) (155ms) Done.
94       Narrow semantics for DP: Project (1, QND) for DP (<D Pekka>)...Project (2, GLOBAL) for DP...Done. Done.
95       "v" with ['PHI:DET:_', 'PHI:NUM:_', 'PHI:PER:_'] was associated at LF with 1. <D Pekka>    (alternatives:
96       Narrow semantics for vP: Project (3, PRE) for v...Project (4, GLOBAL) for vP...Done.
97       "ihaile-" with ['PHI:DET:_', 'PHI:NUM:_', 'PHI:PER:_'] was associated at LF with 1. [D itse]    (alternat
98       Narrow semantics for ihaile-P: Project (5, PRE) for ihaile-...Project (6, GLOBAL) for ihaile-P...Done.
99       Narrow semantics for DP: Project (7, QND) for DP ([D itse])...Project (8, GLOBAL) for DP...Done. Done.
100  Denotations:
101      [D Pekka]~['2', '8']
102      [D itse]~['2', '8']
103  Assignments:
104      Assignment {'1': '2', '7': '2'} (R=set()) (R={'2'}) accepted.
105      Assignment {'1': '2', '7': '8'} (R=set()) (R={'2'}) rejected by binding.
106      Assignment {'1': '8', '7': '2'} (R=set()) (R={'8'}) rejected by binding.
107      Assignment {'1': '8', '7': '8'} (R=set()) (R={'8'}) accepted.
108  Calculating information structure...Done. (165ms) Done.
109  Solution was accepted at 1385ms stimulus onset.
```

Figure 6. A screenshot from the derivational log file associated with sentence (8a), lines 91-109.

Lines 93-99 document the semantic projection process, where expressions populate the discourse inventory. Possible denotations are shown in 101-102. What appears here depends on prior conversation (content of the global discourse inventory) and how the lexical properties (e.g., gender, humanness) restrict search. Final assignments are on lines 104-107. Assignment selection operates as follows. For each assignment considered, feature [OLD:REF] at the reflexive requires that whatever denotation is provided for this element under the particular assignment considered must be found from the set of objects that can be accessed by upward path until the intervention feature [REF] is encountered. If the upward path contains all nodes that dominate the reflexive and the heads of their daughters (marked by circles), then the following elements are considered:

(10)



Feature [REF] halts the search at vP. It follows that, under any assignment, the denotation for the reflexive must be the same as the denotation of the higher DP at SpecvP. This is shown on lines 104-107, Figure 6. Two further properties of (9, 10) merits comment. The preverbal topic subject is reconstructed from SpecTP to the thematic position vP by the syntactic component before assignments are calculated. The mechanism and technical implementation is elucidated in Brattico

(2020). The finite verb *ihaile-e* ‘admire-PRS.3SG’ is decomposed into agreement (3SG), tense (T, present), transitive head (v) and the verb stem V by the lexico-morphological module and then reconstructed into the standard head spread T-v-V, as shown in (9, 10). This mechanism is described in Brattico (to appear). I will make a further comment on the processing of the third person singular agreement cluster in Section 4.4.4.

Reflexive binding ignores referential elements that are not inside the upward path from the reflexive pronoun. This derives (11) and similar expressions.

(11) a. *[John’s$_1$ sister] admires himself$_1$. (#183)

b. *[Peka-n$_1$ sisko] ihaile-e itse-ä-än$_1$. (#184)

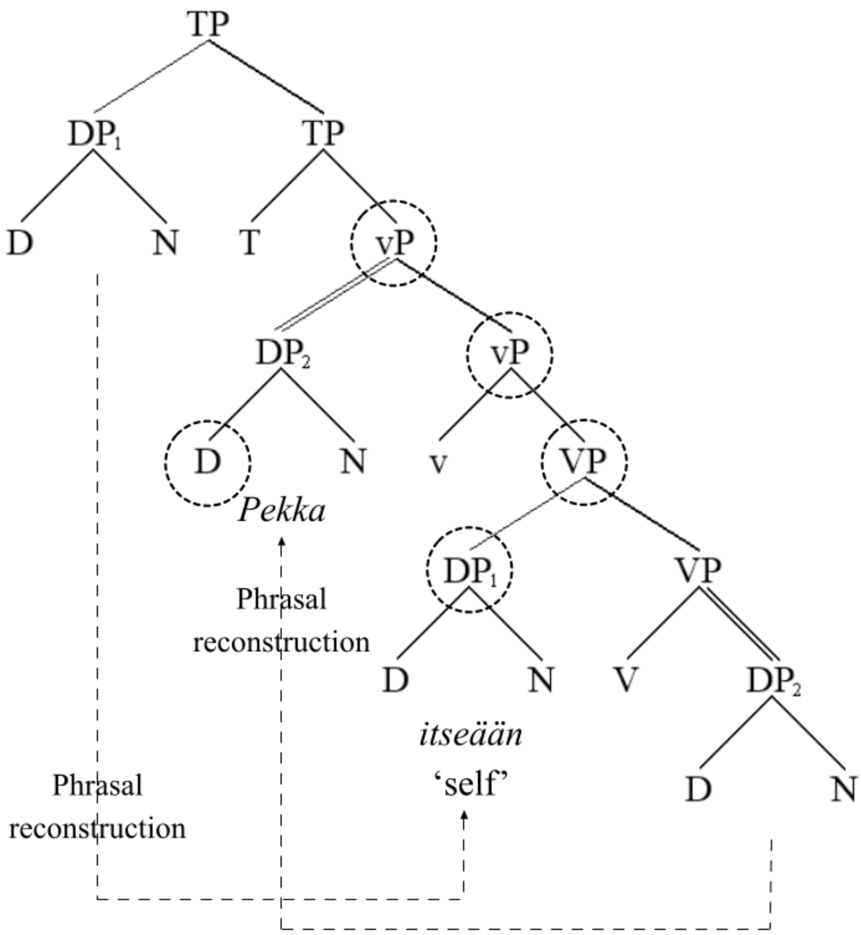
Pekka-GEN sister admire-PRS.3SG self-PAR-PX/3SG

‘Pekka’s sister admires himself/*herself.’

Assignments for (11a) are on lines 169426-169452 in the derivational log file, where we find that there were no assignments where the reflexive pronoun *himself* and *John* denote the same thing. *John* cannot be accessed from the reflexive; the only option is coreference between *John’s sister* and *himself* that was rejected on the basis of gender. Notice that “accidental” coreference between John and himself does not count, since [OLD:REF] requires syntactically verifiable coreference between the reflexive and local subject. In other words, the algorithm is not testing coreference as such but uses a structure-dependent filter.

Narrow semantics works with the endpoint of syntax. If we reversed the order of the arguments (OVS) in the input string, then the syntactic component normalizes the expression and calculates assignments on the basis of the normalized representation. The calculated result is (12). Indeed the binding condition A ignores discourse-based word order permutations as shown by (13).

(12)

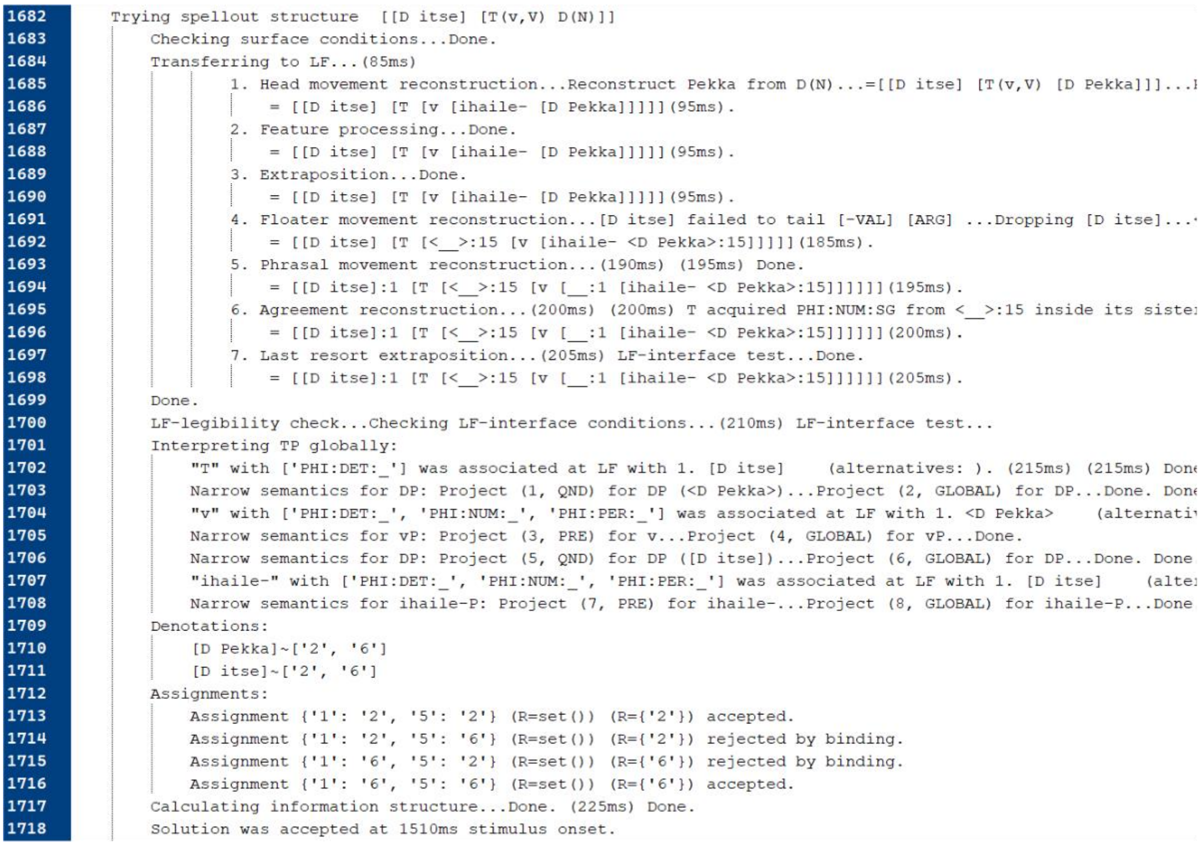


(13) Itse-ä-än$_1$ ihaile-e Pekka$_1$. (#5)

self-PAR-PX/3SG admire-3SG.PRS Pekka.NOM

'Pekka (information focus) admires himself (topic).'

This is visible in the derivational log file (Figure 7) which shows the reconstruction operations (lines 1685-1699) that were applied before semantic calculations (lines 1700-1716).



```
1682 Trying spellout structure  [[D itse] [T(v,V) D(N)]]
1683     Checking surface conditions...Done.
1684     Transferring to LF...(85ms)
1685             1. Head movement reconstruction...Reconstruct Pekka from D(N)...=[[D itse] [T(v,V) [D Pekka]]]...I
1686                = [[D itse] [T [v [ihaile- [D Pekka]]]]](95ms).
1687             2. Feature processing...Done.
1688                = [[D itse] [T [v [ihaile- [D Pekka]]]]](95ms).
1689             3. Extraposition...Done.
1690                = [[D itse] [T [v [ihaile- [D Pekka]]]]](95ms).
1691             4. Floater movement reconstruction...[D itse] failed to tail [-VAL] [ARG] ...Dropping [D itse]...
1692                = [[D itse] [T [<__>:15 [v [ihaile- <D Pekka>:15]]]]](185ms).
1693             5. Phrasal movement reconstruction...(190ms) (195ms) Done.
1694                = [[D itse]:1 [T [<__>:15 [v [__:1 [ihaile- <D Pekka>:15]]]]]](195ms).
1695             6. Agreement reconstruction...(200ms) (200ms) T acquired PHI:NUM:SG from <__>:15 inside its siste
1696                = [[D itse]:1 [T [<__>:15 [v [__:1 [ihaile- <D Pekka>:15]]]]]](200ms).
1697             7. Last resort extraposition...(205ms) LF-interface test...Done.
1698                = [[D itse]:1 [T [<__>:15 [v [__:1 [ihaile- <D Pekka>:15]]]]]](205ms).
1699     Done.
1700     LF-legibility check...Checking LF-interface conditions...(210ms) LF-interface test...
1701     Interpreting TP globally:
1702         "T" with ['PHI:DET:_'] was associated at LF with 1. [D itse]    (alternatives: ). (215ms) (215ms) Don
1703         Narrow semantics for DP: Project (1, QND) for DP (<D Pekka>)...Project (2, GLOBAL) for DP...Done. Don
1704         "v" with ['PHI:DET:_', 'PHI:NUM:_', 'PHI:PER:_'] was associated at LF with 1. <D Pekka>    (alternati
1705         Narrow semantics for vP: Project (3, PRE) for v...Project (4, GLOBAL) for vP...Done.
1706         Narrow semantics for DP: Project (5, QND) for DP ([D itse])...Project (6, GLOBAL) for DP...Done. Done
1707         "ihaile-" with ['PHI:DET:_', 'PHI:NUM:_', 'PHI:PER:_'] was associated at LF with 1. [D itse]    (alte
1708         Narrow semantics for ihaile-P: Project (7, PRE) for ihaile-...Project (8, GLOBAL) for ihaile-P...Done
1709     Denotations:
1710         [D Pekka]~['2', '6']
1711         [D itse]~['2', '6']
1712     Assignments:
1713         Assignment {'1': '2', '5': '2'} (R=set()) (R={'2'}) accepted.
1714         Assignment {'1': '2', '5': '6'} (R=set()) (R={'2'}) rejected by binding.
1715         Assignment {'1': '6', '5': '2'} (R=set()) (R={'6'}) rejected by binding.
1716         Assignment {'1': '6', '5': '6'} (R=set()) (R={'6'}) accepted.
1717     Calculating information structure...Done. (225ms) Done.
1718     Solution was accepted at 1510ms stimulus onset.
```

Figure 7. A screenshot from the derivational log file. Lines 1685-1699 show all reconstruction operations that were performed before the parse was submitted to narrow semantics. The operation that reconstructs the two arguments is on line 1692.

The same reasoning applies to simple Ā-dependencies such as interrogatives: operators are canonicalized inside the syntactic processing pathway (Brattico & Chesi, 2020) and then considered for assignment (14).

(14) Itse-ä-än$_{1,*2}$-kö Pekka$_1$ ihailee __? (#6)

self-PAR-PX/3SG-Q Pekka.NOM admire-3SG.PRS

’Was it himself that Pekka admires?’

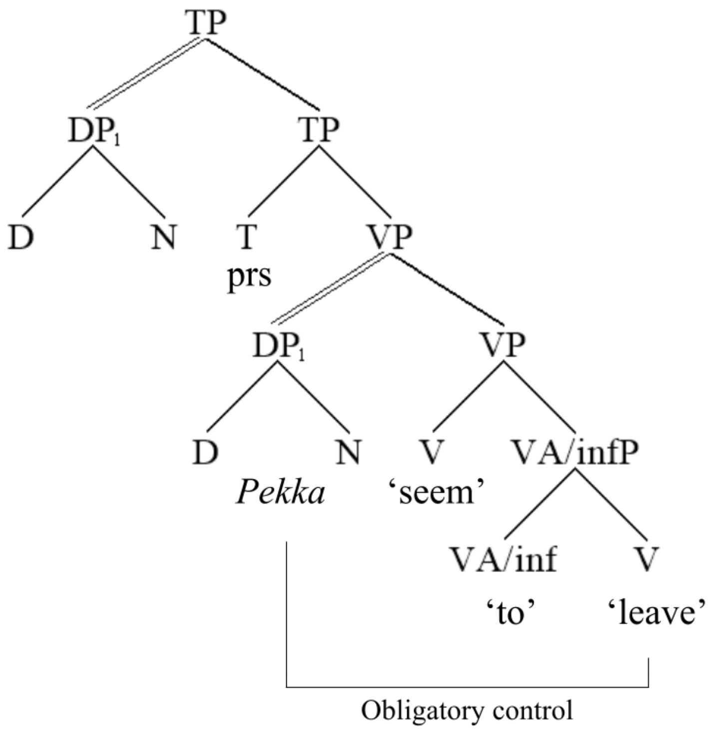
Q is a yes/no particle corresponding to yes/no interrogativization and an interrogative operator reading of the fronted reflexive direct object argument (see the translation). Data from Finnish Ā-reconstruction and adjunct reconstruction therefore support the hypothesis that narrow semantics can access only the syntax-semantics interface. The case with successive-cyclic Ā

-reconstruction and A-reconstruction is more complex (e.g., Barss, 1986; Hicks, 2008; Lebeaux, 2009). To illustrate the issue in Finnish, I used Finnish equivalents of the A-reconstruction constructions discussed by Lebeaux (2009). They are provided in (15).

(15) a.	Pekka$_{1, i}$	näyttä-ä	omasta	mielestä-än$_1$	__$_i$	ole-va-n(sa)	valmis.
	Pekka.NOM	seem-3SG.PRS	own	mind-PX/3SG		be-VA/INF-(PX/3SG)	ready
	‘Pekka seems to his own mind to be ready.’						
b.	Pekka$_{1, i}$	näyttä-ä	opettaja-nsa$_1$	mielestä	_ _$_i$	ole-van	älykäs.
	Pekka.NOM	seem-3SG.PRS	teacher-PX/3SG	opinion		be-VA/INF	intelligent
	‘Pekka seem to his teacher to be intelligent.’						
c.	Pekka$_{1, i}$	näyttä-ä	itse-nsä$_1$	mielestä	__$_i$	komealta.	
	Pekka.NOM	seem-3SG.PRS	self-PX/3SG	opinion		handsome	
	‘Pekka seem to himself (to be) handsome.’						

The subject constitutes a binder for an anaphoric and/or reflexive element inside the main clause. The assignment mechanism accesses, therefore, a representation where the subject resides in the surface subject position. Many linguistic theories assume, however, that the subject is A-reconstructed into the trace position. If assignments are calculated before reconstruction, as assumed here, the required interpretations cannot be accessed. The problem does not arise here, however, because the syntactic background model does *not* as a matter of fact reconstruct the grammatical subject into the embedded infinitival; rather, these sentences are analysed as obligatory control constructions (16)(#7)(control properties are shown on line 237 in the results file).

(16)



This is not due to the lack of A-reconstruction – the underlying model does successive-cyclic A-reconstruction – but rather because the embedded thematic position, the target for the hypothetical A-reconstruction, can only check the genitive, not nominative case (17a-c). Reconstructing a nominative argument into a position where only the genitive case could be checked results in a rejected derivation.

(17) a. Pekka näyttä-ä [$_{\text{VA/infP}}$ lähte-vän.] (#7)
Pekka seem-3SG.PRS leave-VA/INF
'Pekka seems to leave.'

b. Merja näke-e [$_{\text{VA/infP}}$ Peka-n lähte-vän.]
Merja.NOM see-3SG.PRS Pekka-GEN leave-VA/INF
'Merja sees Pekka leaving/to leave.'

c. *Merja näke-e [$_{\text{VA/infP}}$ Pekka lähte-vän.]
Merja.NOM see-3SG.PRS Pekka.NOM leave-VA/INF

Evidence from binding and case assignment therefore converge towards a control analysis of Finnish raising constructions. Despite this, the larger question of whether semantic interpretation has access to syntax-internal computations cannot be judged by looking only at this one construction. I will return to this nontrivial and controversial issue at the end of this article.

English reflexives are processed in the same way, but involve an additional gender factor. Sentence #*John admires herself* (#8, 157) receives no assignment because the gender feature of the reflexive does not match with the gender feature of any object that appears in its reference set (e.g., 'John') (line 275 in the results file). English reflexives and gender mismatches are tested by sentences #151-154 and #157-162. Since the weight of **John*$_1$ *admires herself*$_1$ is zero, it can be changed downstream, for example if it were provided that John prefers to be addressed by a different gender pronoun. Several kinds of English gender mismatches were tested by sentences in groups §3.2, 3.3. Finnish pronouns and reflexives do not exhibit gender distinctions; human and nonhuman distinction (*se* 'it' ~ *hän* 's/he') was used in this study for testing purposes (#9-11). Examples like (18) (#11) show that the system works correctly.[13]

(18)	Pekka$_1$	sanoi	että	Merja$_2$	ihaile-e	sitä$_{*1,*2,3}$ (#11)
	Pekka.NOM	said	that	Merja.NOM	admire-PRS.3SG	it.PAR (nonhuman)

'Pekka said that Merja admires it (of an animal, for example).'

The test corpus has sentences testing inverse subject-reflexive constructions such as *himself admires John* (§3.4), which were correctly ruled out, and reflexives inside conversations (§3.5). Conversation (19)(#179-180) points to a potential problem.

(19) John$_{\{1,2\}}$ admires himself$_{\{1,2\}}$. He$_{\{1,2,3\}}$ sleeps.

The first sentence will project two semantic objects [1] and [2] corresponding to *John* and *himself*, and the reflexive then forces the coreference reading. That is, if *John* denotes [1] under assignment A$_1$, the reflexive will denote the same object; if John denotes [2] under assignment A$_2$, so does the reflexive. Since the third person pronoun in the second sentence will project its own semantic object, it will have tree possible assignments: [1-2] projected by the first sentence plus a third party [3]. This means that there is a reading where ⟨*John*, *himself*⟩ denotes [1] while *he* denotes [2] that was projected momentarily into existence by the reflexive pronoun in the first sentence. This is unintuitive, and native speakers do not have a choice between two third party referents here. The reason I want to allow *himself* to project its own semantic entity is due to the data collected and discussed by Pollard & Sag (1992), further addressed in Section 4.4.3, showing that reflexives can be "exempted" from the antecedent requirement. The problem is more general, however: third person pronouns can, according to the mechanism posited in this study, denote ghost entities deemed irrelevant by prior assignments. The problem arises because assignments are calculated over sentences, not over conversations. This problem was left for future research.[14]

Reflexive binding was tested in connection with control constructions (§3.6). Examples (20) show the tested patterns in English, but the same constructions or equivalents were also tested in Finnish.

(20) a. John wants Mary$_1$ to admire herself$_1$/*himself. (#185, 187)

b. John$_1$ wants to admire himself$_{1,*2}$/*herself (#189-192, 195-6)

c. John$_1$ wants himself$_{1,*2}$/*herself to admire Mary (#197-201)

Although the binding properties were calculated correctly, infinitivals involve an extra complication because their grammatical analyses are controversial, and particularly so in Finnish. The syntactic analyses calculated by the syntactic background model, both Finnish and English, are visible in the output (for quick overview, see lines 6484 and 6524 in the results file) and must be assessed in a separate study; to me they do not appear implausible. I will ignore the issue here. Binding from an embedded *that*-clause into the main clause subject was correctly ruled out (§3.7).

Condition B of the binding theory, tested systematically by sentences in group §2, restricts pronouns into positions where they are not locally bound (see van Steenbergen 1991 for Finnish). Pronouns are endowed with [NEW:REF] requiring an assignment that does *not* denote the same object as another expression inside the reference set. This assumption derives (21). Only the relevant assignments are shown.

(21) a.	Pekka$_1$	ihaile-e		hän-tä$_{*1,2}$. (#12, #79-80)			
	Pekka.NOM	admire-3SG.PRS		he-PAR			
	‘Pekka$_1$ admires him$_{*1,2}$.’						
b.	Pekka$_1$	sanoo	että	Merja$_2$	ihaile-e	hän-tä$_{1,*2,3}$. (#13)	
	Pekka.NOM	says	that	Merja.NOM	admire-3SG.PRS	he-PAR	
	‘Pekka$_1$ said that Merja admires him$_{1,2}$.’						
c.	[Peka-n$_1$	sisko]$_2$	ihaile-e		hän-tä$_{1,*2,3}$. (#14, §2.9)		
	Pekka-GEN	sister	admire-3SG.PRS		he-PAR		
	‘Pekka’s sister admires him.’						
d.	Pekka$_1$	ihaile-e		[hän-en$_{1,2}$	sisko-a-an.] (#83)		
	Pekka.NOM	admire-PRS.3SG		he-GEN	sister-PAR-PX/3SG		
	’Pekka admires his sister.’						

The assignments marked in (21a) are calculated in this way because under no assignment can the pronoun refer to the same person as the subject. This condition does not prevent coreference in (21b), because the embedded clause triggers intervention by the head of the embedded subject DP = [D$_{[\text{REF}]}$ N] = *Merja*. In example (21c), the possessive DP *Peka-n* ‘Pekka-GEN’ does not occur inside the reference set calculated for the pronoun *hän-tä* ‘he-PAR’, because it is not visible in the upward path from the pronoun. Example (21d) will be discussed in detail in Section 4.4.4; the internal structure of the possessive constructions more generally is discussed in Section 4.4.5. Combinations of pronouns, proper names and various phi-features (gender, human) in English, formed from (22), are in the group §2.1 (sentences #64-78) and in group §2.2 (sentences #84-87). The case assignment patters were tested in group §2.3, sentences #90-97. They were computed correctly.

(22) John/Mary/he/she/it admires John/Mary/him/her/it.

The testing of English possessive constructions such as *John admires his sister* (#77, 78) requires a comment. The possessive sentence is represented by *John admires he=’s sister* in the test corpus, where = denotes a clitic boundary and ‘*s* is the possessive suffix. The syntactic model calculates (23), where *his* can share reference with the main clause subject due to the intervening referential constituent D(‘*s*). I will return to the internal analysis of DPs in Section 4.4.5.

(23) [*John*$_1$ [*admires* [$_{DP}$ D(‘*s*) [$_{NP}$ *he*$_{1,2}$ *sister*]]]
[REF]

Pronouns can corefer with the main clause subject if they occur inside embedded that-clauses (24), #98-103 for equivalent sentences in English. These tests are in group §2.4.

(24) a.	Pekka$_1$	sanoi	että	hän$_{1,2}$	ihaile-e	Jukka-a$_{*1,*2,3}$. (#106)
	Pekka.NOM	said	that	he.NOM	admire-PRS.3SG	Jukka-PAR
	‘Pekka said that he (Pekka, third party) admires Jukka.’					
b.	Pekka$_1$	sanoi	että	Merja$_2$	ihaile-e	hän-tä$_{1,*2,3}$. (#105)
	Pekka.NOM	said	that	Merja.nom	admire-prs.3sg	he-PAR
	‘Pekka said that Merja admires him (Pekka, third party).’					
c.	Pekka$_1$	sanoi	että	hän$_{1,2}$	ihaile-e	hän-tä$_{1,*2,3}$ (#107)
	Pekka.NOM	said	that	he.NOM	admire-PRS.3SG	he-PAR
	‘Pekka said that he (Pekka, third party) admires him (Pekka, fourth party).’					

Sentence (24c) involves “dynamic binding” that cannot be represented by simple indexing, because the calculated assignment possibilities for the second pronoun depend on the assignments provided for the first. If the first pronoun *hän* ‘he’ denotes the same object as Pekka under some assignment A, then *under that same assignment* A the second pronoun cannot denote Pekka because the denotation is reserved by the first pronoun (*Pekka*$_1$ – *he*$_1$ – *him*$_{*1,2}$). If the first pronoun denotes somebody else, then this is a possibility (*Pekka*$_1$ – *he*$_2$ – *him*$_{1,*2,3}$). The output data corresponding to this pattern can be found from lines 3941-3967 in the results file.

These data suggest that the complementizer creates an intervention, which was handled by assuming that it has [REF]. This is supported by the observation that infinitivals, such as (25), do not have the coreference reading (group §2.5). The complementizer is missing, hence no intervention.

(25) a. Pekka$_1$ halua-a [hän-en$_{*1,2}$ ihaile-van Merja-a.]
Pekka want-PRS.3SG he-GEN admire-VA/INF Merja-PAR
'Pekka wants him (≠Pekka) to admire Merja.'

b. John$_1$ wants him$_{*1,2}$ to admire Mary.

Perhaps complementizers function like sentential D-elements. They will then project 'thing objects' into the discourse inventory that can function as antecedents of nonhuman pronouns (e.g., *Mary claimed that* [*it was raining*]$_1$ *and John believed it*$_1$). Propositional binding of this type was excluded from this study. If the phi-features match, coreference reading is available from the direct object position, as the embedded subject causes intervention (26)(#108-111, #118-120, #121).

(26) John$_1$ wants Mary$_2$ to admire him$_{1,*2,\,3}$/her$_{*1,*2,\,3}$.

Pronouns can refer to any object inside the global discourse inventory as long as the phi-features match. This feature was tested by embedding pronouns inside conversations (group §2.7). The model calculates these dependencies correctly, as shown by example (27).

(27) a. John$_1$ admires Mary$_2$; he$_{1,3}$ admires her$_{2,4}$. (#127-128)

b. It$_1$ sleeps; he$_{*1,2}$ admires Mary$_{*1,*2,3}$. (#131-132)

In (27a), the first sentence generates two objects 'John' and 'Mary' into the discourse inventory. This inventory is available when denotations are calculated for the pronouns in the second sentence. Taking the phi-features into account, both pronouns can refer either to an existing object in the discourse inventory (*he* = 'John', *her* = 'Mary') or to new objects generated while reading the second sentence. Phi-feature mismatches prevent all coreference readings in (27b). Systematic phi-feature tests are in group §2.8.

Condition C of the binding theory, which was tested systematically by sentences in group §1.4, states that an R-expression (here represented by proper names) cannot be bound. This condition was restated by feature [NEW:_] which requires that the denotation must be new in relation to its reference set calculated by assuming no intervention. This derives the dataset (28). All coreference readings are ruled out in these examples unless specifically marked as possible (e.g., example c).

(28) a. Hän$_1$ ihaile-e Merja-a$_{*1, 2}$. (#15, #56)

he.NOM admire-3SG.PRS Merja-PAR

'He admires Merja.'

b. Pekka$_1$ sanoi että Merja$_2$ ihaile-e Jukka-a$_3$. (#16)

Pekka.NOM said that Merja.NOM admire-3SG.PRS Jukka-PAR

'Pekka said that Merja admires Jukka.'

c. [Hänen$_1$ siskonsa]$_2$ sanoi että Pekka$_{1, 3}$ ihaile-e Merja-a$_{1, *2, *3}$. (#17, #58)

S/he.GEN sister said that Pekka.NOM admire-3SG.PRS Merja-PAR

'His/her$_1$ sister said that Pekka admires Merja$_{1,2}$.'

d. Hän$_1$ sanoi että Pekka$_2$ ihaile-e Merja-a$_3$. (#57)

S/he said that Pekka.NOM admire-PRS.3SG Merja-PAR

'He said that Pekka admires Merja.'

The corresponding English sentences are #50-55, group §1.4. Without intervention feature the dependency extends through the whole structure (28b) (group §1.2 in test corpus). These dependencies are regulated by the upward path mechanism (28c); hence it is possible to use a proper name to denote a discourse old object, as shown by (29) below.

(29) John$_1$ sleeps; John$_{1, 2}$ admires Mary. (#18-19, also group §1.5, #59-62)

The same logic extends to infinitivals (30)(group §1.3), where all proper names must be disjoint in reference.

(30) a. John$_1$ wants Mary$_{*1,2}$ to admire Bill$_{*1,*2,3}$. (#48)

b. Pekka$_1$ sanoo Merja-n$_{*1,2}$ ihaile-van Jukka-a$_{*1,*2,3}$. (#49)

Pekka says Merja-GEN admire-VA/INF Jukka-PAR

'Pekka says that Merja admires Jukka.'

Sentences (31) were also calculated correctly.

(31) a. John$_1$ admires Mary$_{*1,2}$. (#40)

b. John$_1$ admires John$_{*1,2}$. (#42)

The coreference reading in (31a) is ruled out both by the binding conditions and by gender mismatch; in (31b) it is ruled out only by binding. Thus, repetition of upward path connected proper names generates disjoint reference readings that can be resurrected downstream if prompted by pragmatic conditions. All sentences of this type, for English and Finnish, are in group §1.1 in the test corpus.

4.4.3 Violations of Binding Conditions

Previous literature has reported several examples where binding conditions are seemingly violated. The following examples were discussed by Reinhart (1983, pp. 168–169), who cites Evans (1980).

(32) a. I know what John and Bill have in common. John thinks that Bill is terrific and Bill thinks that Bill is terrific. (Example (55a), p. 168, in the original)

b. I know what Bill and Mary have in common. Mary adores Bill and Bill adores Bill / and Bill adores him too. (Example (57a), p. 169, in the original)

Example (32a) can be seen as violating Condition C; example (32b) Condition B. A long list of similar “exempt anaphors” including reflexives were listed in Pollard & Sag (1992), reviewing and relying on much previous work, and then discussed by many others (see Charnavel 2021 for recent work). According to the model proposed here, violations of binding conditions reduce the weights of the corresponding assignments to zero, which means that downstream cognitive processes can resurrect them. While this does not constitute a formal solution to the problem posed by these examples, these data motivated the cognitive architecture underlying the present hypothesis.

4.4.4 Subjectless pro sentences and binding

Finnish is a partial pro-drop language, which allows grammatical subject pronouns to be dropped in all person and number configurations with the exception of the third person (33a-b) (Vainikka, 1989; Vainikka & Levy, 1999). These data create an additional complication.

(33) a. Ihaile-n Merja-a. (#20, 63)
admire-1SG.PRS Merja-PAR
'(I) admire Merja.'
b. *Ihaile-e Merja-a.
admire-3SG.PRS Merja-PAR
Intended: 'He admires Merja.'

The calculated output for (33a) is [$_{TP}$ T$_{pro}$ [$_{vP}$ v [$_{DP}$ *Merjaa*]]] (line 852) where the first person agreement suffix *-n* in the input projects a phi-set φ = [1SG] inside tense (line 24939 in the derivational log file). The pronominal agreement cluster then functions as a pro-element in syntax. Because the assignment mechanism is triggered by nominal phi-features, T$_{pro}$ projects the singular first person object (speaker) into the inventory (line 870 in the results file) and derives (34), where the reflexive is bound by the pro-element inside the predicate.

(34) Ihaile-n$_1$ itse-ä-ni$_{1,*2}$. (#21)
admire-1SG.PRS self-PAR-PX/3SG
'I admire myself.'
[T$_{pro1}$ [v [DP self$_1$]]]

Notice that the model correctly calculates a disjoint reference reading for (33a) due to the Condition C of the binding theory: T$_{pro}$ and the proper name cannot refer to the same thing even though their phi-features match (#63). The same logic applies to (34). Up to this point, then, the system works as intended. A complication, however, is that a third person embedded pro-drop clause is grammatical in

Finnish if (and only if) the null pronoun can be paired with a c-commanding antecedent (35). As shown by the translation, the thematic subject of the embedded but subjectless clause must be the same as the subject of the main clause.

(35) Pekka sanoo että [ihaile-e Merja-a.] (#22)
Pekka says that admire-3SG.PRS Merja-PAR
'Pekka$_1$ says that he (=Pekka$_1$) admires Merja.'

This phenomenon has received much interest in previous literature (Brattico, 2017; Holmberg, 2005; Holmberg & Sheehan, 2010; Vainikka, 1989; Vainikka & Levy, 1999), with one view being that the third person pro-element is 'weak' and requires semantic support from an antecedent (Holmberg & Sheehan, 2010). The syntactic background theory follows this intuition and assumes that the pro element lacks a fully specified D-feature, pairing it with an antecedent (Brattico, 2021b). The problem is that, unless we take some action, this does not constraint assignments. What we need to do is to introduce an additional condition which makes it so that if a predicate is assigned an argument by antecedent recovery, as in (35), its own pro-element must be assigned the same interpretation. Once I added this restriction to the assignment mechanism, the data comes our correctly (36)(also group §2.10). Also reflexive binding was tested inside these environments (§3.8, #204-207).

(36) a. Pekka$_1$ sanoo että pro$_{1,*2}$ ihaile-e Merja-a$_{*1,*2,3}$. (#22, #147)
Pekka says that admire-3SG.PRS Merja-PAR
'Pekka says that he =(Pekka) admires Merja.'

b. Pekka$_1$ sanoo että pro$_{1,*2}$ ihaile-e itse-ä-än$_{1,*2,*3}$. (#23)
Pekka says that admire-3SG.PRS self-PAR-PX/3SG
'Pekka says that he (=Pekka) admires himself.'

c. Pekka$_1$ sanoo että pro$_{1,*2}$ ihaile-e hän-tä$_{*1,*2,3}$. (#24)
Pekka says that admire-3SG.PRS he-PAR
'Pekka says that he (=Pekka) admires him (≠ Pekka).'

d. Pekka$_1$ sanoo että pro$_{*1,2}$ ihaile-n hän-tä$_{1,*2,3}$. (#25, #148)

Pekka says that admire-1SG.PRS he-PAR
’Pekka says that I admire him (Pekka or someone else).’

Pro-subject functions as an intervention element for the pronoun, allowing the pronoun to pair with the main clause subject. This is because it contains the intervention feature [REF], being referential. This captures part of the “Specific Subject Condition” of the original GB-theory. Both the subject and an Agr head (here T_{pro}) can define a local domain for anaphors (Chomsky, 1981: 209–211). The results are the same if *Pekka* is replaced with *hän* ‘he’ (#149, 150).

A further issue is that when the input sentence contains both a grammatical subject and a T_{pro}-element, the model creates impossible interpretations illustrated in (37).

(37) Hän_1 $\text{ihaile-e}_{1,2,3}$ Merja-a_3.
he.NOM admire-3SG.PRS Merja-PAR
’He admires Merja.’

This problem was solved by assuming that Agree^{-1}, which connects the predicate and the argument formally and checks the phi-features of the predicate, pre-empts both antecedent recovery and the projection of a separate pro-element into the discourse inventory. The fact that these connections had to be posited suggests that the three mechanisms, control, agreement and binding, share some underlying mechanism. What this shared resource might be was left for future study.

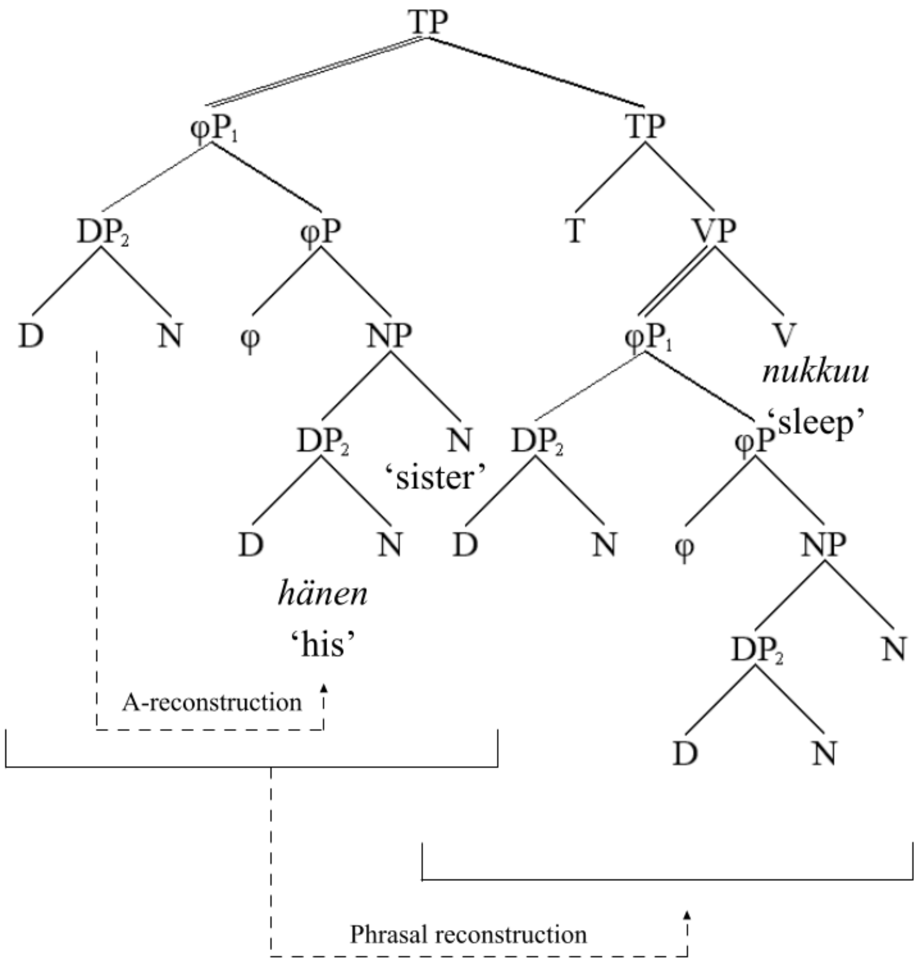
4.4.5 DP-internal binding

The syntax and semantics of full argument DPs and binding inside such constructions present special issues. In some earlier models that used the same syntactic background theory (Brattico, 2020, 2021b; Brattico & Chesi, 2020), full arguments were assumed to consist of $[_{DP}$ D NP] structures, following the DP-hypothesis (Longobardi, 1994). The problem is that Finnish lacks grammaticalized articles and D elements cannot be assumed to be present in the input. This issue was solved in this study by assuming, following the line of analysis by Déchaine & Wiltschko (2017), Déchaine & Wiltschko (2002) and van Steenbergen (1987, 1991), that full bare nominal arguments can be analyzed as $[_{\varphi P}$ φ

N] structures, where φ is a nominal agreement cluster head carrying phi-features. All bare noun arguments in Finnish were analyzed in this way (e.g., *sisko* ‘sister’ → [$_{\varphi P}$ φ sister]). The possessive argument will be generated to SpecφP and reconstructed to SpecNP (38-39).

(38) Hän-en sisko-nsa nukku-u. (#26)
S/he-GEN sister.NOM-PX/3SG sleep-3SG.PRS
’His/her sister sleeps.’

(39)



In English, ‘*s* is interpreted by the syntactic background theory as a clitic, projecting *his sister* = [$_{DP}$ D(‘s) [[D he] N]], assuming that ‘*s* represents D. This is controversial, but what matters is that under both analyses the possessive DP is invisible for upward paths from any element inside the TP. An upward path from TP will see φ but not the possessive pronoun:

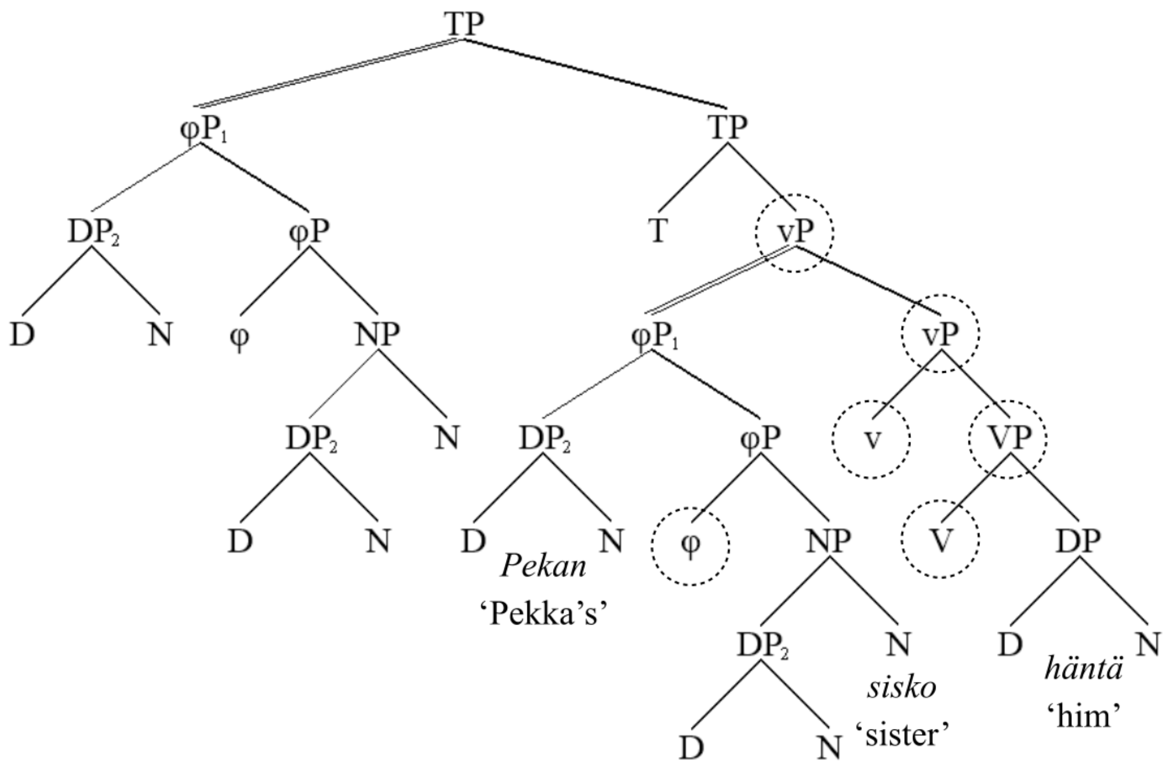
(40) [$_{\varphi P}$ Peka-n$_1$ sisko]$_2$ ihaile-e hän-tä$_{1,*2,3}$. (#27)

Pekka-GEN sister admire-3SG.PRS s/he-PAR

'Pekka's sister admires him.'

The structural analysis, showing the upward path calculations from the direct object pronoun, is (41).

(41)



Another consequence of this analysis is that both (42a-b) are calculated correctly. D^0 and φ^0 intervene, allowing the pronouns to refer to the main clause subject.

(42) a. John$_1$ admires [$_{DP}$ D his$_{1,2}$ sister]$_3$. (#28)

b. Pekka$_1$ ihaile-e [$_{\varphi P}$ φ (hän-en$_1$) sisko-a(-an).] (#29)

Pekka.NOM admire-3SG.PRS (he-GEN) sister-PAR(-PX/3SG)

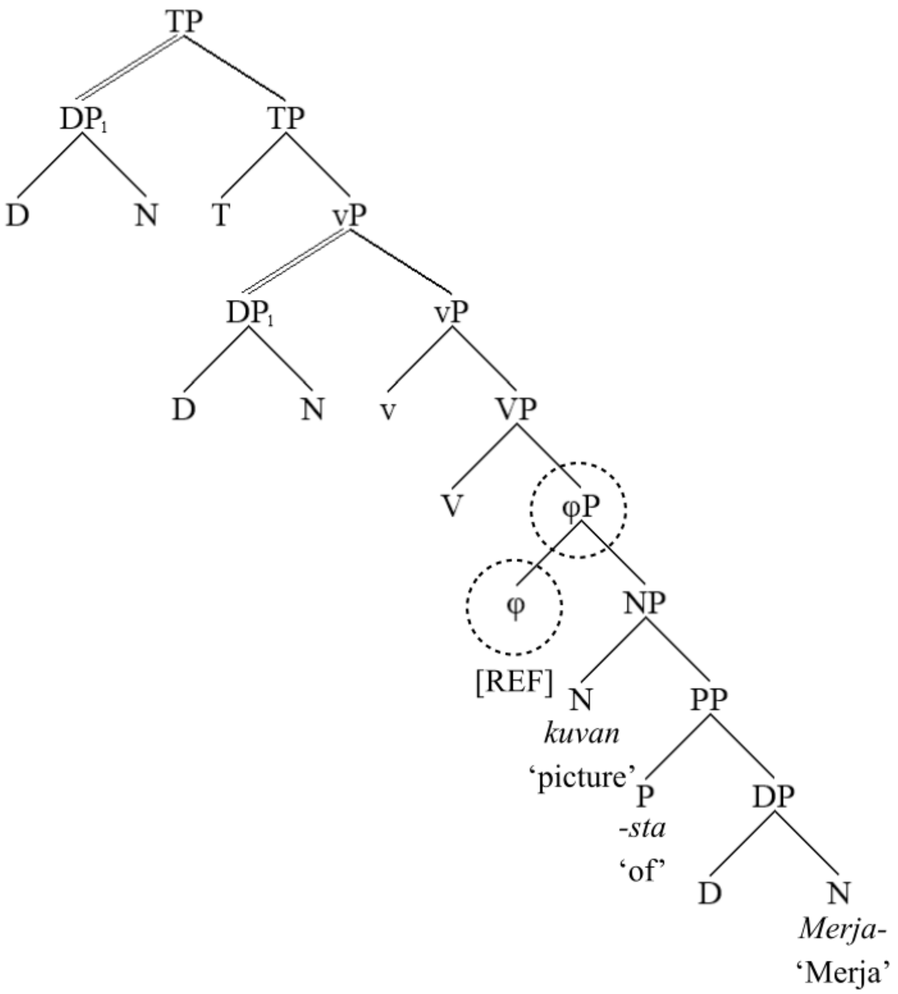
'Pekka admires his sister.'

The Finnish version feels marginal, but not ungrammatical.[15] A potential issue is that both pronouns and reflexives are possible in the complement positions of nouns (43).

(43)	a.	Pekka$_1$	ott-i	kuva-n	itse-stä-än$_{1,*2}$
		Pekka.NOM	take-3SG.PST	picture-ACC	self-ELA-PX/3SG
		’Pekka took a picture of himself.’			
	b.	Pekka$_1$	ott-i	kuva-n	hän-estä$_{??1,2}$.
		Pekka.NOM	take-3SG.PST	picture-ACC	he-ELA
		‘Pekka took a picture of him.’			
	c.	Pekka$_1$	ott-i	kuva-n	Merja-sta$_2$. (#31)
		Pekka.NOM	take-3SG.PST	picture-ACC	Merja-ELA
		‘Pekka took a picture of Merja.’			

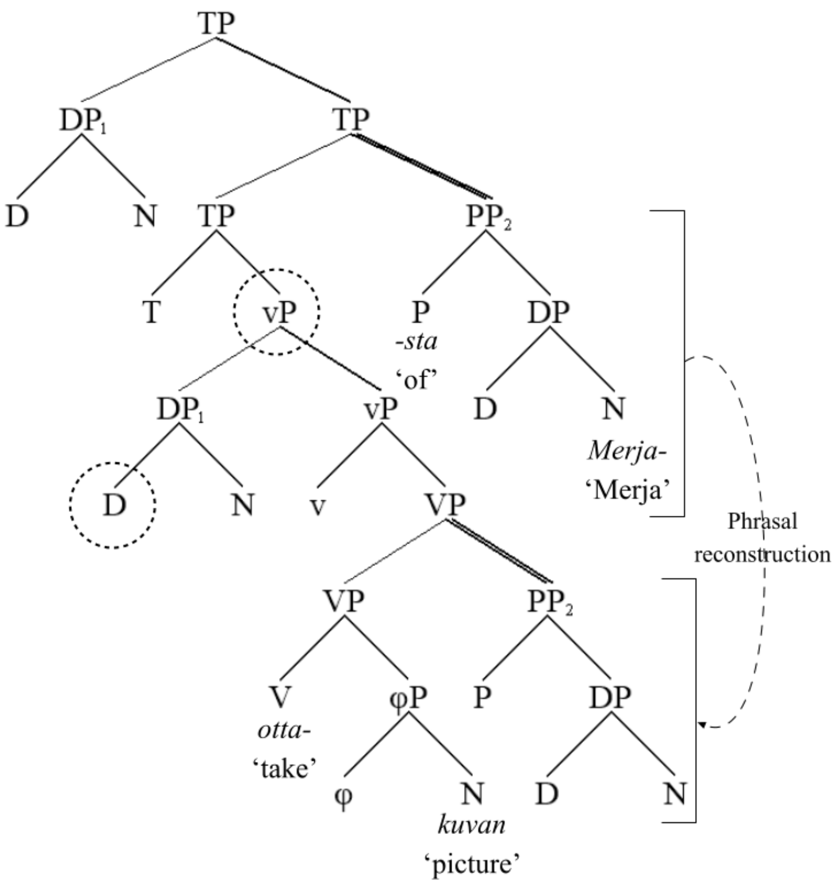
At first this data seems to contradict the present hypothesis, which predicts pronouns and reflexives to be complementary. Feeding these expressions to the syntactic background model reveals a different picture. Due to the discourse-configurationality of the target language, the syntactic background model treats both the accusative-marked direct object and the preposition as adjuncts. This means that input sentences such as (43a-c) will have multiple ambiguities depending on the assumed position of both the direct object and the PP (see lines 1369 and 1398-1404 for overview). The first solution found by the model is (44)(see #31).

(44)



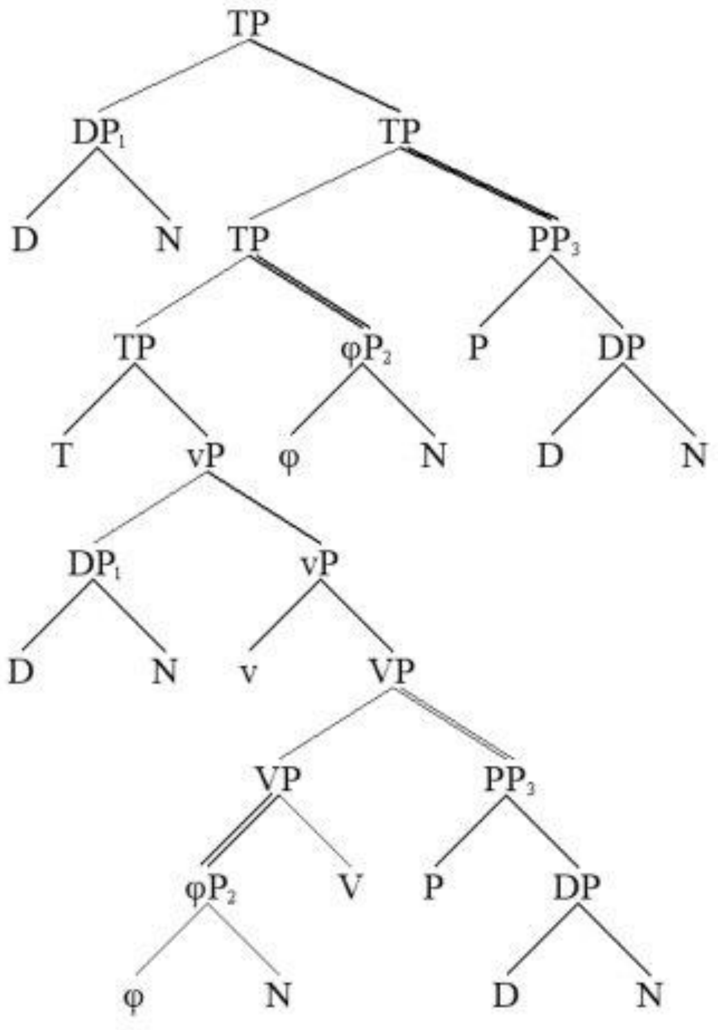
The PP 'of Merja' was analysed as the complement of the noun head 'picture' to create a complex DP with the meaning 'a picture of Merja' (line 1369). In this configuration, due to the fact that φ causes intervention, shown by the circles in (44), upward path will reach φ, licensing 'Pekka$_1$ took a picture of him$_1$' but not 'Pekka$_1$ took a picture of himself$_1$'. The second parse is (45), line 1398.

(45)



The parser assumed that the PP is right-adjoined to the TP, and reconstructed it as right-adjoined to VP. Under this interpretation, the sentence means roughly 'Pekka took a picture, and it was of Merja', so that 'of Merja' is interpreted as an argument of the verb or event and not as the complement of N. The reference set for the DP inside PP contains everything up to the subject and the direct object is invisible, thus we get 'Pekka$_1$ took a picture of himself$_1$' and not 'Pekka$_1$ took a picture of him$_1$'. This ambiguity derives the data in (43). The third analysis, worth mentioning, is (46), line 1402.

(46)



Here both the direct object and the PP were initially analysed as being adjoined to the right of TP, and both were reconstructed. The binding possibilities are those of (45). If we assume that in English picture PPs can be adjoined while DPs can't, then we get (44) and (45) but not (46), which is sufficient to capture data from English.

It is obvious that these calculations are not uncontroversial. Some of the particulars do not matter, however. What matters is that a right-adjoined PP can be analysed both as a complement of the noun and as an "extraposed" right-adjoined VP-modifier, and this ambiguity, when available, causes the complementarity between *him* and *himself* to break down.

4.4.6 Embedded infinitivals

Embedded infinitivals are transparent to upward paths. Thus, embedded pronouns cannot corefer with main clause subjects, while reflexives can. The model calculates these dependencies correctly, both for English (47) and Finnish (48). Note that Finnish has several infinitival forms glossed as A/INF (A-infinitival) and VA/INF (VA-infinitival)(Koskinen, 1998; Vainikka, 1989).

(47) a. John$_1$ wants to admire him$_{*1,2}$. (#32)

b. John$_1$ wants to admire himself$_{1,*2}$ (#33)

(48) a.

Pekka$_1$	halua-a	[ihail-la	hän-tä$_{*1,2}$.] (#34)
Pekka.NOM	want-3SG.PRS	admire-A/INF	he-PAR

‘Pekka wants to admire him.’

b.

Pekka$_1$	halua-a	[ihail-la	itse-ä-än$_{1,*2}$.] (#35)
Pekka.NOM	want-3SG.PRS	admire-A/INF	self-PAR-PX/3SG

‘Pekka wants to admire himself.’

An embedded subject, however, does cause intervention and reverses the pattern (49). These results again correspond to the effects of the Specified Subject Condition of the standard binding theory (Chomsky, 1977, 1981; Chomsky & Lasnik, 1977).

(49) a.

Pekka$_1$	halua-a	[Merja-n$_2$	ihaile-van	hän-tä$_{1,*2,3}$.] (#36)
Pekka.NOM	want-3SG.PRS	Merja-GEN	admire-VA/INF	he-PAR

‘Pekka wants Merja to admire him.’

b.

Pekka$_1$	halua-a	[Merja-n$_2$	ihaile-van	itse-ä-än$_{*1, 2,*3}$.] (#37)
Pekka.NOM	want-3SG.PRS	Merja-GEN	admire-VA/INF	self-par-PX/3SG

‘Pekka wants Merja to admire herself/*himself.’

Positioning the pronouns to the embedded subject position calculates expected results: pronouns cannot corefer with the main clause subject while reflexives can. van Steenbergen (1991) suggests however that the binding domain for the Finnish reflexive is determined by tense and supports the generalization by citing the VA-infinitival construction (example (6a) in the original, p. 235, my glossing):

(50)	Pekka$_1$	näki	[$_{\text{VA/infP}}$	Mat-in$_2$	katso-van	itse-ä-än$_{1,2}$.]
	Pekka.NOM	see.3SG.PST		Matti-GEN	look-VA/INF	self-PAR-PX/3SG
	‘Pekka saw Matti watch himself.’					

To me the long-distance binding configuration is rather marginal, and indeed van Steenbergen cites other infinitival constructions where she agrees with my judgment (e.g., example (8) in her paper). This claim is not isolated, however; also Trosterud (1990, p. 69) judges (51) grammatical (=ex. 35b in the original).

(51)	Maija$_1$	käsk-i	meidän	pes-tä	itse-nsä$_1$.
	Maija.NOM	order-3SG.PST	we.GEN	wash-A/INF	self-PX/3SG
	‘Maija ordered us to wash herself.’				

I find this marginal, and ungrammatical if the embedded subject and the reflexive agree in phi-features (*meidän – itsemme* ‘us – self.PX/1PL’ or *hänen – itsensä* ‘self.PX/3SG’). Trosterud reports the same result from Pyssyjoki Finnish (pp. 95-96), thus his informants did not accept long-distance binding when the intervening subject and the anaphor agreed. Long-distance binding was absent from the Finnmark dialect (pp. 93-94). Finally, Trosterud reported that there was between-speaker variation in the elicited judgments. This instability corresponds with my own intuition, equally unclear and marginal at best. Therefore, I think that a firm conclusion cannot yet be reached. The analysis proposed in this article allows one to define locality on the basis of the minimal tense phrase (by feature [OLD:T]), but the hypothesis must be tested over several constructions in the dialect/language where it looks reasonable. In my Finnish, it does not.

5 DISCUSSION AND RESIDUUM PROBLEMS

A hypothesis was developed and tested which assumes that binding conditions regulate assignments at the outer edge of language, at the language-cognition interface. Referential expressions grammaticalize and lexicalize instructions allowing the hearer to exclude discourse objects from consideration when computing assignments.

Perhaps the main alternative to the proposal developed in this article is an analysis where some coreference and/or non-coreference dependencies are calculated inside syntax (e.g., Chomsky, 1977, 1980, 1981, 1982; Fiengo & May, 1994; Hicks, 2008; Hornstein, 2001; Reuland, 2001, 2006; Rooryck & Wyngaerd, 2011). Due to the existence of contexts where the binding principles can be overridden (Section 4.4.3), this system cannot be interpreted as a strict filter. What could a syntactic binding mechanism do? Perhaps it could leave some kind of formal signal at the syntax-semantics interface to bias downstream assignments towards certain solutions? But since assignment management is required on independent grounds, what possible rationale could a syntactic mechanism of this kind have over one that regulates assignment itself? I was not able to find meaningful role for a purely syntactic binding mechanism and rejected this alternative.

Let us consider Fiengo & May's discussion (1994: Ch. 1) of this issue. They note that a simplistic theory in which syntactic coindexing is equivalent to coreference cannot be true, due to (among other things) the existence of various pragmatic contexts that override the effects of binding. They propose a linking rule (p. 3) according to which syntactic coindexing "contributes" to the meaning of the sentence but does not determine actual interpretative coreference relations because for the latter speakers can "rely on context" (p 10). I think I could indeed design an algorithm following Fiengo & May (1994) that computes binding conditions inside syntax that are then outperformed downstream by pragmatic conditions and/or speaker's communicative intentions. We would then allow indexing, as it arrives from syntax into the interpretative component, to "contribute" to actual assignment. The problem I have with this proposal is that, since it already presupposes an assignment mechanism, the null hypothesis seems to be one where we have assignment but no extra syntactic binding apparatus. In other words, we get assignment for free because it has independent motivation, where syntactic binding seems unprincipled and conceptually less natural. This argument is obviously quite weak and does not rule out the possibility that a more elegant model could be designed by relying on syntactic binding. If so, it remains to be seen what kind of algorithm could be developed on the basis of syntax-internal binding and how it would compare with the one presented here.

Several authors (e.g., Hicks, 2008, Hornstein, 2001; Reuland, 2001) have correctly noted that there exists a strong prima facie reason to formulate binding at the level of syntax and/or by relying on syntactic operations such as Move or Agree, which is that binding clearly follows syntactic constraints (c-command, locality). The argument is weakened, however, by the fact that semantic interpretation feeds the endpoint of syntax, perhaps even syntax-internal events (see below). Thus, I have assumed that assignment management has access to the endpoint of syntax and, for this reason, exhibits the signature of syntactic processing. Of course, the upward path mechanism remains an unexplained and additional primitive of the theory that cannot be explained by, or reduced to, purely syntactic operations. Concerning locality, Reuland correctly observes that “since locality cannot be a characteristic of interpretive dependencies per se,” delegating the conditions to an interpretative component “would only state the problem, rather than solve it” (p. 441). I agree, and the issue cannot be brushed aside. On the other hand, it is also difficult to imagine how and why the system of semantic interpretation accessing the edge of syntax could remain entirely oblivious to formal properties and principles, since the very input is characterized by such structural properties and the system must be therefore intrinsically wired to handle then. Ultimately, though, my view is that conceptual arguments must be inconclusive either way, and therefore only welcome the prospect of comparing the present approach with a fully fletched out algorithmic, syntax-based model for binding.

Long-distance anaphors and logophors do not follow the binding conditions A-C (e.g., Clements, 1975; Hellan, 1988; Huang, 2000a: Ch. 2.3; Sells, 1987; Thráinsson, 1990, 1991). The mechanism posited here is unable to calculate them. On the other hand, pronouns can denote any objects in the global discourse inventory that are consistent with their lexical properties. This gives the model an in-principle access to discourse-based and/or long-distance anaphors. We could add semantic metadata corresponding to ‘salience’, ‘source’, ‘self’ and point of view (e.g., Sells, 1987) to the conversations and use them to bias logophoric dependencies. A mechanism of this type is required on independent grounds since there is linguistic (Ariel, 1990; Givón, 1983; Grosz, Joshi, & Weinstein, 1995; Huang, 2000b; Pollard & Sag, 1992; Schlenker, 2005; Sperber & Wilson, 1995; Thráinsson, 1991) and psycholinguistic (Almor, 1999; Cunnings & Sturt, 2014; Kazanina, Lau, Lieberman, Yoshida, & Phillips, 2007; Malt, 1985; Murphy, 1985a, b; Nicol & Swinney, 2003; Parker, 2019) evidence that assignment management utilizes context.

A particularly controversial and also difficult issue concerns the question of whether binding mechanisms are sensitive to syntax-internal events. In the model reported here, they were not. This could be too restrictive. Huhmarniemi & Vainikka (2010) discussed the Finnish particle *-kin* which generates quantifier pair-list readings but bleeds syntactic configurations that are established before Ā-reconstruction. The authors show that the interrogative pronoun suffixed with *-kin* must be c-commanded by an antecedent interrogative at the structure prior Ā-reconstruction. This is shown in (52).

(52)	a.	Kuka	ost-i	mitä-kin?	
		who.NOM	buy-PST.3SG	what.PAR-KIN	
		'Who bought what?' (only pair-list reading)			
	b.	*Mitä-kin$_1$	kuka	ost-i	__$_1$?
		what.PAR-KIN	who.NOM	buy-PST.3SG	
	c.	Mitä$_1$	kuka-kin	ost-i	__$_1$?
		what.PAR	who.NOM-KIN	buy-PST.3SG	
		'What did who bought?' (Only pair-list reading)			

Whatever mechanism interprets quantifiers needs access to grammatical representations generated before Ā-reconstruction. The second observations is due to Brattico (2018: Ch. 4.4) who shows that the binding of R-expressions and demonstrative anaphora are computed after Ā-reconstruction but before topic/focus reconstruction. These observations are further supported by the well-known fact that part of the Finnish information structure is calculated on the basis of topic/focus configurations creating discourse-sensitive word order permutations (Brattico, 2019b, 2020, 2021a; Holmberg & Nikanne, 2002; Huhmarniemi, 2019; Vilkuna, 1989, 1995). Finally, reflexive binding seems to have access to representations taking place before A-reconstruction, as already discussed in Section 4.4.2, example (15). These observations suggest that semantic interpretation *does* have access to syntax-internal representation and/or computations. There are two ways to implement the access mechanism. One is to let syntax-internal computations leave formal traces (e.g., copies) to the syntactic endpoint and then provide semantic interpretation means to interpret them. This would correspond to a “single interface hypothesis,” where the syntactic component interacts with semantics via single interface that is enriched with shadow traces of syntax-internal operations. The second possibility, call it the “multiple interface hypothesis,” is to provide semantic interpretation direct access to syntax-internal representations. Both hypotheses were considered, and the latter was implemented and tested tentatively. Ultimately, though, the issue was left unresolved and the calculations performed in this paper were done with the simpler model where narrow semantics was granted access only to the endpoint of syntax. This simplification may well require revision in the future.

There must be some reason or rationalization why language makes use of binding, and why binding properties are universal or near universal among world’s languages. One possible explanation is that they make communication easier by allowing the speaker and hearer to negotiate the range of admissible denotations efficiently and reliably. I think, however, that functional explanations should be resisted. Any system can be motivated on such grounds. We could imagine a language that uses only proper names to “make communication as unambiguous as possible.” A language that avoids all proper names would “eliminate repetition.” An alternative explanation is pure accident. It could be that the endpoint of the language processor is intimately connected, in virtue of the neuronal wiring of the human brain and its cognitive architecture, to the attentional mechanism EVAL. Once the connection has matured, the system can grammaticalize. This would agree with the minimalist intuition (Chomsky, 1995) that language satisfies “external conditions” imposed to it by its causal role in the human cognitive architecture.

I conclude this section with a methodological remark. The rigorous computational methodology used in this study is not common in linguistics, but a standard nonnegotiable feature of all advanced sciences. In the latter, it is an absolute requirement that all data is calculated mechanically from the hypothesis in order to avoid contamination by ambiguities, subjective opinions or intuitive unwarranted jumps. This guarantees a minimal level of rigor that all practitioners can agree to. Thus, the use of the more advanced computation methodology does not position the present study in any way outside of the realm of traditional linguistics concerns and into some irrelevant or esoteric field of "computational linguistics" or "computer modeling." Instead, a collection of ordinary linguistic hypotheses were disambiguated into a Python-based formalism and tested by calculation. There is, furthermore, no rational justification for not doing this; an ambiguous theory is always less compelling than a formal one, arguably even when the latter cannot deduce all the data correctly. In the case of the former, it is always unclear what the theory entails, rightly or wrongly. Thus, a strong case can be made, in this author's opinion, that linguistics should follow all other disciplines and use formal justification in its theorizing.

But there is another sense in which the computational methodology adopted here could be seen as involving substantial, empirical matters. The general framework goes back to Marr (1982), who argued that an information processing theory of this type could be seen as involving three levels of analysis, namely the computational level, algorithmic level and the implementation level. At the *computational level*, the researcher is only concerned with abstract input-output dependencies, in this case mappings from input sentences into grammaticality judgments, syntactic analyses and semantic interpretations, and ignores implementation. Looked from this perspective, we could reverse-engineer the present hypothesis and express it by using an enumeration grammar that generates sentence-meaning pairs by using some grammatical operations (e.g., Merge, Move, Agree) instead of recognizing sentences. This is, indeed, the approach taken by most linguists, whether generative or not. The *algorithmic level* brings in additional concerns. It describes one particular computational mechanism (or, rather, a class of such mechanisms) that implements the abstract computational mapping, in the present case this was done by using a Python-based recognition grammar. This is not empirically innocent, because in most cases it requires further cognitive assumptions about language comprehension (or production, depending on the point of view). It is a mistake to think, I think, that such concerns can be brushed aside forever into psycholinguistics or to other fields, since computationally specifier grammars are, as an actual fact, sustained by the human cognitive architecture. That being said, by adding algorithmic detail to a computational linguistic theory does not make it less relevant to linguistics, as the algorithmic details can of course be ignored at will. For example, it is possible to use the present hypothesis in analyzing linguistic data without making any assumptions about its algorithmic implementation.

But the most interesting part of Marr's proposal is the implementation level. The algorithmic analysis adopted in the present study processes the input sentences by using discrete-combinatorial symbolic representations and functions defining operations on such structures. They exhibit no semblance to anything known currently about the human nervous system. But by simply having the functions in this forms opens up an interesting research avenue, where we can try to replace them with alternatives that are more in line with what we know about human neurophysiology and then test, by using large datasets, that the two systems are behaviorally identical. This could allow us to embed linguistics into neurolinguistics, and ultimately to construct a general theory of human brain function that is informed by linguistic data and theorizing. This could benefit both the neurosciences and linguistics.

6 CONCLUSIONS

Properties of binding constructions in Finnish and English were calculated from a formal model which assumes that binding operates at the language-cognition interface. Narrow syntax accesses a cognitive mechanism evaluating whether a cognitive object is in a (reference) set of other cognitive objects. Binding was considered a grammaticalization of this cognitive circuitry.

References

Almor, A. (1999). Noun-phrase anaphora and focus: The informational load hypothesis. Psychological Review, 106(4), 748–765. http://dx.doi.org/10.1037/0033-295X.106.4.748

Aoshima, S., Yoshida, M., & Phillips, C. (2009). Incremental Processing of Coreference and Binding in Japanese. *Syntax*, *12*(2), 93–134. http://dx.doi.org/10.1111/j.1467-9612.2009.00123.x

Ariel, M. (1990). *Accessing Noun-Phrase Antecedents*. London: Croom Helm.

Asher, N., & Wada, H. (1988). A computational account of syntactic, semantic and discourse principles for anaphora resolution. *Journal of Semantics*, *6*(1), 309–344. http://dx.doi.org/10.1093/jos/6.1.309

Badecker, W., & Straub, K. (2002). The Processing Role of Structural Constraints on the Interpretation of Pronouns and Anaphors. *Journal of Experimental Psychology: Learning Memory and Cognition*, *28*(4), 748–769. http://dx.doi.org/10.1037/0278-7393.28.4.748

Barss, A. (1986). *Chains and Anaphoric Dependencies*. Disseration, MIT.

Brattico, P. (2017). Null subjects and control are governed by morphosyntax in Finnish. *Finno-Ugric Languages and Linguistics*, *6*, 2–37.

Brattico, P. (2018). *Word Order and Adjunction in Finnish*. Aarhus: Aguila & Celik.

Brattico, P. (2019a). *A computational implementation of a linear phase parser. Framework and technical documentation (version 10.0)*. Pavia.

Brattico, P. (2019b). Subjects, topics and definiteness in Finnish. *Studia Linguistica*, *73*, 1–38. http://dx.doi.org/10.1111/stul.12129

Brattico, P. (2020). Finnish word order: does comprehension matter? *Nordic Journal of Linguistics*, *44*(1), 38–70. http://dx.doi.org/10.1017/S0332586520000098

Brattico, P. (2021a). A dual pathway analysis of information structure. *Lingua*, *103156*. http://dx.doi.org/10.1016/j.lingua.2021.103156

Brattico, P. (2021b). Null arguments and the inverse problem. *Glossa: A Journal of General Linguistics*, *6*(1), 1–29.

Brattico, P. (to appear). Predicate clefting and long head movement in Finnish. *Linguistic Inquiry*.

Brattico, P., & Chesi, C. (2020). A top-down, parser-friendly approach to operator movement and pied-piping. *Lingua*, *233*, 102760. http://dx.doi.org/10.1016/j.lingua.2019.102760

Brattico, P., & Huhmarniemi, S. (2016). *Finite and non-finite null subjects in Finnish*. Manuscript.

Büring, D. (2005). *Binding Theory*. Cambridge: Cambridge University Press.

Charnavel, I. (2021). Logophoricity, Perspective, and Reflexives. *Annual Review of Linguistics*, *7*, 131–155. http://dx.doi.org/10.1146/annurev-linguistics-030220-085846

Chomsky, N. (1977). On wh-movement. In P. W. Culicover, T. Wasow, & A. Akmajian (Eds.), *Formal Syntax* (pp. 71–132). Academic Press.

Chomsky, N. (1980). On binding. *Linguistic Inquiry*, *11*, 1–46.

Chomsky, N. (1981). *Lectures in Government and Binding*. Dordrecht: Foris.

Chomsky, N. (1982). *Some Concepts and Consequences of the Theory of Government and Binding*, Cambridge, MA: MIT Press.

Chomsky, N. (1995). *The Minimalist Program*. Cambridge, MA.: MIT Press.

Chomsky, N., & Lasnik, H. (1977). Filters and Control. *Linguistic Inquiry*, *8*, 425–504.

Clements, G. N. (1975). The logophoric pronoun in Ewe: its role in discourse. *Journal of West African Languages*, *10*, 141–177.

Clifton, C., Kennison, S. M., & Albrecht, J. E. (1997). Reading the words him and her: Implications for parsing principles based on frequency and on structure. *Journal of Memory and Language*, *36*, 276–292.

Culicover, P., & Jackendoff, R. (1995). “Something else” for the binding theory. *Linguistic Inquiry*, *26*(2), 249–275.

Cunnings, I., & Felser, C. (2013). The role of working memory in the processing of reflexives. *Language and Cognitive Processes*, *28*(1–2), 188–219. http://dx.doi.org/10.1080/01690965.2010.548391

Cunnings, I., & Sturt, P. (2014). Coargumenthood and the processing of reflexives. *Journal of Memory and Language*, *75*, 117–139. http://dx.doi.org/10.1016/j.jml.2014.05.006

Déchaine, R.-M., & Wiltschko, M. (2012). The Heterogeneity of Reflexives. Manuscript, retrieved from https://ling.auf.net/lingbuzz/001665.

Déchaine, R.-M., & Wiltschko, M. (2017). A Formal Typology of Reflexives. *Studia Linguistica*, *71*(1–2), 60–106.

Dechaine, R., & Wiltschko, M. (2002). Decomposing pronouns. *Linguistic Inquiry*, *33*(3), 409–422.

Dillon, B., Mishler, A., Sloggett, S., & Phillips, C. (2013). Contrasting intrusion profiles for agreement and anaphora: Experimental and modeling evidence. *Journal of Memory and Language*, *69*(2), 85–103.

Evans, G. (1980). Pronouns. *Linguistic Inquiry*, *11*(2), 337–362.

Fedele, E., & Kaiser, E. (2014). Looking Back and Looking Forward: Anaphora and Cataphora in Italian. *University of Pennsylvania Working Papers in Linguistics*, *20*(1). Retrieved from https://repository.upenn.edu/pwpl/vol20/iss1/10

Fiengo, R., & May, R. (1994). *Indices and identity*. Cambridge, MA.: MIT Press.

Fischer, S. (2015). Theories of binding. In T. Kiss & A. Alexiadou (Eds.), *Syntax - Theory and Analysis. An international handbook* (pp. 1357–1399). Berlin: de Gruyter.

Garrod, S., & Sanford, A. J. (1994). Resolving sentences in a discourse context: How discourse representation affects language understanding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 675‐698). San Diego, CA: Academic Press.

Givón, T. (1983). Topic continuity in discourse: An introduction. In T. Givón (Ed.), *Topic Continuity in Discourse: A Quantitative Cross-Language Study* (pp. 5–41). Berlin: John Benjamins.

Grosz, B. J., Joshi, A. K., & Weinstein, S. (1995). Centering: a Framework for Modelling the Local Coherence of Discourse. *Computational Linguistics*, *21*(2), 203–226.

Hankamer, J., & Sag, I. (1976). Deep and Surface Anaphora. *Linguistic Inquiry*, *7.3*, 391–426.

Heim, I. (1982). *The Semantics of Definite and Indefinite Noun Phrases*. University of Massachusetts at Amherst.

Helke, M. (1971). *The Grammar of English Reflexives*. MIT.

Hellan, L. (1988). *Anaphora in Norwegian and the Theory of Grammar*. Dordrecht: Foris.

Hicks, G. (2008). Why the Binding Theory Doesn’t Apply at LF. *Syntax*, *11*(3), 255–280.

Holmberg, A. (2005). Is There a Little pro? Evidence from Finnish. *Linguistic Inquiry*, *36*(4), 533–564.

Holmberg, A., & Nikanne, U. (2002). Expletives, subjects and topics in Finnish. In P. Svenonius (Ed.), *Subjects, Expletives, and the EPP* (pp. 71–106). Oxford: Oxford University Press.

Holmberg, A., & Sheehan, M. (2010). Control into finite clauses in partial null-subject languages. In T. Biberauer, A. Holmberg, Ian Roberts, & M. Sheehan (Eds.), *Parametric Variation: Null Subjects in Minimalist Theory* (pp. 125–152). Cambridge: Cambridge University Press.

Hornstein, N. (2001). *Move! A Minimalist Theory of Construal*. Malden, USA: Blackwell.

Huang, Y. (2000a). *Anaphora: A Cross-Linguistic Study*. Oxford: Oxford University Press.

Huang, Y. (2000b). Discourse anaphora: Four theoretical models. *Journal of Pragmatics*, *32*(2), 151–176.

Huhmarniemi, S. (2019). The movement to SpecFinP in Finnish. *Acta Linguistica Academica*, *66*(1), 85–113. http://dx.doi.org/10.1556/2062.2019.66.1.4

Huhmarniemi, S., & Brattico, P. (2015). The Finnish possessive suffix. *Finno-Ugric Languages and Linguistics*, *4*(1–2), 2–41.

Huhmarniemi, S., & Vainikka, A. (2010). Multiple wh-questions and syntactic islands in Finnish. In *Proceedings of Congressus XI Internationalis Fenno-Ugristarum (FU11) Pars VI* (pp. 227–233). Reguly Társaság.

Kaiser, E. (2003). Encoding (Non)Locality in Anaphoric Relations. In D. Nelson & S. Manninen (Eds.), *Generative Approaches to Finnic and Saami Linguistics* (pp. 269–294). CSLI Publications.

Kaiser, E. (2011). Focusing on pronouns: Consequences of subjecthood, pronominalisation, and contrastive focus. *Language and Cognitive Processes*, *26*(10), 1625–1666. http://dx.doi.org/10.1080/01690965.2010.523082

Kamp, H. (1981). A Theory of Truth and Semantic Representation. In J. A. G. Groenendijk, T. Janssen, & M. Stokhof (Eds.), *Formal Methods in the Study of Language*. Mathematical Centre.

Kanerva, J. (1987). Morphological integrity and syntax: The evidence from Finnish possessive suffixes. *Language*, *63*(3), 498–501.

Kayne, R. S. (1984). *Connectedness and Binary Branching*. Dortrecht: Foris.

Kazanina, N., Lau, E. F., Lieberman, M., Yoshida, M., & Phillips, C. (2007). The effect of syntactic constraints on the processing of backwards anaphora. *Journal of Memory and Language*, *56*(3), 384–409. http://dx.doi.org/10.1016/j.jml.2006.09.003

Koornneef, A., & Reuland, E. (2016). On the Shallow Processing (Dis)Advantage: Grammar and Economy. *Frontiers in Psychology*, *0*, 82. http://dx.doi.org/10.3389/fpsyg.2016.00082

Koskinen, P. (1998). *Features and categories: Non-finite constructions in Finnish*. University of Toronto.

Lebeaux, D. (2009). *Where Does Binding Theory Apply?* Cambridge, MA: MIT Press.

Lees, R. B., & Klima, E. S. (1963). Rules for English Pronominalization. *Language*, *39*, 17–28.

Longobardi, G. (1994). Reference and proper names: A theory of N-Movement in Syntax and Logical Form. *Linguistic Inquiry*, *25*, 609–665.

Malt, B. C. (1985). The role of discourse structure in understanding anaphora. *Journal of Memory and Language*, *24*(3), 271–289.

Manzini, R., & Wexler, K. (1987). Parameters, Binding Theory and Learnability. *Linguistic Inquiry*, *18.3*, 413–444.

Marr, D. (1982). *Vision: A Computational Investigation into the Human Representation and Processing of Visual Information*. Cambridge, MA.: MIT Press.

Murphy, G. L. (1985a). Processes of understanding anaphora. *Journal of Memory and Language*, *24*(3), 290–303.

Murphy, G. L. (1985b). Psychological explanations of deep and surface anaphora. *Journal of Pragmatics*, *9*(6), 785–81

Nicol, J., & Swinney, D. (1989). The role of structure in coreference assignment during sentence comprehension. *Journal of Psycholinguistic Research*, *18*(1), 5–19.

Nicol, J., & Swinney, D. A. (2003). The Psycholinguistics of Anaphora. In Adrew Barss (Ed.), *Anaphora: A Reference Guide* (pp. 72–104). Malden, MA.: Blackwell Publishing.

Parker, D. (2019). Cue Combinatorics in Memory Retrieval for Anaphora. *Cognitive Science*, *43*(3), e12715. http://dx.doi.org/10.1111/cogs.12715

Parker, D., & Phillips, C. (2017). Reflexive attraction in comprehension is selective. Journal of Memory and Language, 94, 272–290. http://dx.doi.org/10.1016/j.jml.2017.01.002

Pollard, C., & Sag, I. (1992). Anaphors in English and the Scope of Binding Theory. *Linguistic Inquiry*, *23*(2), 261–303.

Postal, P. (1971). *Cross-over Phenomena*. New York: Holt, Rinehart and Winston.

Raposo, E. (1986). Some asymmetries in the binding theory in romance. *Linguistic Review*, *5*(1), 75–110.

Reinhart, T. (1983). *Anaphora and Semantic Interpretation*. Croom Helm.

Reinhart, T., & Reuland, E. (1993). Reflexivity. *Linguistic Inquiry*, *24*(4), 657–720.

Reuland, E. (2001). Primitives of Binding. *Linguistic Inquiry*, *32*, 439–492.

Reuland, E. (2006). Agreeing to bind. In *Organizing Grammar* (pp. 505–513). Berlin: de Gruyter Mouton.

Rooryck, J., & Wyngaerd, G. Vanden. (2011). *Dissolving Binding Theory*. Oxford: Oxford University Press.

Safir, K. (2004). *The Syntax of Anaphora*. Oxford: Oxford University Press.

Schlenker, P. (2005). Non-Redundancy: Towards a Semantic Reinterpretation of Binding Theory. *Natural Language Semantics 2005 13:1*, *13*(1), 1–92. http://dx.doi.org/10.1007/s11050-004-2440-1

Sells, P. (1987). Aspects of Logophoricity. *Linguistic Inquiry*, *18.3*, 445–479.

Sperber, D., & Wilson, D. (1995). *Relevance: Communication and Cognition*. New York: Blackwell.

Sturt, P. (2003). The time-course of the application of binding constraints in reference resolution. *Journal of Memory and Language*. Academic Press Inc.

Thráinsson, H. (1990). A Semantic Reflexive and the Typology of NPs. In J. Maling & A. Zaenen (Eds.), *Modern Icelandic Syntax* (pp. 289–307). New York: Academic Press.

Thráinsson, H. (1991). Long Distance Reflexives and the Typology of NPs. In Jan Koster & E. Reuland (Eds.), *Long-Distance Anaphora* (pp. 49–75). Cambridge: Cambridge University Press.

Toivonen, I. (2000). The Morphosyntax of Finnish Possessives. *Natural Language and Linguistic Theory*, *18*(3), 579–609.

Trosterud, T. (1990). *Binding relations in two Finnnmark Finnish dialects: A Comparative Syntactic Study*. Dissertation, University of Trondheim.

Trosterud, T. (1993). Anaphors and Binding Domains in Finnish. In A. Holmberg & U. Nikanne (Eds.), *Case and other functional categories in Finnish syntax* (pp. 225–243). Mouton de Gruyter.

Vainikka, A. (1989). *Deriving Syntactic Representations in Finnish*. University of Massachusetts Amherst.

Vainikka, A., & Levy, Y. (1999). Empty subjects in Finnish and Hebrew. *Natural Language & Linguistic Theory*, *17*(3), 613–671.

van Steenbergen, M. (1987). *Binding Relations in Finnish*. Univ. of Groningen.

van Steenbergen, M. (1989). Finnish: Configurational or Not? In L. Marácz & P. Muysken (Eds.), *Configurationality: The Typology of Asymmetries* (pp. 143-157.). Foris Publications.

van Steenbergen, M. (1991). Long-distance binding in Finnish. In J Koster & E. J. Reuland (Eds.), *Long-distance anaphors* (pp. 231–244). Cambridge University Press.

Vilkuna, M. (1989). *Free word order in Finnish: Its syntax and discourse functions*. Helsinki: Finnish Literature Society.

Vilkuna, M. (1995). Discourse Configurationality in Finnish. In K. É. Kiss (Ed.), *Discourse Configurational Languages* (pp. 244–268). Oxford: Oxford University Press.

Appendix A. Detailed contents, names and locations of the raw output files.

Source	**Name**	**Explanation**
Test corpus	binding_theory_corpus.txt	Contains the test sentences, both grammatical and ungrammatical and organized hierarchically
Grammaticality judgments (native)	binding_theory_corpus_grammaticality_judgments_NATIVE.txt	Grammaticality judgments by native speaker
Grammaticality judgments (model)	binding_theory_corpus_grammaticality_judgments_FINAL	Calculated grammaticality judgments by the model
Main results	binding_theory_corpus_results_FINAL	Main results for each test sentence
Simple results	binding_theory_corpus_simple_results_FINAL	Test sentences together with syntactic analysis (or several if ambiguous)
Derivational log	binding_theory_corpus_log_FINAL	Derivational logs that include all linguistically meaningful steps and outcomes
Simple log	binding_theory_corpus_simple_log_FINAL	Shows parsing derivations in a simple format
Semantic interpretation	binding_theory_corpus_semantics_FINAL	Contains semantic interpretations, including the contents of the discourse inventory
Resource consumption (psycholinguistics)	binding_theory_corpus_resources_FINAL	Resource consumption, such as predicted processing times, number of operations, and other measures
Phrase structure images	Compressed folder /phrase structure images	Contains a phrase structure tree in PNG format for each solution

These files are located in the source code repository XXX under directory XXX. Source code used to generate these files is available in the branch XXX.

[1] For earlier work, see Helke (1971), Lees & Klima (1963) and Postal (1971). For general introduction, see Büring (2005), Huang (2000a), Safir (2004) and Fischer (2015).

[2] The principle "blanks out large portions of the discourse from the point of view of an anaphor, guaranteeing that its antecedent will not be in those portions. The fact that when he encounters an anaphor, he can be sure that its antecedent is either in previous discourse or in a higher clause in the same sentence is no doubt very useful to the native listener" (Hankamer & Sag, 1976, p. 425).

[3] The proposed data structure corresponds to and is inspired by Heim's (1982) file semantics and Kamp's (1981) disource representations in how it functions in the overall theory. Technically the discourse inventory will be a Python dictionary of dictionaries where the first level keys are arbitrary identifiers linked from lexical elements and the values are second-level dictionares (Heim's ”files”) containing all knowledge, whether predicates, relations or links to other objects, acquired about the objects in the ongoing discussion or discourse.

[4] This system presupposes that pronouns have features which guide the selection of denotations and assignments. All or most other lexical features are used in this way in language comprehension (Kazanina et al., 2007; Nicol & Swinney, 2003; Parker, 2019; Parker & Phillips, 2017).

[5] This agrees broadly with e.g. Badecker & Straub (2002) who propose that “the early influence of structural [e.g. binding] constraints does not completely exclude inaccessible entities from the candidate set at the outset. Instead, the initial candidate set is created in a manner analogous to the process of activating the set of interpretations associated with an ambiguous lexical form: The salient entities of the local discourse […] that are consistent with the number and gender specification of the pronoun or anaphor make up the set of available interpretations for the referentially dependent expression [i.e. possible denotations, assignments], and the grammatical constraints on interpretation operate quickly and effectively in the process of selecting from among these options” (p. 767).

[6] Several possible intervention features have been provided in the literature (Raposo, 1986), and there appears to be considerable crosslinguistic variation among anaphors, such as reflexives (Déchaine & Wiltschko, 2012, 2017). Manzini and Wexler (1987) mention several options such as subject, Infl, tense, referential tense and root tense (see their (29), p. 422) and propose that the matter is subject to parametrization. Thus, it makes little sense to limit the feature system a priori pending further crosslinguistic investigation.

[7] This assumption is motivated by reports which show that structure-dependent mechanisms limit the antecedent search during language comprehension (Aoshima et al., 2009; Asher & Wada, 1988; Clifton, Kennison, & Albrecht, 1997; Cunnings & Felser, 2013; Cunnings & Sturt, 2014; Dillon,

Mishler, Sloggett, & Phillips, 2013; Fedele & Kaiser, 2014; Hankamer & Sag, 1976; Kazanina et al., 2007; Koornneef & Reuland, 2016; Nicol & Swinney, 1989; Sturt, 2003).

[8] Finnish demonstrative anaphora will be ignored in this study due to the fact that it seems to require access to syntax-internal events. This issue, which is controversial and nontrivial, will be discussed in Section 5, but is ultimately left undecided.

[9] Notice that neither *he* nor *himself* is in any way defective in its capacity to refer. They are both assigned independent denotations. This could be seen as controversial in the case of reflexive pronoun *himself*, but the assumption is made due to the data reported and discussed by Pollard & Sag (1992).

[10] When a lexical item is connected with its meaning, it is endowed with an index feature that points to the relevant semantic entry. Index features do not here capture capture grammatical (coreference, binding) dependencies, contra Fiengo & May (1994). The proposal is not a purely pragmatic coreference theory either. Communication between language and general cognition is mediated by narrow semantics which accesses structural objects and creates situations where coreference is regulated by logico-linguistic rules, as observed by Evans (1980).

[11] The source code can be found from www.gitbhub.com/pajubrat/parser-grammar and is documented in Brattico (2019a).

[12] The possessive occurs in many other grammatical environments besides reflexives (e.g., prepositions *minun lähellä-ni* 'my near-PX', nouns *minun koira-ni* 'my dog-PX', infinitivals *uskon lähtevä-ni* 'believe.1SG leave.VA/INF-PX', adjectives *ostama-ni koira* 'bought-PX dog'; see Kanerva (1987). The possessive can be analysed as its own anaphoric possessive head or pronoun (Trosterud, 1993; Vainikka, 1989), an infinitival agreement marker that licenses pro-drop (Brattico, 2017; Brattico & Huhmarniemi, 2016; Huhmarniemi & Brattico, 2015; Kaiser, 2003; van Steenbergen, 1989, 1991) or both (Toivonen, 2000).

[13] Nonhuman pronoun *se* 'it' is used in colloquial speech for both human and nonhuman referents, while *hän* 's/he' is deserved for honorific and official uses in spoken language. We could model

colloquial speech by neutralizing the human feature, including a honorific feature and using the same mechanism.

[14] It would seem psycholinguistically realistic to assume that assignments are linked with assignment-specific discourse inventory instances when the conversation is ongoing. This is technically nontrivial and resource-intensive, however, due to the requirement that the algorithm must implement full recursion and provide access to all possible interpretations. The problem was left for future research.

[15] Chomsky (1981, p. 65) proposes that these constructions exhibit an “avoid pronoun” principle that prefers null pronouns when an overt pronoun would be redundant. See Kaiser (2003), footnote 2, p. 9, who notices that her native speakers “permit” reading (43b) against “standard judgments.” It is unclear what “standard judgments” means, most likely it refers to a normative rule. To me (43b) is possible, but marginal.