Assembling Syntax:
Modeling Constituent Questions
in a Grammar Engineering Framework

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Abstract

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This dissertation is dedicated to a cross-linguistic account of constituent (aka *wh-*) questions as part of a grammar engineering toolkit, the Grammar Matrix, couched in the Head-driven Phrase Structure Grammar formalism (HPSG). The main **research question** is: What, in formal grammar terms, constitutes an analysis of the various attested ways to form constituent questions which is demonstrably compatible with analyses of other phenomena that also vary typologically? I assume here a working definition of *analysis* as a set of HPSG types, including lexical and phrasal, and ways in which these general types vary depending on a given language. By "varying typologically" I mean that as the analyses presented here were driven by a review of typological literature on constituent questions, the interacting analyses that are part of the Grammar Matrix were driven by typology of other phenomena. My research question is related to a big question in linguistics: What is the range of possible variation of human languages? Specifically, this work aims to contribute to this big question by providing a set of analyses which are (i) driven by typological surveys; (ii) demonstrably integrated with existing analyses; and (iii) rigorously tested. Thus, while not a claim about possibilities and impossibilities, this work is a step towards establishing a range of specific linguistic analyses which are consistently successful across languages.

I test the analyses in terms of the coverage, the overgeneration, and the ambiguity with respect to test suites which include constituent questions along with other syntactic phenomena and come

from typologically and genealogically diverse languages. I look in particular detail into Russian for which I compile a test suite of 273 sentences including various types of simple and complex declarative and interrogative clauses. I additionally evaluate the system on five "held-out" languages, all from different language families which I did not consider at all during development.

On the **theoretical** level, I conclude that the HPSG filler-gap construction in combination with non-local features such as SLASH and QUE provides a functional basis for cross-linguistic modeling of obligatory question phrase fronting in main clauses but it is not yet fully clear whether they are sufficient to model the contrast between clause-embedding predicates meaning e.g. *think* and *ask*, cross-linguistically. I conclude also that question phrase fronting which seems optional on the surface is difficult to formally model as such, which suggests it could be more readily analyzed as a combination of obligatory fronting, with any material appearing in front of the question word licensed by a separate information structure fronting mechanism. I furthermore conclude that "lexical threading", the HPSG mechanism by which lexical heads project their arguments' nonlocal features, complicates the analysis of fronting and that the entire Grammar Matrix system can be reasoned about more simply without the lexical threading assumption — although interrogative morphology can be modelled more straightforwardly with that assumption. On the **grammar engineering** level, I conclude that the existing Grammar Matrix system with its lexicon, morphotactics, polar questions, and case libraries can be successfully extended to support an analysis of constituent questions. The Grammar Matrix's information structure library however would require more substantial revisions in order to be integrated with an analysis of constituent questions, especially to support data from languages with flexible word order and data with embedded clauses, from all languages. At the level of the DELPH-IN HPSG **formalism**, I conclude that the recently suggested append list type can be conveniently used for modeling question phrase fronting instead of the cumbersome difference list append. Finally, on the **methodological** level, I conclude that using at least one larger test suite with more complex sentences during Grammar Matrix development (along with multiple smaller test suites for typological diversity) involves a cost for typological breadth and a danger of “overfitting” the cross-linguistic system to one language but it is still important to uncover issues in the analysis which would otherwise be ignored.

TABLE OF CONTENTS

LIST OF FIGURES

Figure Number Page

LIST OF TABLES

Table Number Page

GLOSSARY

The glossary defines terms as they are used in this dissertation. The goal is not to offer general definitions or to insist that this is how the terms must be used by everyone, but merely to offer working definitions, for the purposes of making reading of this document easier. In many cases, the usages stem specifically from the grammar engineering community; the definitions may differ from the ones the reader is used to.

ADJUNCT: An optional part of the clause which, if discarded, will not leave the sentence ill-formed; aka a modifier.

ANALYSIS: A collection of rules/constraints designed to handle some specific phenomenon. Secondarily, it refers to the central ideas or intuitions that those rules/constraints formalize.

ARGUMENT: A constituent which bears a relationship with a predicate (such as a verb or a noun) and helps complete the meaning of that predicate. For example, subjects and objects are typical arguments of verbs.

AVM: Attribute-value matrix; a visualization of a structure where features are specified to have values of certain types and have a geometry; each feature has a particular path to it starting at the beginning of the structure. Any feature structure can also be represented as a graph.

BROAD-COVERAGE GRAMMAR: A grammar which one can rely on to parse lots of well-formed sentences in a language, such as in a real-world well-edited text. This is in contrast to smaller grammars which only cover a narrow selection of sentences, either because they do not have a large enough lexicon, do not include morphological analysis, or lack syntactic analyses for many phenomena (or a combination of the above).

CHOICES: The Grammar Matrix questionnaire allows the user to choose from a number of typological options and to fill out (so, also choose) lexical and morphological information for a language. For example, the choices for "basic word order" include SVO, SOV, free, etc. See also SPECIFICATION.

COMPLEMENT: Same as ARGUMENT. Usually used to mean specifically the non-subject arguments, but can mean any argument, especially in the context of clausal complementation (Noonan, 2007).

COMPS: A list-valued feature for complements. Many lexical types can have nonempty COMPS lists. An empty COMPS list specified at the lexical level means the type cannot have any complements.

COVERAGE: The percentage of grammatical items from a test suite for which the grammar assigns a structure. Only correct structures should count towards coverage, but the correctness of a structure usually needs to be checked by hand, so automated tools often report coverage based on whether any structure was assigned.

CUSTOMIZATION (GRAMMAR MATRIX): In the Grammar Matrix system, the process of adding language-specific constraints to a basic HPSG grammar (set of types) which is assumed to only have cross-linguistically valid constraints.

DAUGHTER: A daughter in a tree is a child node, or a node which is dominated by another (parent) node. For example, in a context-free grammar, grammar rules (e.g. S→NP VP) have the left-hand side (S) and the right-hand side (NP VP); the right-hand side are the daughters. In HPSG, the substructure which corresponds to what would be visualized as a child in the tree.

ELEMENTARY PREDICATION (MRS): In Minimal Recursion Semantics, a primary unit, a single relation with its associated arguments (e.g. beyond(x,y)). EPs usually correspond to a single lexeme. In MRS, EPs are never embedded in one another (it is a "flat" represenetation).

EXTRACTION: Removing an argument or an adjunct from its canonical position in a structure (such as an HPSG valence list). Related to FRONTING.

FOCUS: New information in a sentence. See also INFORMATION STRUCTURE.

FRONTING: A mechanism assumed to be responsible for some arguments and adjuncts appearing not in its normal position but rather in the front of the sentence, including across the clause boundary. Related to EXTRACTION.

GAP: A missing element on the arguments list. Related to EXTRACTION.

GRAMMAR: A formal linguistic description of a language's syntax which can be paired with (i) a parser which, given sentences as input, provides syntactic and semantic structures which are correct with respect to a particular set of hypotheses about the given language; (ii) a generator which, given a semantic representation, outputs one or more corresponding grammatical strings. In computational linguistics, a grammar must be written in a formalism which is explicit enough to be implemented on the computer.

GRAMMAR MATRIX: A meta-grammar engineering project which includes a web-based questionnaire, a core HPSG grammar, and a customization system which allows the user to input typological, lexical, and morphological information via the web and automatically obtain a grammar for this language.

HEAD: In a phrase, a word which determines syntactic properties of the phrase. For example, in HPSG, verbs typically are heads in complete sentences.

HPSG: Head-Driven Phrase Structure Grammar, a constraint unification-based theory of syntax.

INFORMATION STRUCTURE: A level of linguistic structure related to how the meaning expressed in a sentence is integrated into the discourse, e.g. the ways in which new vs. old information is expressed.

IGT, INTERLINEAR GLOSSED TEXT: A form of presentation for linguistic examples. An IGT consists (at a minimum) of a language line (a sentence in some language, sometimes morpheme-segmented), a gloss line (a linguistic categorization of each item in the language line), and a translation line (the translation of the sentence into a *lingua franca* such as English). The language line and the gloss line are aligned.

IN SITU QUESTION: A question phrase which appears in a position normal for a non-question argument of the verb.

LABEL (MRS): In Minimal Recursion Semantics, a label is a handle which identifies an elementary predication as belonging to a particular position in the scope tree (Copestake et al., 2005).

LEXICAL RULE: In HPSG, a structure which has a substructure for strictly one daughter which must be a word, and which adds constraints to the mother substructure, such as properties marked by inflectional affixes.

LIBRARY (MATRIX): A set of parts of the Grammar Matrix which are primarily responsible for supporting one particular syntactic phenomenon. A library usually has an associated web questionnaire page, a set of lexical and/or phrasal types, and customization logic.

LICENSING: In grammar terms, something that allows a structure to appear as well-formed. For example, a lexical entry can license a terminal node in a syntax tree; a phrase structure rule can license a binary branching structure, etc.

LOGICAL FORM: Generally, the logical form (LF) of an expression is an abstract, precisely formulated semantic version of that expression. For example, "There exists an *x* such that *x* belongs to a set of things which are *dogs* and also to a set of things which are named *Fido*" is a logical form for the sentence *Fido is a dog*. (In Minimalist syntactic theory, LF is a syntactic level which interfaces with semantics. This is not how the term is used here.)

LONG-DISTANCE DEPENDENCY: The ability of some arguments and adjuncts to cross the clause boundary and appear at the very front of the sentence even if they belong to an embedded clause, with potentially unbounded depth of embedding. Same as UNBOUNDED DEPENDENCY. Related to FRONTING.

MATRIX: Same as GRAMMAR MATRIX.

MOTHER: A mother in a tree is the parent node, or a node which dominates other (children) nodes. For example, in a context-free grammar, grammar rules (e.g. S→NP VP) have the left-hand side (S) and the right-hand side (NP VP); the left-hand side is the mother. In HPSG, the substructure which corresponds to what would be visualized as the mother in the tree.

OVERGENERATION: The percentage of ungrammatical items in a test suite for which the grammar assigns a structure.

PARSER: A program which takes a string and a grammar as input and outputs syntactic and semantic structures corresponding to that string according to the grammar.

PHRASE STRUCTURE RULE: An HPSG structure whose substructure for the MOTHER is a phrase rather than a word. Lexical rules in HPSG can only have lexical entries and other lexical rules as daughters; phrase structure rules do not have that distinction. For example, grammar rules which are used to form complete sentences must be phrase structure rules.

PSEUDOLANGUAGE: a Matrix-readable specification and a list of sentences which do not necessarily correspond to a language spoken anywhere in the world but were constructed to test that the customization system can handle a certain combination of user choices.

QUE: An HPSG feature indicating that a word is a question word or that the constituent contains such a word.

QUESTION: A kind of expression (meaning) people use to ask for information. Questions can in particular be expressed with interrogative sentences (constructions). In Ginzburg and Sag's (2000) terms, a question is a type of entity expressed by an interrogative construction.

QUESTION WORD: A word which is used to ask to identify a particular participant of the clause, e.g. *who* is used to ask about the subject. Because in many languages such words have similar shape and in particular in English they tend to start with *wh*, it is common to refer to them as *wh*-words.

REGRESSION TEST (MATRIX): In the Grammar Matrix framework, a regression test is a pairing of a Matrix-readable specification and a list of test sentences composed in a language corresponding to the specification and illustrating one or more syntactic phenomena.

RELATIONAL CONSTRAINT: A constraint which stipulates the value of one feature to be some function of the value of one or more other features (a function other than the strict identity).

ROOT: A type that licenses a stand-alone sentence. A structure which does not unify with *root* will not be admitted by the parser as a success.

SIGN: A concept in HPSG originating from *language sign* of de Saussure. A *sign* in HPSG is a "structured complex of phonological, syntactic, semantic, discourse, and phrase-structural information" (Pollard and Sag, 1994, p.15).

SLASHED: A structure (such as a sentence constituent) for which one or more of its arguments (e.g. a subject or an object of a verb) is missing from its usual place. The etymology here is due to the notation of VP/NP kind in GPSG (Gazdar, 1981), where the slash signifies that the verb phrase is missing one of its noun phrase arguments.

SPEC: A list-valued HPSG feature of specifiers, encoding what kind of heads they can serve as specifiers of.

SPECIFICATION: A machine- and human-readable file that contains the choices the user made about the language and that can directly be input into the customization system to obtain a grammar for that language. See also CHOICES.

SPR: A list-valued HPSG feature of heads, encoding what kind of specifiers they take.

TDL: A deprecated term for DELPH-IN Joint Reference Formalism which is still convenient to refer to the specific text written in that formalism (this usage is akin to something like "code"). It stands for Type Description Language.

TEST SUITE: A list of sentences in some particular language intended to illustrate one or more syntactic phenomena. May contain both possible (grammatical) and impossible (ungrammatical) sentences.

TOPIC: Old information in a sentence (see also INFORMATION STRUCTURE).

UNBOUNDED DEPENDENCY: Same as LONG-DISTANCE DEPENDENCY.

WH-WORD: See QUESTION WORD.

ACKNOWLEDGMENTS

I was born and grew up in a town full of researchers; it is possible that I simply had no other choice but to try and go into research myself (despite several smart people advising me against it). I am not in fact sure whether I should be happy about it or lament it; but the fact is, I am happy about it. So I am grateful to the Siberian town called Akademgorodok, to those who built it, to those who were brave enough to relocate there, and to those who continue living and working there today.

My Russian language teacher Vladimir Fyodorovich (V.F.) Rudak, an Akademgorodok legend to whom this work is dedicated, was probably the reason I chose linguistics. On the surface, he was a prescriptivist, as most teachers were at the time. However, perhaps without fully realizing it himself, he was teaching us a lot of linguistics. It was then that my heart was set on the subject, particularly morphosyntax, as we spent countless class periods analyzing syntactic structure in sentences he picked from various sources. What influenced me especially was that in many cases, when looking at a particular phenomenon in a sentence, a perfectly acceptable (and in fact, preferable) answer was “Well, this is hard to explain given the exact set of rules that we talked about”. One of my favorite stories about V.F. concerns his pedagogy practice in an Altaic village back when he just graduated. Children there spoke a variety which had a word for *bear* with syllables metathesized compared to the standard Russian dialect (*vedmed* vs. *medved*). V.F. sensed he was an extraordinarily good teacher, I think, and so he was confident he would be able to teach them to adopt the standard word by finding some sort of logic which would explain why that is the right thing. But to his surprise, he failed. At the time, there was no way for him to contextualize that episode the way we would today, and so it was not like he became

well-versed in sociolinguistics as a result, and not like he stopped making prescriptivist comments in class. However, he also did not — could not — simply ascribe what happened to an assumption that something was wrong with the children. He saw perfectly well something was wrong with the logic he was using. I still remember his pensive look, decades after that Altai trip, and how he kept saying: “And you know, no matter what I did... No matter what I tried... They just kept saying *vedmed*.” It remained puzzling to him his whole life, but I think it was then that he actually did realize, on some level, that language as a natural phenomenon is not necessarily captured in school textbooks, and that the prescriptivist logic often fails to account for what we observe, and that looking at native speaker data is a better way of learning about language, be it Standard Russian or not. We never touched the textbook in his class, and I do think it was very much for the better. It is a tragedy that V.F. died when he was only 49 years old; he could have given the world quite a few linguists.

My dearly missed father is forever my paragon of scholarly and human integrity and talent. I wish he were alive and I could discuss my work with him and ask his opinion about methodologies and approaches. While he was alive I had no intention of becoming a researcher, yet he managed to teach me a great deal simply by being himself in front of me, and I keep learning from the memories of him more than two decades later. It was the sparkle in his eyes that instilled in me a core belief that research is valuable and wonderful.

My advisor Emily M. Bender welcomed me to her research group and to the field. It never ceases to amaze me how she treats various kinds of students and various types of student work with equal respect. My dissertation builds directly on Emily’s own work as well as her former students’, and in choosing the topic I was inspired mainly by her vision, imagination, and multiyear efforts, particularly her dedication to working with data from understudied languages. Her generosity with her time and attention was extraordinary,

and I simply would not be able to list all the things I am grateful to her for. To pick just one: many thanks to her for motivating me to rewrite some of these chapters several times, until they started making sense. It is in these final stages of writing that I finally felt like a grown up (researcher) — which is kind of the point.

I have made many trips to conferences, both in the U.S. and overseas, mostly using my advisor's grant and travel money. Without those trips, this dissertation would not be possible, or at least would be very different. I am very grateful, both to Emily and to my department, particularly the then-administrator Mike Furr (to whom a monument should be erected for his tireless work to make graduate students' lives better).

Michael Wayne Goodman, Joshua Crowgey, Glenn Slayden, David Inman, Kristen Howell, and more generally the "EMB-students" group have been a strong motivator; I am not sure I would've stayed on this path if it were not for the sense of community which they gave me.

The wonderful DELPH-IN community as a whole and the annual DELPH-IN summits in particular made writing this dissertation very easy;[1] I just wanted to keep developing and writing simply because I was hoping it might be a contribution to them, an incredible group of people who stick together to do science and to have fun. Slow and steady wins the race. I believe that.

I am deeply indebted to Emily M. Bender, Woodley Packard, and Guy Emerson for investing lots of their valuable time and attention in helping me debug various complex issues in my grammars and analyses. My most heartfelt thanks go to John Carroll who was ever so helpful with any issues I had with the parsing software and who made a version of the LKB grammar engineering environment available for MacOS computers. This made my work much faster.

I had a wonderful dissertation committee, which included Emily M. Bender, Barbara

[1] In a certain sense.

Citko, Sharon Hargus, and Gina Levow. They were supportive and enthusiastic and carefully read all the 300+ pages of my work (and Luke Zettlemoyer kindly agreed to be the Graduate School Representative). And if this text is at all speaking to non-HPSG syntacticians, it is mainly thanks to Barbara Citko who helped me make the connections, where relevant.

I am grateful for the strong criticisms I was offered by Henry Davis and Richard Larson, when I visited University of British Columbia and Stony Brook University in 2019 and 2020, respectively, with invited talks. It is their criticisms that kept motivating me to think more deeply about what I do and why I do it. Two relatively short conversations with these two scholars have been slowly re-shaping my thinking and my work ever since. I also thank Francis Bond and Berthold Crysmann for gently but consistently reminding me of the existence of certain related work during DELPH-IN summits.

I thank my colleague Marina Oganyan, for being there, for calling me regularly on the phone (which I generally hate, except when it is her), and for always talking to me about my work as if it was something important. I feel like I did not always do the same for her. Maybe I can do better in the future. Above all I thank Marina for becoming a close friend. I thank other current and former graduate students of UW Linguistics for inspiration and support, especially Sarala Puthuval, Amie De Jong, Nathan Loggins, Brent Woo, Alec Sugar, Dan McCloy, and Esther Le Grezauze.

Back to earlier stages of my life now: My school, the Novosibirsk school №130, in which the aforementioned V.F. Rudak was a Russian grammar teacher, played a very important role in my life in general. Most of the teachers there were very good, and it is not just that I remember some of them very fondly; they were instrumental in making me who I am, particularly in making me a person who feels knowledge is worth pursuing. I am thankful to quite a few people there. I thank especially Tatiana Lysenko (who taught me that ultimately what is important is what is clear and interesting, and what memory can actually retain); Olga Sidorova (who showed me convincingly that some things, like art and architecture (and research?) are indeed *longi (vita brevis)*); Olga Bannova (who taught me whatever math she could, even though that was a very ungrateful task, with a student like me); and the late Meri Mukhametova (who had two goals in life: that the children enter a university and that they attend theater at least once in their lives). But I do think, ultimately, what that great school gave me, I owe to the Principal. Alexander Mitrofanovitch Bannov, thank you. You were a truly great Principal. Among other things, you created a school where every student was more or less guaranteed to graduate with a useful level of English — more than most schools in Russia could claim, back in the day. I would not be in American academia if it were not for you and for the teachers of English that you systematically hired. I thank especially Tatiana Delfontseva who was my English teacher in 1996–1998.

That being said, I spent a significant part of my late-middle and high school years skipping classes and not doing homework. Instead I was at Novosibirsk State University, hanging out with a bunch of awesome people. Some were history graduate students, some undergraduates of various majors, and others just fans of J.R.R. Tolkien, their affiliation unknown. (The grad students did not suspect I was skipping classes, I am sure.) That was unforgettable and made me love universities even more. I thank especially Alexander ("Petrovich") Nikolaev, Sergey Kozlov, Julia Albova, Leonid Trofimov, Dmitry and Natalia Simonov, Alexander Minakov, Inna Larina (Bogdanova), Andrei Bolvanov, and all of the wonderful people I met during that fabulous time.

While my time at Moscow State University (1998–2003) did not directly lead me into a graduate program, and it could even be said that it led me "astray" in life somewhat, I was nonetheless inspired and positively affected by some of the atmosphere there, particularly by the very clear sense of appreciation of hundreds of years of scholarly tradition that can be found in such places. I am deeply grateful to Pavel Balditsyn, Ksenia Balditsyna, the

late Ninel Vannikova, and Tamara Teperik who were so wonderfully illustrious and who I really wanted to be like.

I thank Mike Calcagno and other people who were part of Microsoft Natural Language Group back in 2005–2008, particularly Miki Kasahara, Kumiko Sato, Mari Olsen, and the late Rene Valdez for drawing my attention to the fact that computational linguistics existed and was thriving in Seattle. Steve Jones, whom I also met there, wholeheartedly supported my decision to apply to UW and went through the miserable first attempt of my essay, making sure I stood a good chance. Debbie Milam Berkely, another colleague from that time, went through all the English examples in this document and vetted the grammaticality judgments on them, which was very kind of her. I was particularly impressed that she did it right away, within a couple hours from when I sent her the list of examples. She says she always loves to do anything linguistics.

Now to my family. My mother quite stereotypically kept asking me when I would finally finish my dissertation; my brother never asked about it once. My thanks go to both of them; it was helpful.

I thank my childhood friend Tanya Ivanova (Konovalova) who “adopted” me at the age of 6 (her age of 9) and cultivated whatever little there was in me of logical reasoning. A friend of us both, Masha (Marie) Lobanova also took a substantial part in that.

Without Denny Gursky and his financial, moral, and tutoring support, I doubt I would have ever gotten any degree in the United States. I would have said I was forever in his debt, but the concept of debt does not seem to easily apply here. I wish him every bit of happiness.

In the times when university campuses closed indefinitely in reaction to the COVID-19 pandemic, my partner Denis Altudov became my university. He was always ready to discuss any aspect of any research-related question with me, sometimes for hours. It really felt like I was attending a conference sometimes (and could be equally mentally

exhausting!). It was extraordinary luck to have someone with such intellect and such curiosity right next to me all day during this time (his confidence in being able to reason about any subject is supported by a degree in physics).[2] In addition, he simply has been making my life easier and more fun in the past years, and he made sure I had something to eat while I was writing this document for many hours a day. My cat Murka continuously reassured me that my dissertation was clearly important (by getting in between me and my screen all the time).

I am grateful for all these things. These have been the happiest 6.5 years of my life (so far).

[2] https://xkcd.com/793/

DEDICATION

Вэфу

Chapter 1
INTRODUCTION

This dissertation presents a cross-linguistic account of constituent (aka *wh*-) questions integrated into the Grammar Matrix grammar customization system. The main goal is to present a fully implemented analysis which was concretely tested against test suites from multiple typologically diverse languages, and to discuss the takeaways from that. The implementation is in DELPH-IN HPSG which is an explicit syntactic formalism. There is no prior cross-linguistic account of the phenomenon in HPSG, and I am also not aware of any implemented HPSG grammars which model multiple *wh*-fronting, and so my study is a step towards a more complete analysis of interrogatives, on the one hand, and long-distance dependencies, on the other. The fact that the analysis is fully implemented means that it can be built upon quite literally; for example, an analysis of information structure and free word order can include my analysis of *wh*-questions. Conversely, my analysis directly uses the existing HPSG analyses for a variety of syntactic phenomena as they are implemented in the Grammar Matrix system, and as such tests those analyses in terms of how they generalize to constituent questions as well as to languages on which they were previously not tested. In order to situate my research question, this chapter provides some definitions and connects philosophical and methodological aspects which together constitute motivation for my work. The research question is, basically: What constitutes an analysis of constituent questions in the context of a multilingual grammar engineering framework? It is stated fully and contextualized at the end of the chapter. In the given setting, I see it as a step towards answering one of the biggest questions in linguistics: What is the possible variation in human languages?

1.1 Definitions and philosophy: Modeling grammar

The idea that human language syntax can be conceived of as a formalized system probably goes back very far in history but the set of ideas most relevant to this dissertation belongs to the schools of Ferdinand de Saussure and later Noam Chomsky and Richard Montague. De Saussure (1911) talked about language as a system of *signs* (mappings between form and meaning); Chomsky (1957) revolutionized the field of linguistics by describing a formal mathematical system which, given a *grammar* consisting of some explicit rules and lexical entries, will either accept or reject any string as belonging to the language which the grammar represents; Montague (1974) put forth the idea that *semantic compositionality* in logic (Frege, 1884) — the meaning of the whole is computed from the parts — can be applied to linguistic analysis, in particular that the meaning of the mother node in a syntactic representation of a sentence is computed from the meaning of the daughters. Montague (1974) also conceptualized a *method of fragments* which suggests it is worthwhile to understand grammars as partial (e.g. a grammar may only cover some of the strings possible in a language) but fully formalized in what they cover — and extendable over time. Through the Montagovian fragment methodology, theoretical ideas are validated; this principle is central to my work.

While formal grammar is certainly not the only view which can be taken on human language (which undoubtedly has, at a minimum, fundamental social components that may or may not be formalizable), it is important that this set of ideas opened up avenues for a particular empirical approach to studying syntax: namely, grammar *modeling* and *testing*. Modeling grammar in this context means coming up with sets of rules and lexical entries (one way or another) and in some cases implementing them directly on the computer, as a program which can accept or reject a string by attempting (and either succeeding or failing) to find a syntactic structure that can correspond to the input string given the grammar. Testing (defined in this context by Oepen (2002)) means deploying this program on a list of sentences and then assessing whether or not the grammar indeed correctly parsed all grammatical sentences and rejected all the ungrammatical ones — an alternative to the computer being doing the testing with pen and paper, performing computations in one's head. *Correctly* here means that each structure assigned by the grammar to any grammatical sentences is in fact meaningful. This last assessment is done with respect not to the syntactic tree but with respect the to resulting sentence semantics, assuming a *semantic structure* is directly paired with the syntactic one.

1.2 Grammar engineering philosophy, methodology, and value

This dissertation is couched within a *grammar engineering* system (the Grammar Matrix, §3.4). The concept of grammar engineering arises naturally from the idea that modeling grammar is akin writing a computer program that accepts or rejects strings. An important characteristic of a grammar engineering system such as the Grammar Matrix is rigor; it actually implements the grammar-program idea on the computer, precluding human mistakes that are due to e.g. human operational memory constraints or inconsistency of attention. But moreover, the Grammar Matrix is a research framework which aims to combine typological breadth with formal-syntactic depth (Bender et al., 2010b). With respect to current linguistic thought, the philosophy behind the Grammar Matrix is perhaps somewhere in between the original philosophy of theoretical syntax (Chomsky, 1964, 1993; Pollard and Sag, 1994) and the opposing philosophy as presented in particular in Martin Haspelmath's papers and blog posts,[1] which appeals, in particular, to typology and psycholinguistics.[2]

Historically, theoretical syntacticians tended to focus on one or a few languages (Zwart, 2009)[3] and emphasized concepts which were taken to refer to innate and universal properties of human

[1] For example, `https://dlc.hypotheses.org/2324#more-2324`.

[2] Presenting the philosophies as opposing here is meant to mark a continuum of thought in which the Grammar Matrix philosophy was shaped, and position it with respect to two specific points of view. It is not meant to argue that one point of view is correct, nor to imply that there are no other points of view, nor to state that any particular linguist subscribes to one of these specific points of view today. Put simply, I am not saying Noam Chomsky or any of the most prominent representatives of the Chomskyan school has the same views today as in 1967 or 1993, nor that Martin Haspelmath's views have not changed since 2010, etc.

[3] Chomsky's early work (Chomsky, 1957, 1964) and much of classic work that followed mostly used data from English; in recent decades, there has certainly been work on languages other than English including non-Indo-European, some of which draws also on concepts from typology (e.g. Baker 1996 focusing on Mohawk), and there are at least a few truly broadly cross-linguistic studies like Harbour 2014, among other works by the same author.

language sometimes referred to as the "building blocks" of grammar (Barsky, 2016; Chomsky, 1995, 1964). If one assumes there is an innate structure that is the same in any language, enough in-depth work with just one language is in principle sufficient to eventually fully reveal that structure. The details of this framework have been changing over time (Chomsky 1957 and Chomsky 2005 being two possible landmarks to compare), but the notion of universal grammar remained key. At the other end of this spectrum, linguists, perhaps most notably Martin Haspelmath, have been arguing that similarities between languages are not biologically pre-programmed (many of them could be convergent; Haspelmath 2020); that each language may have completely idiosyncratic grammatical features and as such no general theoretical framework is applicable; but that some set of applicable *comparative concepts* may exist (e.g. Haspelmath, 2010a,b, 2007).[4] In a way, this reminds one of the millennia-old debate between Plato's idealists and Democritus's materialists, only applied in the 21st century to language: Should linguists be in pursuit of a theory which will arise as a product of the mind and then prove to be correct with respect to all language data, or do correct ideas (and concepts, and theories) emerge only from observing the data objectively and without bias?[5]

If idealists and materialists' debate has indeed lived this long, one cannot help but wonder if both approaches are in fact instrumental to scholarly progress.[6] While the in-depth syntactic approach focusing on one language has been criticized for lack of evidence that the claims generalize across languages (e.g. Postal, 2004), it is clear that without paying attention to one language

[4]Haspelmath's position is aligned in this respect with Basic Linguistic Theory (Dixon and Dixon, 2010), which is a framework designed for typological and field work which relies on concepts useful cross-linguistically and eschews formalism-specific mechanisms.

[5]The analogy may be a stretch in that no approach to syntax that I know of rejects the importance of data; indeed, all work is usually organized around data, and it is the innateness assumption of the Minimalist Program that is behind the claims about generalizability of their analyses, not an assumption that the theory somehow miraculously arises without data. Still, there is something about the expectation that one set of ideas which arose from a narrow set of examples and perhaps out of introspection of one person will apply to all languages, that reminds me of idealism. Pullum (2017) makes a similar distinction between what he calls "intuitional solipsism" (relying on introspection and rejecting any corpus evidence) and "corpus fetishism" (ignoring any intuition) while arguing that both extremes should be abandoned. Like Pullum, I am talking here about philosophical extremes; the whole point is that actual practice of individual researchers differs.

[6]Indeed, one is relatively sure. Note also how this relates to "Hegelian dialectics" and the idea that the nature of things can be elucidated ("synthesized") via the tension of opposing philosophies (Chalybäus, 1854).

in detail and by looking only at maximally abstracted, isolated phenomena across languages, one will have to limit oneself to just a handful of sentences from each language and will inevitably miss crucial examples of interactions between phenomena. In other words, while typological breadth can help draw on other languages to find counterexamples to syntactic claims, in-depth language study can similarly help find counterexamples to typological claims drawing on e.g. the complexity of examples.[7] Finally, going back to the general terms of the ancient debate, it seems easy to point out the low likelihood of a correct theory emerging without broad enough observation, but it is also easy to point out that observing without bias is impossible. It seems that historically, both philosophies have played influential roles in advancing scholarship, and I see the Grammar Matrix as a framework which recognizes the importance of and incorporates both — with the crucial addition of rigorous testing relying on computational aid.

While the Grammar Matrix (§3.4) relies on the HPSG formalism and was originally mostly informed by an in-depth HPSG analysis of English, Japanese, and to a lesser extent German,[8] it prioritizes analytical flexibility needed in cross-linguistic descriptive work (Bender et al., 2010b; Poulson, 2011a). Of course the Grammar Matrix is far from practicing Haspelmath's (2010b) "describe each language in its own terms" ideal (and indeed it is not clear what that would look like in a computational scenario where the language description must ultimately be machine-readable)[9] but the set of concepts that the Grammar Matrix relies on to elicit a language specification from the linguist-user via the web questionnaire may be seen as tested for being comparative. According to Haspelmath (2010a), comparative concepts are universally applicable, and so the parts of the questionnaire which continue to easily apply to many languages over time may lead to identifying such concepts.

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[7]Ideally, on number of examples, too (see the rest of this section).

[8]Bender et al. (2002) "distilled" the English Resource Grammar (Flickinger, 2000) to elements which were hypothesized to be non-English-specific, based on the work that was being done at the same time on German (Crysmann, 2003) and Japanese (Siegel et al., 2016). Hereafter, citations for implemented grammars refer not only and not so much to the publications as to the grammar implementations themselves, which may significantly predate publications.

[9]It would seem that rebuilding most of the formal and software machinery from scratch would be prohibitively time consuming.

I see the Grammar Matrix as a framework which, while not assuming a universal, biologically determined building blocks of grammar, is positioned to establish over time a set of concepts which are demonstrably useful for describing the variation in human languages. My conviction is rooted in three features of the framework, particularly of its development: (i) the Grammar Matrix design is informed by typological literature (while relying on established HPSG concepts); (ii) the development prioritizes cross-linguistic applicability and as such leaves flexibility to define concepts and features motivated by the data; (iii) whichever new analyses are suggested as part of Matrix development, there is a system in place (Bender et al., 2007) which allows one to automatically test them in integration with the existing ones, thus building and extending, over time, a system of analyses for which we have a proven area of applicability — which also grows over time.

Note that without computational aid (implemented grammars being one example), both the theorists and the typologists are ultimately left to test their hypotheses with small sets of sentences from each language that they study. Even though field linguists work with large collections of sentences and typological work undoubtedly draws on extensive field work, it is unclear to what degree it is possible to review all of the data one had consulted again and again to check for consistency as claims are revised over time. Similarly, while one could argue that theoretical syntax efforts, put together, do cover large numbers of sentences from some well-studied languages, for a human it is hardly possible to assess how all the different analyses presented in these works interact with each other unless they are implemented on the computer (Bierwisch, 1963; Bender, 2008; Müller, 2015). This consistent rigor is exactly the feature grammar engineering and particularly the Grammar Matrix, provide. Grammar engineering means the analyses are both modeled formally and implemented in a machine-readable way so that the grammars which contain them can be automatically run and rerun on test suites of sentences — however large. This makes the proven area of applicability of the analyses well defined and clear, and makes it possible to build on previous work literally, making sure the analyses interact with each other smoothly — or clearly exposing their shortcomings. The Grammar Matrix adds to this a typological dimension; now the analyses are demonstrably applicable not only to *large* but also to *many* test suites. Crucially, as analyses are added or modified and as the test suites grow in size and number, the ability to automatically and consistently rerun all the existing and new tests makes it possible to always substantiate the claims about what the analyses actually cover.

1.3 Research question and a definition of analysis

The main research question of this work is: Given the constraints of building on existing implemented analyses, what set of HPSG structures (types, lexical and phrasal) constitutes an analysis of constituent questions, as they are attested in typological literature, that will furthermore be demonstrably compatible with the existing analyses of other phenomena? In line with the philosophy, methodology, and framework described above in §1.2, I am assuming a working definition of *analysis*: A collection of rules/constraints designed to handle some specific phenomenon. *Analysis* often also refers to central ideas or intuitions that the aforementioned rules and constraints formalize; in this work, this interpretation of *analysis* plays a secondary role. This is in line with the distinction between formalism and theory which is a definitive trait of HPSG. The formalism has to be fully distinct from the theory so as to be stable enough for implementation (Bender, 2008). This has an important consequence, namely that one formalism can be used to

[10]The related but separate distinction between the object of study and the metalanguage used to describe it is very old, including in linguistics. That the object language is distinct from the metalanguage was clearly understood by e.g. Tarski (1956) and Bar-Hillel (1953), and at least as early as Ajdukiewicz 1935. Such a distinction is often seen as axiomatic (see e.g. Haspelmath (2010b) who lays out a system of definitions based on a similar distinction which he assumes in sciences in general). Interestingly, Chomsky (1957, p.54) notes:

> Linguistic theory will thus be formulated in a metalanguage to the language in which grammars are written - a metametalanguage to any language for which a grammar is constructed.

The above footnote from *Syntactic Structures* could in principle be interpreted as assuming a distinction between a formalism (the language in which a grammar is written) and a theory, and indeed it was originally suggested to me as such. But from the context, it is more likely that Chomsky (1957) is arguing for a distinction between a particular grammar and a general theory of language, thus actually skipping the distinction between a theory and a formalism in which it is encoded (interpreting “metalanguage” as “formalism” in the above quote does not make sense in the context of my discussion, because that would mean theories describe formalisms; the choice of a formalism influences the theory, as argued e.g. in Miller 1999, however this does not mean a theory is a metalanguage for a formalism). Indeed, as argued in detail (if not neutrally) by e.g. Givón (1979, p.5–9), the distinction between the formalism and the theory is in practice often conflated in syntax. I would like to thank Antonio Machichao y Premier, Rui Chaves, Gerald Penn, and especially Guy Emerson for suggesting most of the above references and interpretations to me.

posit not only one theory it was picked/developed for, but also multiple future theories (Bender and Emerson, in press).[10] My work is directly connected to the theories proposed by Pollard and Sag (1994), Ginzburg and Sag (2000), Bouma et al. (2001a), *inter alia*, however my goal here is not so much to propose a theory of language as to observe which formal devices prove to be useful to model a range of linguistic data. In terms of contributing to one of the biggest questions in linguistics —what is the range of variety in human languages? —this work contributes to building a computerized platform of interacting analyses which are both data driven and then in turn rigorously tested on language data. Such a platform extends the proven area of applicability of HPSG analyses for a number of syntactic phenomena and, in the Montagovian sense, is a way of arriving at what the range of successful analyses of these phenomena is.

1.4 Organization

The dissertation is organized as follows. I start by describing the constituent questions typology as presented in the typological and also syntactic literature (Chapter 2). My analysis is narrower in scope than what is laid out in Chapter 2; it aims to cover a subset of the phenomena mentioned there. I then give background on the Head-Driven Phrase Structure Grammar formalism (Pollard and Sag, 1994), the DELPH-IN formalism, and the Grammar Matrix system (Chapter 3). Chapter 4 is a brief overview of existing theoretical work on consituent questions in HPSG as well as of existing grammar engineering work which informed my analysis or on which I rely in other ways. I provided a glossary at the beginning of this document which is intended to help the reader through those two chapters. Developing a library for the Grammar Matrix system has an established methodology (Bender et al., 2010b) which I outline in Chapter 5. Chapter 6 presents the main aspects of my analyses and is organized around data from several illustrative languages. The library with all its components is then described in Chapter 7. I tested my analyses on a range of languages according to the methodology described in Chapter 5, both during development and after "freezing" the development, using "held-out" languages from "held-out" language families (which is to say that these languages or language families were not considered during development). That is the content of Chapter 8. Finally, I offer some discussion about future work directions in Chapter 9 where I also summarize the conclusions.

1.5 A note on completeness vs. readability

This dissertation has an engineering component which, by definition, only works and makes sense as a whole, each detail being important. As such, it was tempting to me as the writer to try and describe each such detail of the system in the document. However, that is probably impossible, and at any rate, it would make the dissertation very hard to read and comprehend. As I was writing this document, I did in principle try to describe all of the decisions I made during the implementation; however, clarity and readability were ultimately the goal, and if the reader is after reproducing some of the things which are described here, I suggest that they also work with the code which accompanies this dissertation and which is by definition a complete snapshot of the system described here.[11]

[11] The snapshot described in this document: `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`

Chapter 2

THE TYPOLOGY OF CONSTITUENT QUESTIONS

This chapter summarizes some of the knowledge about the morphosyntax of constituent questions presented in the typological literature. Not all of this knowledge is in scope of this dissertation; the goal of the chapter is to outline the more general space in which the dissertation is situated.[1]

Following Idiatov (2007), I focus here on questions which represent a conventional and direct way of asking for information about a referent, what Idiatov (2007) calls prototypical constituent questions. Some examples from English ([eng]; Indo-European) are given in (1)-(4).[2]

(1) What did you do? [eng]

(2) Who did you see? [eng]

(3) Which person did you see? [eng]

(4) Where did you go? [eng]

The primary use of utterances like these is to elicit information about a person, thing, or location

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[1]A note on the usage of the word *typology*. This term is used by different linguists and in general it refers to classifying languages by certain features. It is important to note that these features can be different depending on the kind of linguist. For example, while typologists like e.g. Dryer (2013b) classify languages based on the "position of the interrogative phrase", syntacticians like e.g. Chomsky (1964) classify them with respect to whether or not they exhibit "*wh*-movement", which results in different typologies. In this chapter, I mostly talk about typological facts in Dryer's (2013b) sense, i.e. concerned more with the surface data than with any syntactic analyses. The data here is purposefully separated from any formal-syntactic hypotheses about it. The syntactic analyses presented later in Chapter 6 are meant to be informed by typology but not conflated with it. This determined the reference structure of the chapter; when I talk about "multiple question phrase fronting", for example (§2.5.2), I am concerned less about the concept of *wh*-movement and who first talked about multiple movement (it was Wachowicz (1974)) and more about the fact that in e.g. Russian, multiple question phrases appear at the front of the sentence — an observation which would be hard to attribute to anyone in particular in the case of such a widely spoken and widely studied language as Russian.

[2]Unless otherwise noted, I constructed the English examples myself, although I am not a native speaker of English. They were vetted by Debbie Berkeley and Leanne Rolston, who are native speakers of English.

in space or time. This is in contrast to polar and tag questions which are eliciting a Yes/No answer about whether or not a particular proposition is true, and in contrast to echo questions which do not inquire about a specific entity but rather express confusion or disbelief or indicate that the speaker did not hear the previous utterance well enough.

I start with question words as this seems to be a cross-linguistically universal strategy of forming constituent questions (§2.1) and briefly talk about multiple questions (§2.2). Then I present clause-embedding verb typology (§2.3) (since questions can be embedded), and then talk about so-called long-distance questions, which is when question words/phrases cross clause boundaries (§2.4). Then I summarize the specific strategies different languages use to express constituent questions: fronting (§2.5), particles (§2.6), scope marking (§2.7), morphological marking (§2.8), and finally bound roots (§2.9) and interrogative verbs (§2.10). Not all of the phenomena described in this chapter are included in my analysis (Chapter 6); in particular, scope marking and serial words and bound roots are not included; superiority effects and island constraints are not included either.

2.1 Question words

Constituent questions can involve special types of pronouns (1)-(2), determiners (3), adverbs (4), and verbs (§2.10), as well as special inflectional paradigms of verbs (§2.8), and bound roots (§2.9). Idiatov (2007), who did an extensive review of question words in the world's languages in his dissertation, defines constituent questions as questions which "ask for an instantiation of variable *x*", and question words are usually understood to denote such a variable. Many languages though not all have separate question words denoting a person (e.g. English *who*) vs. a thing (e.g. English *what*) while separate adverbs may exist to inquire about the position in space or time (English *where, when*), as well as for reasons and manner of the event (English *why, how*).[3]

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[3]The *why* has some special properties; for example, in English:

(i) *Who left why? [eng]

(ii) Who left when? [eng] (Ginzburg and Sag, 2000, p.245)

Question determiners (like the English *which*) are used to ask about a closed or limited set of possibilities (which person of the group; which time of day, etc.). For this reason, they were termed "Discourse-linked" (D-linked) by Pesetsky (1987). Morphologically, question words are usually members of the appropriate paradigms in the language, e.g. while question adverbs may not have many forms in Indo-European languages, pronouns usually inflect for case, person, number, and gender; determiners agree with nouns in gender and number, etc. Question words are present in most examples throughout this dissertation.

One property of question words is that answers to them are foci of the answer-sentence (being new information), and some linguists argue that question words are foci themselves (Culicover and Rochemont, 1983). However, Erteschik-Shir (1986) argues against this, and, following Chafe (1970), points out that while the answer to a constituent question is usually the focus, the question word itself need not necessarily be. On a conceptual level, the difficulty that Erteschik-Shir (1986) observes has to do with the fact that the referent which is the answer to the question has not yet presented itself and therefore does not necessarily constitute a specific object that can be in focus. Whatever the case may be, it seems clear that question words play a role in the information structure of the sentence.

2.2 Multiple questions

Most languages allow for sentences that ask more than one thing at a time (5).

(5) Who saw whom? [eng]

Languages which appear to not allow more than one question phrase in one sentence seem to be rare but there are such claims about Italian ([ita]; Indo-European), Somali ([som]; Afro-Asiatic), Tomasheq Berber ([taq]; Afro-Asiatic; (6a)-(6b)), and Irish ([gle]; Indo-European) (Stoyanova, 2008).

(6) a. May t-sghu terbatt
what.CM 3FS-bought girl
'What did the girl buy?' [taq] (Stoyanova, 2008, p. 174)

b. *Wiy yzrin may?
who.CM saw.PART what.CM
Intended: 'Who saw whom?' [taq] (Stoyanova, 2008, p. 174)

2.3 Questions in complex clauses

In complex clauses, questions (constituent and polar) can be embedded as subordinate clauses, regardless of whether the main clause is a proposition (7) or a question (8).

(7) I wonder who arrived. [eng]

(8) Who wonders who arrived? [eng]

In English, there is a special complementizer (*whether*) that can mark the embedded clause as a question (9a)-(9b). In Russian ([rus]; Indo-European), the question particle *ли* which is optional in main clauses (10a)–(10b) becomes obligatory in embedded questions (11a)–(11b).

(9) a. I asked whether Kim arrived. [eng]

b. *I asked Kim arrived. [eng]

(10) a. Приехал ли Иван?
priehal li Ivan?
arrive.PAST.MASC Q Ivan.NOM
'Did Ivan arrive?' [rus][4][5]

b. Приехал Иван?
Priehal Ivan?
arrive.PAST.MASC Ivan.NOM
'Did Ivan arrive?' [rus]

(11) a. Я хочу знать приехал ли Иван.
Ya hochu znat priehal li Ivan.
1SG want.1SG.PRES know.INF arrive.PAST.MASC Q Ivan.NOM
'I want to know whether Ivan arrived.' [rus]

[4] I constructed the Russian examples myself using my native speaker judgment, unless otherwise noted.

[5] The Russian examples are given in Russian orthography and then the second line of the IGT is a common transliteration `https://en.wikipedia.org/wiki/GOST_7.79-2000`.

b. *Я хочу знать приехал Иван.
*Ya hochu znat priehal Ivan.
1SG want.1SG.PRES know.INF arrive.PAST.MASC Ivan.NOM
Intended: 'I want to know whether Ivan arrived.' [rus]

Not all clause-embedding verbs can embed questions. In particular, it is fairly clear that some verbs embed strictly propositions, (12a)-(12b), (14a); some specifically embed questions (13a)-(13b) or answers to questions (14b) (Ginzburg and Sag, 2000; Egré, 2008).

(12) a. I think that Kim arrived. [eng]

b. *I think who arrived. [eng]

(13) a. *I ask that Kim arrived. [eng]

b. I ask who arrived. [eng]

(14) a. I know that Kim arrived.[eng]

b. I know who arrived. [eng]

2.4 Long-distance dependencies

Questions can be "long distance", meaning the dependency crosses clause boundaries (15).

(15) Who do you think arrived? [eng]

Another (precise but perhaps cumbersome) way of describing a long-distance (LD) question is: a question phrase which is an argument of an embedded clause at the same time refers to the answer to the question that the main clause is asking. This can be illustrated by considering (16). In example (16), (16d) is not a felicitous answer to (16b) because (16b) is not a question about who arrived; it is a question about what Kim thinks. At the same time, *who* is the syntactic subject of *arrive*.

(16) a. Alex arrived yesterday but Jo did not. However Kim believed that Jo arrived. Sandy is talking to Lee about that.

b. Sandy: Who does Kim think arrived?

c. Lee: Funny, but Jo, actually. Kim thinks Jo arrived even though we all had a video call with Jo earlier this morning and Jo was clearly still in Zurich.

d. #Lee: It is Alex who arrived.

Long-distance dependencies (LDDs) need not be questions, as illustrated by (18):

(17) Who does Dana believe Chris knows Sandy trusts? [eng]

(18) Kim, Dana believes Chris knows Sandy trusts. [eng] (Pollard and Sag, 1994, p.158)

The surface syntactic phenomenon which is usually involved in LDDs is often called *fronting*, although fronting is more general and can be used to refer to clause-internal variation in word order.

2.5 Fronting

In many languages, question words or phrases must be fronted.[6] This is one of the most salient characteristics of constituent questions; English is one example. While (19a) is a typical constituent question as defined at the very beginning of this Chapter, (19b) is not possible. The only way such a word order is possible in English is in an echo question (19c), which is not a way to ask for new information.

(19) a. What did Mary read? (The book). [eng]

b. *Did Mary read what? [eng]

c. Did Mary read WHAT?! [eng]

Fronting is often discussed along with long-distance dependencies (§2.4). While writing this review, I did not come across a language which would exhibit clause-bound *wh*-fronting (require fronting in simple clauses but not allow long-distance questions), and it is not a feature/dimension

[6]Dryer (2013b) says that there are verb-final languages which exhibit a "weak" tendency to place interrogative phrases at the end of sentences, e.g. Tennet (Nilo-Saharan). I do not include this possibility in the range of my analyses in Chapters 6–7 although there would be no issue in presenting a symmetric HPSG analysis for this kind

in e.g. WALS (Dryer, 2013b), although sometimes Russian is described as a language which only allows long-distance extraction from subjunctive clauses (Antonenko, 2008, *inter alia*).[7]

I will consider two dimensions of fronting here: obligatoriness/optionality of fronting and whether a single question phrase or multiple question phrases are fronted.

2.5.1 Fronting optionality

It is clear that some languages exhibit fronting and others do not (languages which do not allow fronting will be discussed later in §2.5.5). A separate question is whether, in languages which do exhibit fronting, such fronting can be optional.[8] In some languages (like English), there is clearly obligatory fronting of one question phrase, at least to form prototypical (not echo) questions (19a)-(19c); in others, question words may appear both fronted or in the normal argument position (20a)-(20b).[9]

(20) a. Где ты работаешь?
Gde ty rabotaesh?
where 2SG work.2SG.PRES
'Where do you work?' [rus]

b. Ты где работаешь?
Ty gde rabotaesh?
2SG where work.2SG.PRES
'Where do you work?' [rus]

In syntactic literature, it has been argued that in fact there is multiple movement in such cases and that the subject of the clause also moves (Bošković, 2002; Stjepanovic, 2000; Mišmaš, 2015, *inter alia*). However a theoretical notion of optional fronting also exists (Sabel, 2003).

of inverse fronting; it would simply involve a phrase structure rule with a different constituent order.

[7]There is a notion of clause-intenal *wh*-movement (Aldridge, 2010, *inter alia*) but that seems different from the discussion of the surface word order that I am concerned with here.

[8]In the classic syntactic typology by Rudin (1988), languages are classified into four types: (1) obligatory single fronting, (2) *in situ*, (3) optional fronting, and (4) obligatory multiple fronting. This typology can be applied here if it is taken separately from the specific syntactic formalism in which it is couched.

[9](20b) is absolutely fine as a prototypical constituent question, not an echo question. In fact, intuitively it seems to me that it is a more common way of asking where someone works than (20a).

Typological work (Dryer, 2013b) has identified the following distribution of how question phrases can be positioned in the sentence (Table 2.1): Although Table 2.1 uses phrasing which could be

Position of question phrases	Num. of languages
Obligatorily initial	264
Not obligatorily initial	615
Mixed, some obligatorily initial, some not (depending on type of phrase)	23

Table 2.1: Question phrase positioning across languages (Dryer, 2013b)

interpreted as if most languages had optional fronting, as a matter of fact the second row in the table corresponds to languages usually classified as *in situ* in syntactic literature. Specifically, Dryer (2013b) defines the phenomenon as follows:[10]

> "In other languages, interrogative phrases do not obligatorily occur at the beginning of the sentence, and occur naturally in other positions in the sentence, most often in whatever position is natural for the corresponding noninterrogative phrase."

It seems like this classification does not necessarily exclude optionally fronting languages from the second row but rather points out that *in situ* is the most common possibility unless fronting is obligatory. Last but not least, Dryer (2013b) clearly states (not in relation with the second row) that there are languages where fronting is truly optional.

In Malagasy ([mlg]; Austronesian), a V-initial language, question phrases are in the left periphery but they are also marked for focus, and non-question phrases which are marked for focus are in the left periphery, too (21)–(22).

(21) amin=inona no manasa lamba Rasoa
with=what FOC wash clothes Rasoa
'With what did Rasoa wash the clothes?' [mlg] (Dryer, 2013b; Keenan and Li, 1976)

(22) amin=ity savony ity no manasa lamba Rasoa
with=this soap this FOC wash clothes Rasoa
'It is with this soap that Rasoa is washing the clothes.' [mlg] (Dryer, 2013b; Keenan and

[10] Accessed online on March 13 2021 `https://wals.info/chapter/93`.

Li, 1976)

Malagasy would be considered an *in situ* language by analyses which assume a special operation for *wh* movement (Potsdam, 2004; Sabel, 2003); however, if fronting is analyzed as a more general phenomenon (e.g. one that can be observed with respect to both interrogative and non-interrogative constructions), then Malagasy can be seen as a fronting language. In my dissertation, I do not work directly with Malagasy data but a language like it should probably be modeled as fronting under my analysis.[11]

In some languages, question phrases appear in a focus position which itself can be preceded by any number of topic constituents, like in Hungarian ([hun]; Uralic) (23).

(23) János ki-t hív-ott fel?
Janos.NOM who-ACC call-PAST.3SG VM
'Who did Janos call?' [hun] (Mycock, 2006, p.208)

Examples like (23) resemble the Russian example (20b).

2.5.2 Multiple question phrase fronting

As for the number of things which can not only be asked about in one sentence but which can also form long-distance dependencies, in many languages exactly one question phrase can be fronted. English is one example (24a)-(24b) although this is certainly not an Indo-European phenomenon and such languages are found in Tungusic, Pama-Nyungan, Wakashan, and many other families Dryer (2013b).

(24) a. Who saw what? [eng]

b. *Who what saw? [eng]

In some languages, perhaps most famously Slavic (Wachowicz, 1974; Rudin, 1988; Citko, 1998, *inter alia*), more than one question word may be fronted (25).

[11] The goal of such an exercise would be to see what the area of applicability of such an analysis is, like what is described in Chapter 8.

(25) Кто что видел?
Kto chto videl?
Who.NOM what.ACC see.PST.3SG
'Who saw what?' [rus]

There may be preferences about the order of fronted elements, and in Russian, (26) usually sounds better than (27), and (28) almost always sounds better than (29) (animacy is a factor, as summarized in e.g. Fanselow et al. 2011). In Bulgarian, the order of question phrases in sentences expressing three questions is more free than the order in sentences expressing two questions (Bošković, 1997; Citko, 1998). There are also limitations on extracting from the embedded clause as well as from the main clause, exemplified in (30), although according to Rudin (1988), in Romanian ([ron]; Indo-European) such extraction is possible (31).

(26) Кто кого видел?
Kto kogo videl?
who.NOM who.ACC see.PAST.SG
'Who saw whom?' [rus]

(27) Кого кто видел?
Kogo kto videl?
who.ACC who.NOM see.PAST.SG
'Who saw whom?' [rus]

(28) Кто что видел?
Kto chto videl?
who.NOM what.ACC see.PAST.SG
'Who saw what?' [rus]

(29) ?Что кто видел?
Chto kto videl?
what.ACC who.NOM see.PAST.SG
'Who saw what?' [rus]

[12] Consider a scenario: You are a suspect in a murder investigation. I am your lawyer and we are discussing your defense. Now, it looks like maybe you told detective Poirot that you saw a tall person but you told detective Maigret that you saw an average height person at the site of the murder. I need to establish very clearly, which detective has which information: did you actually tell Poirot that you saw a tall person and Maigret that you saw an average height person, or vice versa?

(30) ??Кому что ты сказал (что) ты видел?
??Komu chto ty skazal (chto) ty videl?
who.DAT what.ACC 2SG tell.2SG.PAST (that) 2SG see.PAST.SG
Intended:"?Who did you tell that you saw what?"[12]

(31) Cine ce ziceai [că își închipuie [čă ai descoperit]]?
who what say.PAST.2S that to himself imagines that have-2S discovered
'Who did you say imagines you discovered what?' [ron] (Rudin, 1988)

Przepiórkowski (1998) is of the opinion that the discussion of restrictions on the order of multiple fronting largely amounts to the discussion of superiority effects (§2.5.3).

2.5.3 Constraints on extraction: Superiority effects, Island constraints, and pied-piping

Syntacticians have long observed that some things front more easily than others. Such constraints on extraction/fronting seem to have to do with the order in which things tend to front and with the internal structure of the phrase to which the question phrase is linked as an argument or adjunct.

Superiority effects

In English, in many cases, if both the subject and the object of the verb are replaced with question words, only the one asking about the subject can be fronted:

(32) a. Who read what? [eng]

b. *What did who read? [eng]

This was explained by Chomsky (1973) in terms of Logical Form movement and called *the Superiority Condition.* Much syntactic literature attempted to explain the so-called *superiority effects* in purely syntactic terms, insisting that a theory of syntax must account for them. However, it has also been observed that superiority effects do not always hold:

(33) a. Which man did you persuade to read which book?

b. Which book did you persuade which man to read? [eng] (Pesetsky, 1987, p.106)

(34) a. Mary asked which man read which book.

b. Mary asked which book which man read. [eng] (Pesetsky, 1987, p.106)

Pesetsky (1987) suggests that the difference between the *which*-phrases and the "normal" usages of *who* and *what* is that *which*-phrases are "linked to discourse" (*D-linked*), perhaps another way of saying what Idiatov (2007) refers to as "selective" (vs. "nonselective") question words. With *which*, the range of felicitous answers is more limited than with *what*. Ginzburg and Sag (2000, p.248) note that, while there is clearly some presuppositional difference between *which* and *who/what* phrases, both can be used for the same purposes (independently, functionally, and to reprise) and furthermore, the condition for felicity of *which*-phrases is orthogonal to the study of interrogatives, as fixing of the domain is required for full comprehension of any utterance. In particular, they note that it is implausible to suggest that in uttering (35), the speaker has in mind a range of answers any more specific than when any of the examples in (36) are uttered.

(35) I don't know anything about cars. Do you have any suggestions about which car, if any, I should buy when I get a raise? [eng] (Ginzburg and Sag, 2000, p.248)

(36) a. I don't know anything about cars. Do you have any suggestions about what car, if any, I should buy when I get a raise?

b. I don't know anything about cars. Do you have any suggestions about what, if anything, I should buy when I get a raise?

c. I don't know anything about cars. Do you have any suggestions about how many (cars), if any, I should buy when I get a raise? [eng] (Ginzburg and Sag, 2000, p.248)

Furthermore, Bolinger (1978) argues that it should be possible to contextualize almost any example (with very heavy stress assumed on the *wh*-words):

(37) a. ?I know what just about everybody was asked to do, but *what* did *who* actually do?

b. I know that we need to install transistor A, transistor B, and transistor C, and I know that these three holes are for transistors, but I'll be damned if I can figure out from the instructions *where what* goes! [eng] (Bolinger, 1978)

There are also exceptions to superiority effects which appear more arbitrary (Falk, 2012):

(38) a. Where did you do what? [eng]

b. What did you do where? [eng]

Mycock (2006) as well as before that Ginzburg and Sag (2000) argue that superiority effects should be explained in terms of pragmatics and processing. Pragmatics plays a role accounting for examples like (37a), when properly contextualized. Falk (2012) agrees that processing plays a role but thinks that the effects probably are partially syntactic, still; Falk (2012) agrees also with Bošković (2002) in that the *which*-phrases, being not completely novel, are not completely focal. I do not offer an analysis of superiority effects in this dissertation, both because of time and space constraints, given the typological breadth of the work,[13] and because the literature argues that this phenomenon might not be purely syntactic.

Island constraints

Extraction islands (Ross, 1967) is a term for certain constraints on how far away the displaced argument or adjunct can appear from its normal position. In Ross's (1967, p.iii) own words, an island is "the maximal domain of applicability of all rules of a specified type." Various types of islands have been identified in the literature, starting from Ross (1967), among them so-called adjunct, *wh*-, subject, left branch, coordinate structure, complex noun phrase, and non-bridge-verb islands. I will not talk about all of them here; example (39b) illustrates an adjunct island, meaning that *what* (referring to a book) would have to be extracted from an adjunct *without reading X*:

(39) a. He criticized Chomsky without reading *Aspects*. [eng]

b. *What did he criticize Chomsky without reading? [eng] (Borsley, 2014, p.218)

An analysis of island constraints is not in the scope of this work though I do not argue that they should not or could not be analyzed syntactically.

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[13] The depth to which I worked with Russian (§8.3.2) would warrant modeling superiority effects, however in Russian they are not exhibited strongly (Rudin, 1988). This is an example of how the choice of an illustrative language (§5.2) influences the resulting analysis.

Pied-piping

Pied-piping (Ross, 1967) refers to constraints where a non-*wh*-word can or must be fronted along with a *wh*-word. For example, a *wh*-determiner can optionally or obligatorily be extracted along with other, non-question words, such as nouns or adpositions. In some languages, for example in English, pied-piping of nouns is obligatory (40b) while pied-piping of adpositions is optional (41a)-(41b).[14]

(40) a. Which book did you read? [eng]

b. *Which did you read book? [eng]

(41) a. With what did you reach for the bag? [eng]

b. What did you reach for the bag with? [eng]

In other languages, for example in Russian, pied-piping of nouns is optional (42a)–(42b) while pied-piping of adpositions is obligatory (42b)–(42c).

(42) a.

В какой	город	Иван	приехал?
V kakoi	gorod	Ivan	priehal?
in which.ACC	city.ACC	Ivan.NOM	arrive.PAST.SG

‘In which city did Ivan arrive?’ [rus]

b.

В какой	Иван	приехал	город?
V kakoi	Ivan	priehal	gorod?
in which.ACC	Ivan.NOM	arrive.PAST.SG	city.ACC

‘In which city did Ivan arrive?’ [rus]

c.

*Какой	Иван	приехал	город	в?
*Kakoi	Ivan	priehal	gorod	v?
which.ACC	Ivan.NOM	arrive.PAST.SG	city.ACC	in

Intended: ‘In which city did Ivan arrive?’ [rus]

2.5.4 *Subject-auxiliary inversion*

Subject-auxiliary inversion is characteristic of English polar questions (43a)-(43b) and constituent questions which are not about subjects (44a)-(44c).

[14] Ross (1967) called left-branch extraction what I call optional pied-piping.

(43) a. Did Kim arrive? [eng]

b. *Kim arrived? [eng]

(44) a. What did Kim see? [eng]

b. *What Kim saw? [eng]

c. Who arrived? [eng]

Because this phenomenon is characteristic of English, theories of grammar usually make sure they cover it; however in the typological context, it is less prominent. Dryer (2013a) lists 13 languages with "interrogative word order" in *polar* questions; of these most are Germanic and most involve subject-verb inversion. Subject-auxiliary inversion in *constituent* questions seems even rarer (I did not find a typological study focused on it).

2.5.5 "In situ" languages

Languages which do not employ the fronting strategy to mark constituent questions are sometimes called the *in situ* languages in the mainstream, syntactic literature, meaning the question phrase does not move and stays in its place. For example, in Sogdian ([sog]; Indo-European), an SOV language, the question word is in the same position where the non-question object would be (45).[15]

(45) taγu peernamstar ču əktya kθaare?
2SG before what deed do.PRET.2SG
'What was it that you did before?' [sog] (Hölzl, 2018, p.149)

Long-distance questions can be formed without any fronting, as illustrated by the Japanese ([jpn]; Japonic) example (46).

(46) Mary-wa John-ga nani-o yonda to itta-no
mary-TOP john-NOM what-ACC read.PST that say-Q
'What did Mary say that John read?' [jpn] (Pesetsky, 1987, p. 109)

In situ questions are sometimes additionally marked by intonation or sometimes with a question

[15] By using this term in this dissertation, I do not suggest that fronting is the most common strategy to form questions or that it somehow more "natural" than other strategies.

particle, like in Japanese (47), with some literature arguing for a correlation between question particles and *in situ* languages (Cheng, 1997).[16]

(47) John-wa nani-o yonda-**no**?
John-NOM what-ACC read.PST-Q
'What did John read?' [jpn](Pesetsky, 1987, p.109)

2.6 Question particles

Most languages have question particles of some sort (Bruening, 2007). In Russian, the question particle can be used in a polar question (48a) but not in a constituent question (48b).

(48) a. Иван ли пишет диссертацию?
Ivan li pishet dissertatsiju?
Ivan.NOM Q write.3SG.PRES dissertation.ACC
'Is it Ivan who writes the dissertation?' [rus]

b. *Кто ли пишет диссертацию?
*Kto li pishet dissertatsiju?
who.NOM Q write.3SG.PRES dissertation.ACC
Intended: 'Who writes the dissertation?' [rus]

At the same time, a *focus* particle *же*, not unique to questions, is possible in constituent questions and must come directly after the question word (second position). When the particle is present, the question word is fronted. Furthermore, with this particle, the order of fronted *wh*-phrases appears to be freer than without it:

(49) a. Кто кого когда видел?
Kto kogo kogda videl?
who.NOM who.ACC when see.PST.SG
'Who saw whom, and when?' [rus]

b. ?Когда кто кого видел?
?Kogda kto kogo videl?
when who.NOM who.ACC see.PST.SG
'Who saw whom, and when?' [rus]

[16] But Bruening (2007) disagrees with that.

c. Когда же кто кого видел?
Kogda zhe kto kogo videl?
when FOC who.NOM who.ACC see.PST.SG
'And when is it, and who is it that saw whom?' [rus]

According to Miyagawa (1987), Japanese presents a case where a particle can be used in an embedded question (50) but not in a main clause question (51):

(50) Boku wa [dare ga kuru ka] sitteru
I TOP who NOM come.FUT Q know
'I know who will come.' [jpn] (Miyagawa, 1987)

(51) *Dare ga kuru ka?
who NOM come.FUT Q
Intended: 'Who will come?' [jpn] (Miyagawa, 1987)

In some languages, for example in Tlingit ([tli]; Dene-Yenisean), the question particle must follow not the *wh*-word but the entire NP or PP that the *wh*-word is part of (52).

(52) waá kwligeyi xáat sá i tuwáa sigóo?
how is.it.big.REL fish Q your spirit is.it.glad
'How big of a fish do you want?' [tli] (Cable, 2010, p.7)

For the purposes of this dissertation, it is important to note that question particles can be optional, obligatory, or impossible in constituent questions; that the same particles may or may not be used in polar and constituent questions; and finally that a particle can be clause-initial, clause-final, or second position.

2.7 Scope marking

In some languages, a question phrase in the matrix clause marks the scope of another question element in the embedded clause, e.g. in Passamaquoddy ([pqm]; Algic) (53).

(53) Keq kt-itom-ups [tayuwe apc k-tol-i malsanikuwam-ok]?
what 2-say-DUB when again 2-there-go store-LOC
'When did you say you're going to go to the store?' [pqm] (Bruening, 2006)

This is often called '*wh*-scope marking' (Riemsdijk, 1982). Stepanov (2000) finds an exemplar of this in Russian (among other languages), where a felicitous answer to (54) is one to the embedded question, the matrix question being merely rhetorical semantically.

(54) Как вы считаете, что прочитали студенты?
Kak vy schitaete, chto prochitali studenty?
how 2PL presume.2PL.PRES what.ACC read.3PL.PAST student.PL.NOM
'What do you think the students read?'
Lit: 'How do you think, what did students read?' [rus] (Stepanov, 2000)

2.8 Morphological marking

In morphologically rich languages, for example from the Uralic family and the many isolates scattered across Siberia, there is a special interrogative paradigm that is used to form questions, as illustrated by example (55) from Yukaghir ([yux]; Isolate).

(55) qodo lʔe-t-ōk
how be-FUT-ITRG.1PL
'What shall we do?' [yux] (Hagège, 2008, p. 9)

In Central Alaskan Yupik ([esu]; Eskimo-Aleut), subject marking on the verb in interrogative sentences is in complementary distribution with the morphemes which appear in declarative mood (56):

(56) a. nùk'àq tekít-ùk
PN.ABS.SG arrive-3SG.IND
Nuk'aq arrived. [esu] (Hölzl, 2018, p.132)

b. ki-na tekít-a-∅
who-ABS.SG arrive-3Q-3SG.Q
'Who arrived?' [esu] (Hölzl, 2018, p.132)

This may sometimes be referred to as interrogative mood, particularly in Russian literature on Uralic and Eskimo-Aleut languages (Malchukov and Xrakovskij, 2015) but also in some Western literature (Hölzl, 2018).

2.9 Serial verbs and bound roots

Serial verbs and bound roots (57)–(59) play a role in forming constituent questions in some languages, for example in Abui ([abz]; Trans-New Guinea). This does not seem to be addressed much in the literature dedicated to constituent questions specifically, but rather is evident from particular descriptive grammars.

(57) te **wi**-r = te a enra?
where be.like.MD.CPL.-reach = INCP.C 2SG cry.CNT
'Why do you cry?', lit.: Where does it make so that you cry? [abz] (Kratochvíl, 2016)

(58) kaai te **wi**-d-a hu he-l rui nee
dog where be.like.MD.CPL-hold-DUR SPC 3II.LOC-give rat eat
'What kind of dog did eat the rat?' [abz] (Kratochvíl, 2016)

(59) ma e-d-o a te = **ng** yaar-i?
be.PRX 2SG.LOC-hold-PNCT 2SG where = see go.CPL-PFV
'Well, you, where did you go?' [abz] (Kratochvíl, 2016)

In Abui, verbs like *wi-d-a* are a closed class, and in particular, *wi* is a bound form. These do not resemble special interrogative verbs (§2.10) as they require a separate *wh*-word. Verbs like *ng* are also a closed class and most of them are also bound roots, and they also are not special interrogative items. In particular, *ng* can encode direction, so, the question word *te* (*where*) combines with the generic root *ng* when the direction is questioned, like in (59).

2.10 Interrogative verbs

Hagège (2008) defines 'interrogative verbs' as words which function as the main or secondary predicate in the sentence and at the same time question the state of affairs denoted by the predicate. Hagège (2008) clarifies that interrogative verbs do not question their arguments but again, the very state of affairs that they themselves denote.

Interrogative verbs are found in Chukchi ([ckt]; Chukotko-Kamchatkan) according to Dunn (1999) and Mackenzie (2009), *inter alia*, and, according to Hagège (2008), in a number of other languages, such as Mandarin Chinese ([cmn]; Sino-Tibetan), Tiri ([cir]; Astronesian), Lavukaleve ([lvk]; Papuan), Comox ([coo]; Salishan), among others. *Do.what* is a common way of glossing an interrogative verb (60)-(61); others include *be.what, be.where, say.what, go.where* (62)-(65).

(60) req-ərkən-əm igirkej gə-nin ekək?
do.what-PROG-EMPH right.now 2SG-POS son-ABS
'What is your son doing right now?' [ckt] (Mackenzie, 2009, p. 1147)

(61) nǐ zà gànmá?
2SG PROG do.what
'What are you doing?' [cmn] (Hagège, 2008, p. 2)

(62) ke trò?
2SG be.what
'What is the matter with you?' [cir] (Hagège, 2008, p. 5)

(63) vasia-m oina?
be.where-SG.M SEMIACT.MED.SG.M
'Where is he?' [lvk] (Hagège, 2008, p. 5)

(64) ʔeʔenət-čxw?
say.what.PROG-SG.S
'What are you saying?' [coo] (Hagège, 2008, p. 5)

(65) čem-šen-0?
go.where.PST-foot-3SG.S
'Where did he walk to?' [coo] (Hagège, 2008, p. 5)

Interrogative verbs do not seem to involve incorporation, at least not synchronically. Although the degree to which they are morphologically analyzable is variable (Hagège, 2008), many interrogative verb stems are very simple.

2.11 Summary

Languages form constituent questions using lexical, morphological, and syntactic means. On the lexical level, most languages employ special question words (like *wh*-words in English). On the morphological level, some languages employ special verbal morphemes to indicate that the event is being questioned, as well as whole special inflectional paradigms for verbs. Finally, it is common for constituent questions to have special syntax. Question phrase and question word fronting is common, and the fronting can be obligatory or optional, sometimes with what is called 'pied-piping', when it can be required that noun phrases and/or adpositions front along with the question words. Some languages use serial verb constructions and bound roots to form constituent questions. Second-position clitics attaching to question words or question phrases and generally words that are often referred to as 'question particles' are also a common device. Finally, sometimes there is no special syntax associated with the question, in which case intonation or just the question word become the main device to convey the interrogative meaning. It is normal to ask more than one thing in one sentence, in which case there will typically be more than one question word or phrase; however, some languages disallow multiple questions in one sentence, which may have to do with information structure (specifically, focus) constraints in these languages. Constituent questions seem to be closely tied to focus, and it is common to say that, for instance, question phrases are always in focus, however there is not a 100% consensus in the literature on this point. *Wh*-arguments of embedded verbs can form matrix questions while maintaining a long-distance dependency with the embedded verb. A subset of these phenomena are analyzed in this dissertation in the HPSG formalism; that is presented in Chapter 6. The next chapter gives some necessary background for those not familiar with the framework.

Chapter 3
BACKGROUND

The goal of this chapter is to provide the necessary background information for my dissertation. This includes an overview of the specific framework that I use, including the Head-Driven Phrase Structure Grammar formalism (§3.1) and the particular version of it, DELPH-IN JRF (§3.2); various software solutions which made my work possible (§3.3); and finally the Grammar Matrix project to which the implementation part of my dissertation serves as a component (§3.4). As for the HPSG theory and the DELPH-IN formalism, although in the subsequent chapters the focus will be on the aspects which are relevant to constituent questions, particularly nonlocal features and lists, I provide all the basics here which I thought were necessary for a reader not familiar with HPSG.

3.1 Head-driven Phrase Structure Grammar

In my dissertation, I work with the Head-driven Phrase Structure Grammar formalism (Pollard and Sag, 1994), specifically with its DELPH-IN variant which was developed with practical issues in mind (§3.2). Head-driven Phrase Structure Grammar (HPSG) is an explicit syntactic formalism first introduced by Pollard and Sag (1994) and used, also first by them, for a theory of syntax. The theory itself is also often referred to as HPSG. As explained in Chapter 1, a number of theories can be posited using the formalism, and there are in fact different versions of the HPSG theory. The Grammar Matrix uses one version, while the CoreGram project (Müller, 2015) uses another, for example.[1] HPSG is a constraint unification formalism which relies on a hierarchy of types and on several principles having to do with structure sharing. In constraint unification (Carpenter, 2005), variables may be constrained to have a particular value or to be equal to the value of another

[1]CoreGram assumes certain operations to be native to the grammar which the Grammar Matrix does not.

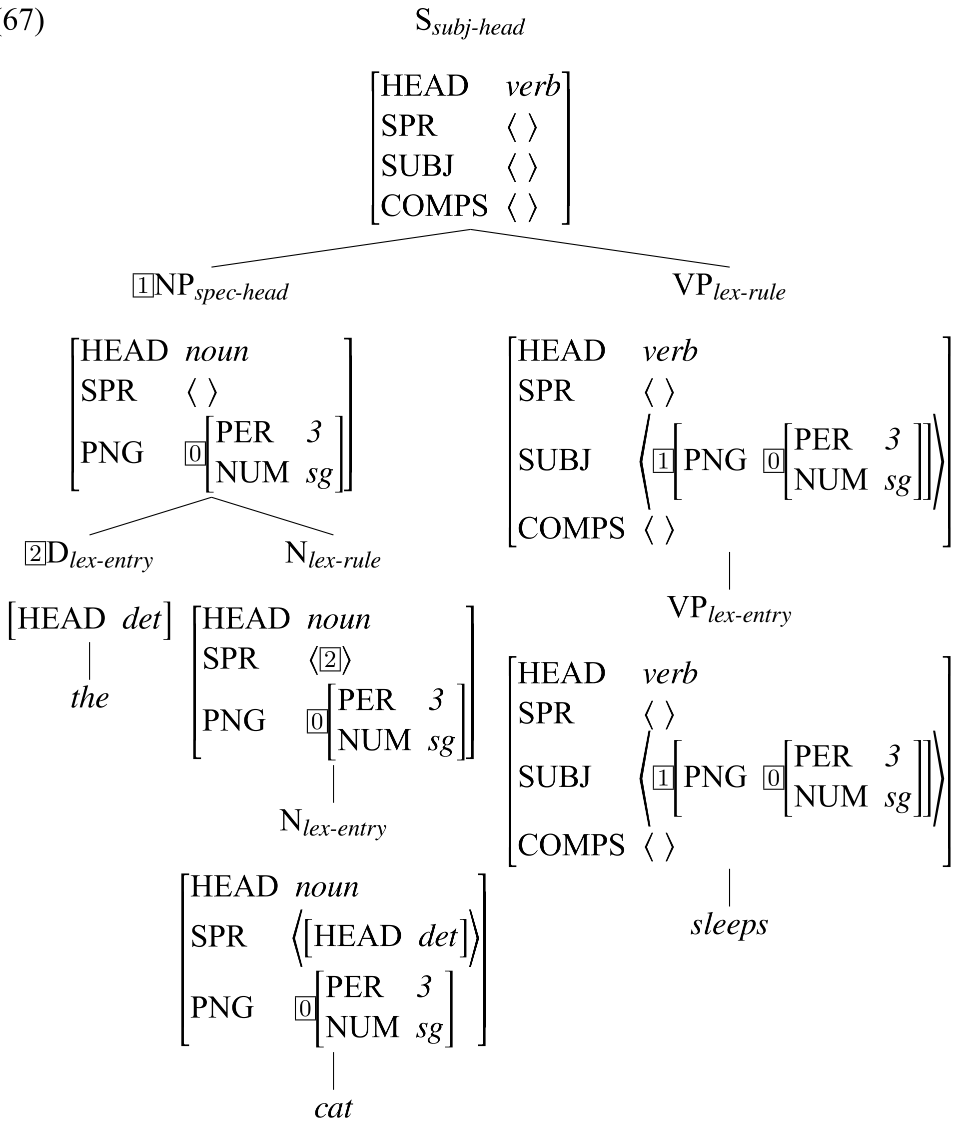
variable. Constraints can be **relational**, meaning a variable may be constrained to be the result of an operation over some other variables.

As a simplified example, consider a tree of feature structures representing an HPSG parse for the English sentence (66).[2] The feature structures in the tree are visualized as attribute-value matrices (AVMs). This tree includes only selected feature-value pairs and substructure sharing tags ($\boxed{0}$ etc.), to illustrate the particular role of each node in the tree that I would like to emphasize here.

(66) The cat sleeps. [eng]

[2]This tree is a simplified version of a tree produced by a grammar of English output by the Grammar Matrix. In particular, I only show the features HEAD, SPR, SUBJ, COMPS, and PNG, with only NUM and PER within the latter (in reality, there is also GEN).

(67)



The tree (67) illustrates several properties of HPSG which are crucial to understanding HPSG in general and by extension the framework in which my dissertation is situated. In addition to the general concept of constraint unification (Carpenter, 2005) introduced above, these properties are: (i) lexicalism; (ii) headedness (in particular, the Head Feature Principle); (iii) structure sharing (aka identities, re-entrancies); (iv) feature-value pairs; (v) types; (vi) lexical entries; (vii) lexical rules; (viii) phrase structure rules.

Consider the tree (67) bottom-up. Suppose that the terminal nodes in the tree (corresponding to *the*, *cat*, and *sleep*) are provided by some lexicon. The **lexical entries** in that lexicon are instances of **lexical types** and specify the syntactic category of each word (such as noun or verb) and what arguments they require, if any. For example, the intransitive verb *sleep* requires exactly zero complements and one subject element, furthermore, it requires a noun subject. The noun *cat* has a PNG feature which in turn has PER and NUM features appropriate for it, the values of which in this particular lexical entry are specified to be PER *3* at the lexical entry level, NUM underspecified to just *number* in the lexical type to which the lexical entry belongs (68), and further specified to NUM *sg* after a **lexical rule** (69) applies. The SYNSEM feature in the lexical rule is the *mother* of the unary rule; the DTR feature is the **daughter**.[3] Note that while the NUM value is identified between the mother and the daughter in the lexical rule, a lexical entry like (68) can unify with the daughter because its own value is underspecified. In the fully specified tree (67), the NUM has already been identified with the mother's of the lexical rule (same with the SUBJ identity between the verb's lexical entry node and the verb's lexical rule node). Something that is not a noun however would not be able to go through the lexical rule because that would violate the HEAD constraint. Lexical entries in HPSG determine many of the syntactic properties of the grammar; HPSG is a **lexicalist** theory.

(68)
$$\begin{bmatrix} \textit{noun-lex} & \\ \text{HEAD} & \textit{noun} \\ \text{PNG} & \begin{bmatrix} \text{PER} & \textit{3} \\ \text{NUM} & \textit{number} \end{bmatrix} \\ \text{SPR} & \left\langle \begin{bmatrix} \text{HEAD} & \textit{det} \end{bmatrix} \right\rangle \end{bmatrix}$$

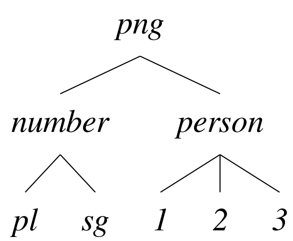
(69)
$$\begin{bmatrix} \textit{sg-lex-rule} & \\ \text{SYNSEM} & \begin{bmatrix} \text{ORTH} & \boxed{0} \\ \text{HEAD} & \textit{noun} \\ \text{PNG}|\text{NUM} & \boxed{1}\textit{sg} \end{bmatrix} \\ \text{DTR} & \begin{bmatrix} \text{ORTH} & \boxed{0} \\ \text{HEAD} & \textit{noun} \\ \text{PNG}|\text{NUM} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

All **types** in the grammar are part of some **type hierarchy** which presumably has other types,

[3] This lexical rule does not have an overt grammatical marking (these are sometimes called "zero-marking" rules); a lexical rule for plural marking would add the affix *s* to the orthography.

like *pl*, for example. There must be the most general type in the hierarchy, which in the Matrix is just called **top**. A toy portion of such a type hierarchy is presented in (70).

(70)



What is important here is that each type is specified to have features appropriate for it, and each subtype of a type may set the values for those features. At the same time, types themselves may be feature values. HPSG relies on the notion of type hierarchy for compactness, elegance, and scalability.

Next consider how feature-value pairs get propagated in the tree. In theoretical HPSG, a small number of general principles is assumed, and one of the most important ones is the Head Feature Principle. It stipulates that feature-value pairs that are appropriate for the feature HEAD in any structure, as well as the type of the value of HEAD, are shared between the mother node and the designated head daughter node. If there is more than one daughter node and the rule is a headed one, the grammar needs to indicate which one is the head daughter. In (67), the HEAD category is propagated because the Head Feature Principle is implemented in the grammar (see also §4.2.1). Other information is propagated because the particular phrase structure or lexical rules are defined specifically to do that; for example, the head-specifier rule identifies the non-head daughter with the sole element on the SPR list of the head daughter (67), etc. This is called **structure sharing**.

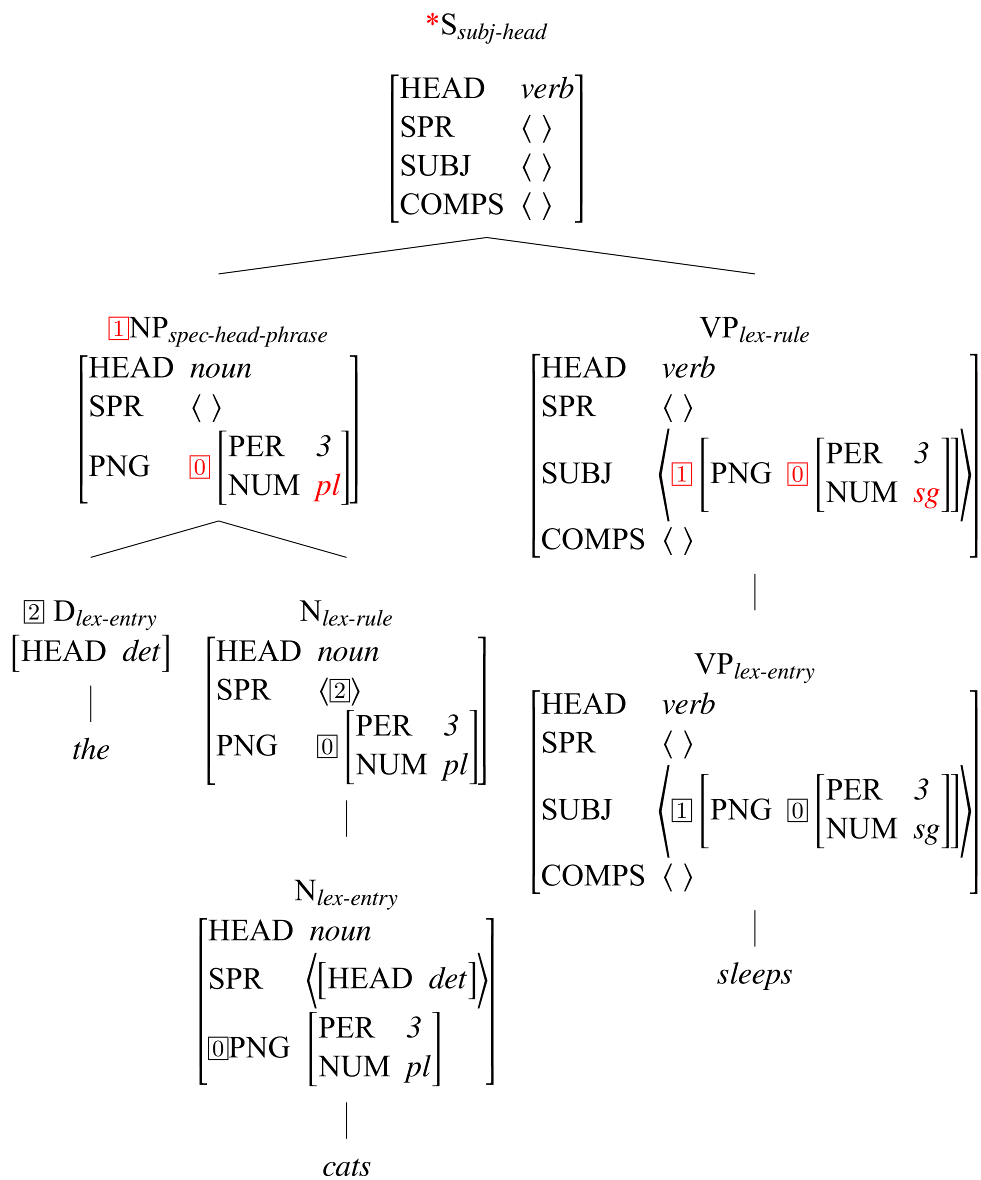
Structure sharing means some parts of the structure are the same. Any feature structure can be visualized also as a graph (see Pollard and Sag 1994, p. 16-17), and indeed in the implementations, they are literally stored as graph data structures. The identity tags in the AVM will be **reentrancies** in the graph, meaning the arcs will converge in the exact same place. In other words, in (67) the subject of the head daughter and the entire non-head daughter are not only similar (identical); they are literally the same structure. This is how HPSG phrase structure rules give rise to specific structures, e.g. how verbs become associated with specific arguments, etc.

The notion of structure-sharing is closely related to the notion of **constraint unification** generally, and to **unification failure**, which is the mechanism which leads to HPSG grammars rejecting ungrammatical input, or in other words not generating ungrammatical strings. Suppose that the same HPSG grammar licensing sentence (66) by assigning it the structure (67) is given the sentence (71) as input instead.

(71) *The cats sleeps. [eng]

Because in order to become *cats*, the lexical entry *cat* had to go through a lexical rule which specifies its previously underspecified value to *pl*, now if we attempt to use the head-subject rule to license (71), we will fail because there will be a unification failure between the verb's expected subject's PNG value and the one specified for the noun phrase (72).

(72)



One last thing about the HPSG formalism that is important for understanding my dissertation is the notion of **list**, presented in tree (67) as values for SPR, SUBJ, and COMPS (specifier, subject, and complement lists). Lists are a type in the type hierarchy, just like everything else. They are convenient for modeling different parts of grammar, most notably the notion of children of a node in the tree, and also arguments (e.g. of a verb).

---

[4] `www.delph-in.net`, `https://github.com/delph-in/`

3.2 DELPH-IN

DELPH-IN (DEep Linguistic Processing with Hpsg INitiative)[4] is an international consortium of researchers who are interested in engineering grammars using HPSG. Specifically, HPSG is a framework which includes a formalism which is both plausible and interesting theoretically and explicit enough to be implemented on the computer. Furthermore, the DELPH-IN Joint Reference Formalism (JRF; Copestake, 2000) is an HPSG formalism restricted to rely on only unification as a **native operation**, without **relational constraints** such as list reordering or counting. This feature of DELPH-IN JRF allows for relatively fast parsing and makes it possible to deploy DELPH-IN grammars for practical applications.

DELPH-IN JRF encodes HPSG feature structures as machine- but also still human-readable text. For example, (73) shows a definition for the type *sign* in JRF, including all the types it inherits from (:=), while (74) shows the corresponding AVM visualization of a fully expanded *sign*, including all the inherited features.[5] Note how features that are appropriate for *sign-min* and *basic-sign* are actually part of *sign* and how JRF allows for a compact definition.

(73)
```
sign := basic-sign &
  [ SYNSEM synsem,
    ARGS list,
    INFLECTED inflected ].

basic-sign := sign-min &
  [ KEY-ARG bool ].

sign-min := avm &
  [ STEM list ].
```

(74)
$$\begin{bmatrix} \textit{sign} & \\ \text{STEM} & \textit{list} \\ \text{KEY-ARG} & \textit{bool} \\ \text{SYNSEM} & \textit{synsem} \\ \text{ARGS} & \textit{list} \\ \text{INFLECTED} & \textit{inflected} \end{bmatrix}$$

[5] The AVM is intended to show what *sign* looks like when it is inspected in an implemented grammar. Of course the AVM notation can itself be used to show only selected features and constraints, as I just did in (72) above.

Sign is a very general type from which many types inherit in the same way it itself inherits constraints from *basic-sign*.

Another important notion is that of a **root condition**. In the Grammar Matrix hierarchy, *root* is a type like everything else (75). The purpose of *root* is to declare constraints corresponding to a complete, well-formed sentence. The parser program checks the root condition after finding all possible structures that span the input string, and returns only those structures which satisfy the *root* constraints.[6] The set of constraints for root (75) is essentially saying that, in order to be considered a complete sentence, the structure must have empty valence lists (in other words, the structure must have the subject and and object(s) realized), must not be a coordinand (e.g. start with *and*), must have a main clause (MC), and must not have any unrealized gaps in it (see §4.1.1 for the discussion about gaps and nonlocal features).

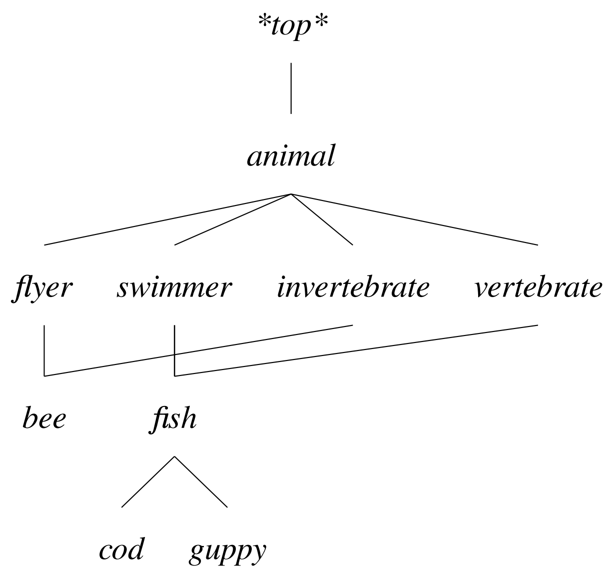
(75)
$$\left[\begin{array}{ll} \textit{root} & \\ \text{SYNSEM} & \left[\begin{array}{ll} \text{LOCAL} & \left[\begin{array}{ll} \text{CAT} & \left[\begin{array}{ll} \text{VAL} & \left[\begin{array}{ll} \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{array}\right] \\ \text{MC} & + \end{array}\right] \end{array}\right] \\ \text{COORD} & - \\ \text{NON-LOCAL} & \textit{non-local-none} \end{array}\right] \end{array}\right]$$

The *root* structure will come into play in some of my analysis in Chapter 6.

Finally, **constraint unification** in DELPH-IN is defined in the context of the "closed world" type hierarchy assumption. This means that, in order for any two types to unify, there must be a single (unique) type in the hierarchy which represents their combination (Copestake, 2002, p.42). It will be helpful for the reader to know this in order to interpret some of the type hierarchies that I will present in later chapters. For now, I offer a toy example from Copestake (2002, p.42); note how, it is possible to conclude from (76) that if something is of type *vertebrate* and also of type *swimmer*, then in this particular world, it must be a *fish* (though we do not know whether it is a *cod* or a *guppy*).

[6]In general parsing (e.g. parsing of programming languages), the Start symbol is somewhat similar to *root*.

(76)



This is because *fish* is the **unique greatest common descendant**, or unique greatest lower bound (GLB) for both *vertebrate* and *swimmer*. Without GLBs, the unification operation is not well-defined, as it is not guaranteed to yield a unique result. But looking at it from another angle, two types are said to unify if they have a GLB in the given type hierarchy.

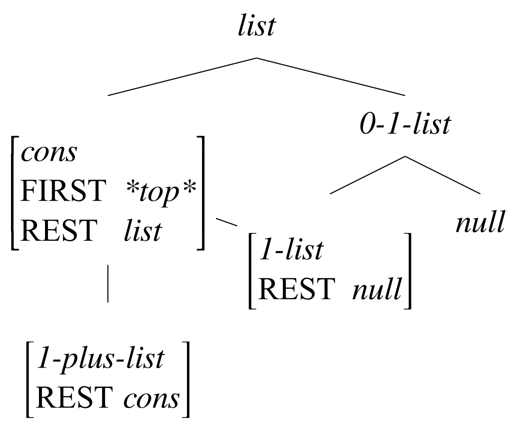
3.2.1 Lists in DELPH-IN JRF

Projects implemented in DELPH-IN JRF such as the Grammar Matrix (§3.4) use several list-valued features, such as SPR, SUBJ, COMPS, and some other. The type *list* is defined recursively as having features FIRST and REST, where the feature REST is itself list-valued.

Conceptually, the type *list* has two subtypes representing a nonempty list and an empty list. The nonempty list type has the two aforementioned features, where FIRST holds the first element of the list (which can be of any type), and REST holds the rest of the list. This allows a list to be specified recursively, following the REST feature multiple (0 or more) times, eventually terminating in an empty list. Note here that, because a list terminates with an empty list, it cannot be extended further.

The actual Grammar Matrix type hierarchy for lists is presented in (77).

(77)



The hierarchy shows that there are several kinds of lists available: a nonempty list (*cons*), an empty list (*null*), a list of length exactly 1 (*1-list*), a list of length 0 or 1 (*0-1-list*), and a list of length 1 or more (*1-plus-list*). Of these list subtypes, some unify with each other and some do not, according to the definition of unification given above: two types can unify if they have a unique common descendant. For example, *cons* and *0-1-list* unify as *1-list*; *null* and *1-list* do not unify with each other but both unify with their parent. On the other hand, *1-list* unifies with *cons* but *null* does not, etc. It makes sense intuitively that an empty list is incompatible with a nonempty list; the point here is that in DELPH-IN, that takes the form of a hierarchy as above.

As explained later in §4.1.3, DELPH-IN grammars use special types of lists in cases where the theory calls for appending lists to each other, including for analyses of long-distance dependencies. These special lists make it possible to perform the *append* operation without having this operation natively defined in the formalism. The clearest motivation for appending to lists in a grammar is perhaps **semantic composition**. Assuming the semantics of a sentence is built up piece by piece along with the syntax tree, lexical entries as well as lexical rules may contribute one or more semantic predications (see also §3.2.2). This means that the mother node of a phrase structure rule which combines, for example, the subject and the verb, must have a way of putting lists of predicates together, which necessitates the *append* operation. Pertinent to constituent questions, appending to lists becomes necessary because extracted elements are appended to a list (of a list-valued HPSG feature) (§6.5.1). DELPH-IN JRF does not define *append* as a native operation, and instead defines special types of *list*. In this dissertation, I use a type of list called *append* *list* (§3.2.1). Prior to this work, however, another type of list was used in the Grammar Matrix, namely *difference list*.

Difference lists

Difference lists in the context of DELPH-IN grammars are structures which embed (wrap) a list and a pointer to its end (78).[7]

(78) $$\begin{bmatrix} \textit{diff-list} & \\ \text{LIST} & \textit{list} \\ \text{LAST} & \textit{list} \end{bmatrix}$$

They were introduced in order to approximate the append operation (a relational constraint). *Append* is generally an operation that combines two lists by adding the elements of one to the other. In DELPH-IN JRF, this is not possible to do because a fully specified lists in DELPH-IN ends with an empty list; and empty list cannot be appended to, by definition.[8] Difference lists end instead with an underspecified *list*, which can be appended to.

With a type definition like (78), it becomes possible to implement a list append via just unification, by utilizing the LAST feature, as shown in (79) where the general supertype for *lexical rule* ensures that values like the semantic relations (RELS) of the mother of the rule are the append of those of the daughter's node and the rule's own C-CONT|RELS value. This means, if a lexical entry introduces a semantic predication and the lexical rule introduces an additional relation, the result of applying this lexical rule to this lexical entry will be semantically compositional. Semantic features like RELS (basic semantic relations), HCONS (handle constraints, see §3.2.2), ICONS (individual constraints, see §4.2.6) all traditionally rely on difference lists in DELPH-IN. So do features relevant to fronting and extraction (§6.3.1).

For grammar engineers, difference list append is notoriously easy to break when introducing

[7] According to Geske and Goltz (2007), the concept of difference lists dates back to the early history of logic programming. For an exposition related directly to DELPH-IN, see Copestake 2002, §4.3.

[8] Historically, the append operation was not natively defined in DELPH-IN for a combination of processing efficiency and theoretical parsimony-related reasons, even though Pollard and Sag (1994, p. 21) call append a "necessary" operation for linguistic descriptions.

new types to the grammar. An example of what an implementation of dl-append looks like in the general supertype for lexical rule in the Grammar Matrix is given in (79).

(79)
```
lex-rule := phrase-or-lexrule & word-or-lexrule &
  [ SYNSEM.LOCAL.CONT [ RELS [ LIST #first,
                               LAST #last ],
                        HCONS [ LIST #hfirst,
                                LAST #hlast ],
                        ICONS [ LIST #ifirst,
                                LAST #ilast ] ],
    DTR #dtr & word-or-lexrule &
    [ SYNSEM.LOCAL.CONT [ RELS [ LIST #first,
                                 LAST #middle ],
                          HCONS [ LIST #hfirst,
                                  LAST #hmiddle ],
                          ICONS [ LIST #ifirst,
                                  LAST #imiddle ] ] ],
    C-CONT [ RELS [ LIST #middle,
                    LAST #last ],
             HCONS [ LIST #hmiddle,
                     LAST #hlast ],
             ICONS [ LIST #imiddle,
                     LAST #ilast ] ],
    ARGS < #dtr > ].
```

In this case, the lists on the daughter are treated as the first part (from the beginning to the middle) of the resulting list; the lists on the C-CONT feature, which is the type's own semantic contribution, are treated as the second part (from the middle till the end). The result starts at the beginning and ends at the end. With the middle explicitly specified, this results in a list which is an append of two lists. The problem with this way of writing an append is that it involves too many lines of code; as such there is more space to make a mistake and it is more difficult to read the code and understand what it is doing, thus making it more difficult find mistakes, correct them, or generally build on the existing type hierarchy.

Furthermore, it is difficult to count elements on a difference list. Guy Emerson explains in Zamaraeva and Emerson (in press):

> "...there is an important but awkward division of labour between a difference list

and the value of its LIST. The elements of the notional list are to be found in the value of LIST, but the length of the notional list is implicitly defined by the value of LAST. Because the length is only implicitly defined, it is not directly accessible, which means it is even difficult to check if the notional list is empty or nonempty."

For this reason, the English Resource Grammar (Flickinger, 2000, 2011) constrains SLASH lists to be of length at most 1:[9]

(80) $$\begin{bmatrix} \text{REL} & \textit{0-1-dlist} \\ \text{QUE} & \textit{0-1-dlist} \\ \text{SLASH} & \textit{0-1-dlist} \end{bmatrix}$$

This constraint was inherited by the Grammar Matrix. However, to accommodate multiple *wh* fronting, this constraint needs to be taken out, as discussed later in §6.5.1.

Append-lists[10]

Emerson (2017) suggested an alternative to difference list appends, called *append-lists*. *Append-list* is a "wrapper" type which includes ("wraps") normal lists and defines a recursive operation which results in one list being appended to another (81).

(81) $$\begin{bmatrix} \textit{append-list} & \\ \text{LIST} & \boxed{0}\textit{list} \\ \text{APPEND} & \begin{bmatrix} \textit{list} & \\ \text{APPEND-RESULT} & \boxed{0} \end{bmatrix} \end{bmatrix}$$

For a more detailed exposition of how exactly *append-list* works, see Emerson 2017, 2019, in prep.; Zamaraeva and Emerson in press. *Append-list* has a feature APPEND which allows for what on the surface looks like a simpler and more elegant syntax[11] that will also be easier to maintain, as illustrated by example (82), cf. (79). Below the surface, it actually results in a fairly

[9] *0-1-dlist* is a subtype of *difference list* which is defined to be of length 0 or 1. Compare to the lists hierarchy (77); a similar hierarchy is defined for difference lists.

[10] Some content of this section was published as Zamaraeva and Emerson (in press).

[11] The word *syntax* is used here to mean not a branch of linguistics but rather generally a way to arrange words in a language, including a programming language.

complex recursive feature structure. In essence, while difference lists were only an approximation, append lists are a more complete implementation of a relational constraint without using a native definition of such a constraint (unification remaining the only native operation implemented in DELPH-IN JRF).

(82)
```
lex-rule := phrase-or-lexrule & word-or-lexrule &
  [ SYNSEM.LOCAL.CONT [ RELS.APPEND < #r1, #r2 >,
                        HCONS.APPEND < #h1, #h2 >,
                        ICONS.APPEND < #i1, #i2 > ],
    DTR #dtr & word-or-lexrule &
    [ SYNSEM.LOCAL.CONT [ RELS #r1,
                          HCONS #h1,
                          ICONS #i1 ] ],
    C-CONT [ RELS #r2,
             HCONS #h2,
             ICONS #i2 ],
    ARGS < #dtr > ].
```

Aguila-Multner and Crysmann (2018) were the first to apply one version of Emerson's (2017) proposal, append done directly on lists, to the problem of gender and person agreement for French coordinated noun phrases. In Zamaraeva and Emerson (in press), we implemented the first analysis of multiple *wh*-fronting using *append-lists*, which is also presented as part of this work (§6.5.1, §7.11.1).

$$\begin{bmatrix} \text{TOP} & h0 \\ \text{INDEX} & e2 \\ \text{RELS} & \left\langle \begin{bmatrix} \textit{person}\langle 0{:}3\rangle & \\ \text{LBL} & h4 \\ \text{ARG0} & x3 \end{bmatrix}, \begin{bmatrix} \textit{which\_q}\langle 0{:}3\rangle & \\ \text{LBL} & h5 \\ \text{ARG0} & x3 \\ \text{RSTR} & h6 \\ \text{BODY} & h7 \end{bmatrix}, \begin{bmatrix} \textit{\_chase\_v\_1}\langle 4{:}10\rangle & \\ \text{LBL} & h1 \\ \text{ARG0} & e2 \\ \text{ARG1} & x3 \\ \text{ARG2} & x8 \end{bmatrix}, \begin{bmatrix} \textit{thing}\langle 11{:}15\rangle & \\ \text{LBL} & h9 \\ \text{ARG0} & x8 \end{bmatrix}, \begin{bmatrix} \textit{which\_q}\langle 11{:}15\rangle & \\ \text{LBL} & h10 \\ \text{ARG0} & x8 \\ \text{RSTR} & h11 \\ \text{BODY} & h12 \end{bmatrix} \right\rangle \\ \text{HCONS} & \left\langle \begin{bmatrix} \textit{qeq} & \\ \text{HARG} & h11 \\ \text{LARG} & h9 \end{bmatrix}, \begin{bmatrix} \textit{qeq} & \\ \text{HARG} & h0 \\ \text{LARG} & h1 \end{bmatrix}, \begin{bmatrix} \textit{qeq} & \\ \text{HARG} & h6 \\ \text{LARG} & h4 \end{bmatrix} \right\rangle \end{bmatrix}$$

Figure 3.1: MRS representation for the sentence *Who chases what?*. There are no lexical items in the MRS, only semantic relations. E.g. the lexical entry for *who* provides the quantifier which_q and the noun relation person.

3.2.2 Minimal Recursion Semantics

DELPH-IN JRF incorporates the Minimal Recursion Semantics formalism (MRS; Copestake et al., 2005). MRS models semantics that is built compositionally in the process of parsing a sentence consisting of lexical entries and rules which encode certain semantic information such as something to stand in for the inherent lexical semantics of a word (perhaps _life_n_rel for the word *life*); the information structural notions of *focus* and *topic*; quantifier scope, etc. MRS also encodes the predicate-argument structure. Figure 3.1 shows a sample MRS structure for the English sentence (83) obtained from the English Resource Grammar.[12]

(83) Who chases what? [eng]

The MRS is a meta-language for the description of logical forms. More concretely, an MRS structure is a structure which contains a **bag of elementary predications**, which is an unordered multi-set[13] of simple semantic structures. In Figure 3.1, the main event is indexed *e2* and it corresponds to the relation _chase_ v_1 which means this is one of the possible senses of the

[12]Obtained from ERG 2018 release via `http://delph-in.github.io/delphin-viz/demo`. The formatting of the MRSs which I include as figures in this document may differ slightly (in terms of color), depending on which software was used to obtain them.

[13]A multi-set is a set which allows for multiple instances of each of its elements. The difference with lists is that lists are ordered while in multi-sets, the order does not matter.

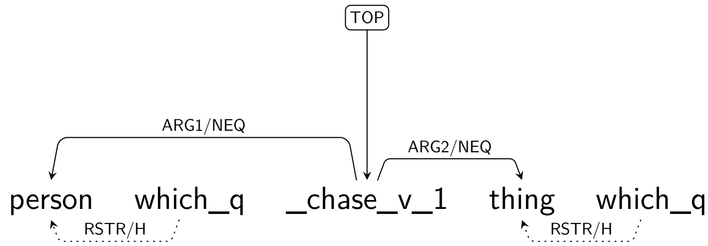


Figure 3.2: A dependency graph for the English sentence (83).

verb *chase*. This event predication has four components: the LBL, (the label, needed to construct a scope tree), the ARG0 (the intrinsic argument), the ARG1 (depending on the predicate; e.g. the agent), and the ARG2 (depending on the predicate; e.g. the theme). The LBL works as a linking property; the verb's LBL is linked to the TOP of the graph (see the qeq relation in the HCONS set; this means the two labels are "equal modulo quantifier", which is to say they are identified unless a quantifier intervenes). The verb's agent is linked via its index *x3* to the person relation which in turn is linked via its LBL to the which_q quantifier's RSTR (**restriction**). The verb's patient is linked via its index *x8* to the 'thing' relation which also has a quantifier. Such representations allow fully scoped forms to be computed by monotonically building this scope-underspecified form, and it can be converted straightforwardly into a **dependency graph**, as illustrated in Figure 3.2 (Oepen and Lønning, 2006; Copestake, 2009).[14]

Interim summary

This concludes my brief overview of the formalisms which are most relevant to understand my work. The Grammar Matrix (§3.4), which this dissertation is a direct contribution to, is a DELPH-IN project. Other highly relevant projects include the LKB grammar engineering environment (Copestake, 2002) and the [incr tsdb()] regression testing system and database (Oepen, 1999). A newer set of DELPH-IN tools include the ACE parser (Crysmann and Packard, 2012) and PyDelphin tools for visualization and testing.[15] In the course of working on this dissertation,

[14]Obtained from ERG 2018 release via `http://delph-in.github.io/delphin-viz/demo`.

[15]`https://github.com/delph-in/PyDelphin`

I was using all of them for grammar exploration and evaluation, so I present them in the next section (§3.3).

3.3 DELPH-IN toolkit

3.3.1 LKB and LKB-FOS

The LKB system (Copestake, 2002) is a grammar engineering environment which includes a DELPH-IN JRF compiler paired with parsing and generation algorithms as well as grammar exploration tools. It can load a grammar written in DELPH-IN JRF and then use this grammar to parse and generate sentences. The output to a grammatical sentence input is a syntactic and a semantic structure (or a set of such structures, if there is ambiguity in the sentence according to the grammar). LKB-FOS[16] is an open-source version of LKB developed by John Carroll. Figures 3.3 and 3.5 illustrate an English grammar being loaded into the LKB-FOS and then providing a syntactic and a semantic structure for the sentence *The cat sleeps*. Figure 3.4 shows an abbreviated structure (AVM) for the top S node in the tree.

3.3.2 [incr tsdb()]

The [incr tsdb()] (Oepen, 1999) regression testing system and database is a system which interacts with the LKB and which can store test *profiles* which include test suites of grammatical and ungrammatical sentences along with the results of processing them with a particular version of the grammar, which [incr tsdb()] allows the user to query in a variety of ways. This system is invaluable for grammar comparison as it shows which sentences in the test suite two grammars differ with respect to, while the interaction with the LKB allows the developer to load one of the grammars and see what it is doing for that particular sentence. This makes it easier to assess analyses and find and fix issues. Figure 3.6 is a screenshot of the system.

[16] `http://moin.delph-in.net/wiki/LkbFos`

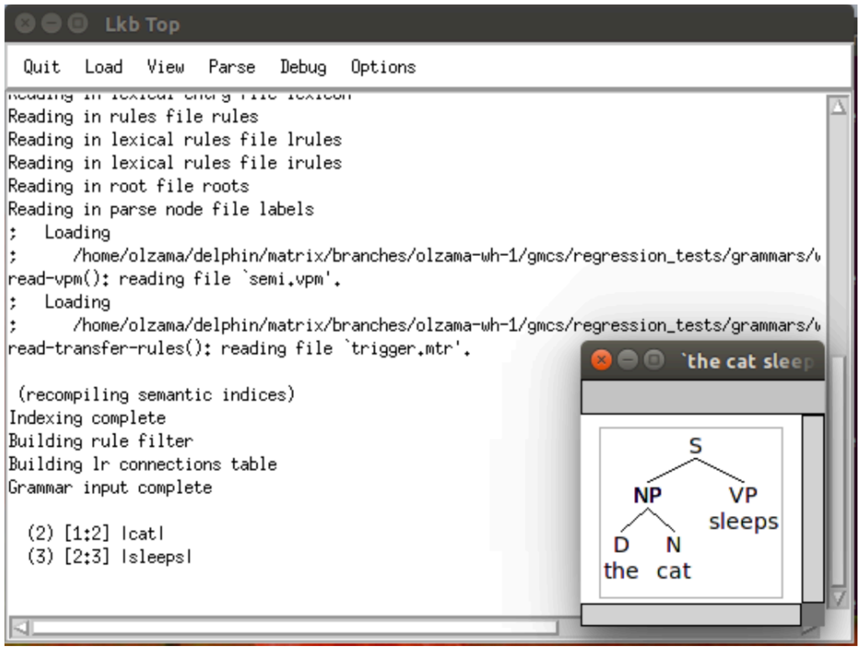


Figure 3.3: A grammar for English is loaded into the LKB system. The sentence The cat sleeps is parsed.

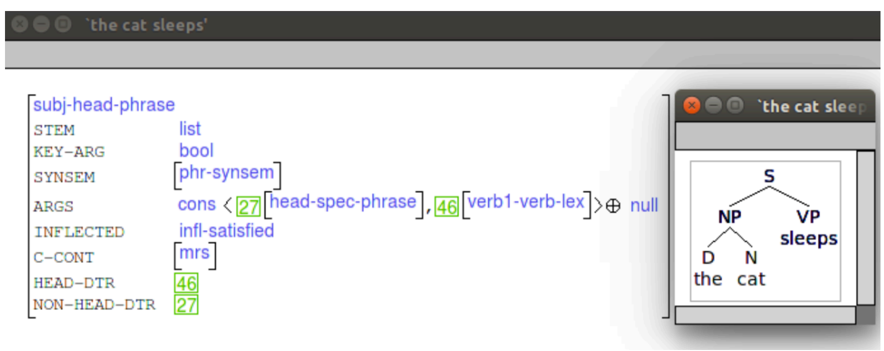


Figure 3.4: The (collapsed) feature structure corresponding to the sentence *The cat sleeps*, according to the grammar.

[17]http://sweaglesw.org/linguistics/ace/

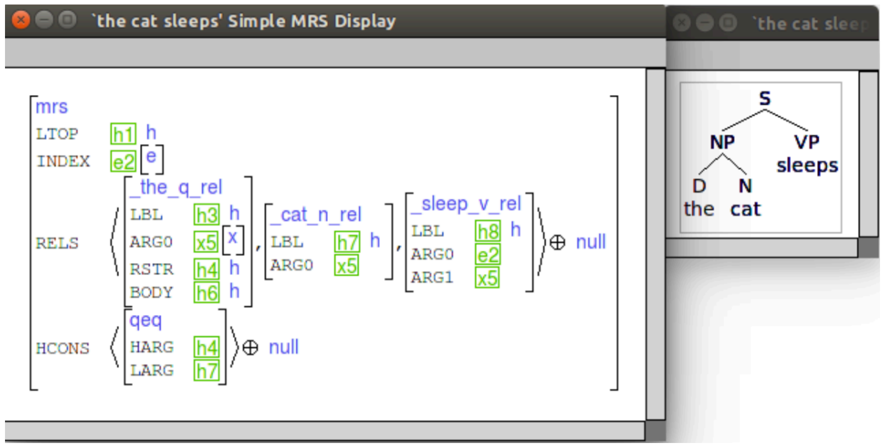


Figure 3.5: The Minimal Recursion Semantics structure corresponding to the sentence *The cat sleeps*, according to the grammar.

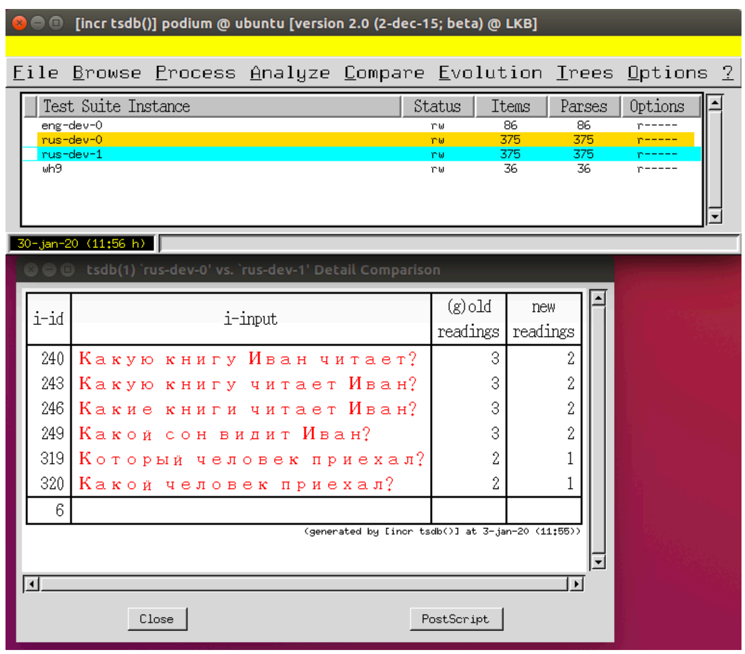


Figure 3.6: The [incr tsdb()] system shows the 6 differences between two Russian grammars on the same test suite containing 375 sentences total.

3.3.3 ACE

ACE (Crysmann and Packard, 2012)[17] is a DELPH-IN JRF parser/generator that is relatively fast and has a command line interface. I used the parser as part of the Grammar Matrix regression testing system (§5.9).

3.3.4 PyDelphin

PyDelphin[18] is a set of tools for DELPH-IN-based technology and research. It includes utilities for MRS comparison and I used it as part of the Grammar Matrix regression testing system (§5.9). Some of the examples in this dissertation, for example Figure 3.2, were obtained using PyDelphin.

3.4 The Grammar Matrix

The Grammar Matrix (Bender et al., 2002, 2010b) is a DELPH-IN-based meta-grammar engineering project that includes a web questionnaire, a core HPSG grammar, and a grammar customization system programmed in python. This means that the user fills out a **questionnaire** with typological, lexical, and morphological information, and, based on the particular combination of such choices, the system applies a **customization logic** to output an implemented grammar fragment encoded in DELPH-IN JRF and MRS formalisms (§3.2).

As a simple example, consider one of the earliest additions to the Grammar Matrix, namely the word order support added by Bender and Flickinger (2005). Taking just the part of the grammar specification having to do with the order of subject and verb, the user first makes an appropriate choice in the web questionnaire, let us say SVO (which implies SV) (Figure 3.7). The next step is that the back-end code maps this choice to a machine-readable specification, as shown in (84):

(84)
```
section=word-order
word-order=svo
```

Finally, the customization system will add a head-final head subject rule executing the customization logic implemented as python code:

(85)
```
if wo in ['osv', 'sov', 'svo', 'v-final']:
    hs = 'subj-head'
    mylang.add(hs + '-phrase := decl-head-subj-phrase & head-final.')
```

[18] `https://github.com/delph-in/PyDelphin`

Please indicate which pattern best describes the basic word order of your language in matrix (main) clauses:

- ○ SOV
- ◉ SVO
- ○ VSO
- ○ OSV
- ○ OVS
- ○ VOS
- ○ V-final
- ○ V-initial
- ○ free (pragmatically determined word order)
- ○ finite verb or auxiliary in second position, else free word order
- ○ finite verb second, non-finite verb clause-finally

Figure 3.7: A portion of the Grammar Matrix word order questionnaire

The basic type for the head-subject rule as well as the head-final type come from the Grammar Matrix **core**.[19] The core types are structures which are assumed to be cross-linguistically applicable and worth including in all grammars. The Grammar Matrix system already contains core types for many general grammatical notions in HPSG (in DELPH-IN flavor) such as head-subject, head-complement, and head-adjunct rules, various basic lexical types, types for encoding semantic relations, and so on. In this case, to declare the customized HSR, the system states that the customized type is a type that inherits from two core supertypes, namely *decl-head-subj-phrase* and *head-final*. It furthermore states that the complements of the head daughter should already be realized by the time this rule applies (86); this last constraint is needed to avoid spurious ambiguity which would arise in the analysis of transitive clauses if this *subj-head-phrase* attached both below and above the head-complement rule. As is, it must attach above it.

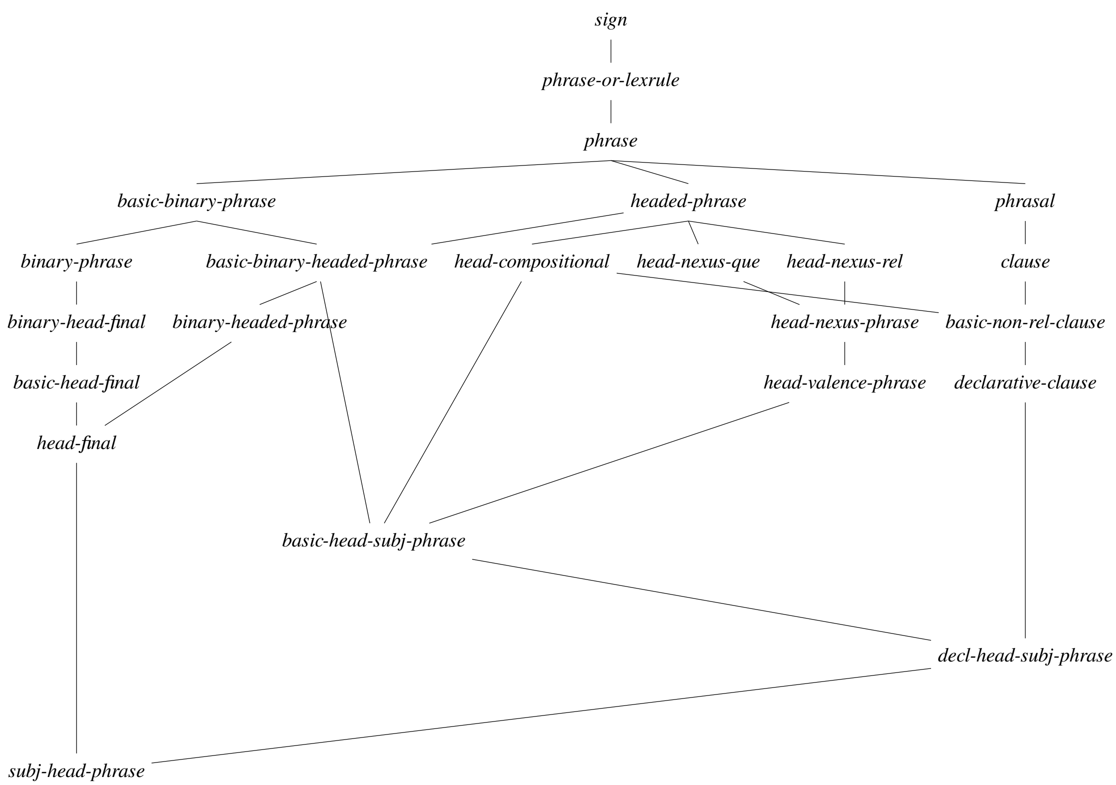
(86)
```
subj-head-phrase := decl-head-subj-phrase & head-final &
   [ HEAD-DTR.SYNSEM.LOCAL.CAT.VAL.COMPS < > ].
```

The core types were originally 'distilled' from the English Resource Grammar (Flickinger, 2000), as part of Bender et al. 2002. The type hierarchy is large and features multiple inheritance. Only few types are intended as rules for actual licensing of strings in the grammar though, and

[19]Not intended as the same as Chomsky's core vs. periphery (Chomsky, 1995).

most of them will not be core but rather some customized version of a core type. For example, (87) shows part of the hierarchy with all the parents of *subj-head-phrase* with their parents. The *subj-head-phrase* is not core but only *subj-head-phrase* will be licensing strings in a grammar. Its parents are all core types which contribute various constraints These types, in various combinations, serve as parents for many customized types.[20]

(87)



This means that the type for *subj-head-phrase* will include constraints declared in all of the types in the graph. While such a type hierarchy may not be easy to read, it streamlines the statement of constraints. Ideally, any given constraint is stated in only one place, so that if it needs changing, it doesn't have to be tracked down throughout the grammar. The hierarchy allows for easy grammar customization stating that a set of constraints is to be inherited from existing supertypes, and so only the new constraints must be stipulated on the subtype. Most of the types presented in (87) are part of the syntactico-semantic machinery which is necessary for the grammar to work. For

[20]These are just the type names; each type has a feature structure that can be found in the Matrix core which is the `matrix.tdl` file. The parent-child direction is top-down.

example, exactly two daughters are in the rule (*binary-phrase*), there is a head in the phrase (*headed-phrase*), etc. Ultimately it is a *sign*, as all phrase structure rules are in HPSG.

The customization system is a set of python files separate from the core `matrix.tdl` file.[21] The code features a large number of literals which represent lexical and phrasal types in the DELPH-IN formalism. There are also python classes which are designed to store such literals and are capable of correctly editing them, given a path. For example, assuming a type called *comp-head-phrase* already exists in the grammar in the following form:[22]

(88)
```
comp-head-phrase := basic-head-1st-comp-phrase & head-final-head-nexus &
[ NON-HEAD-DTR.SYNSEM.LOCAL.CAT.HEAD noun ].
```

then the python code below will not overwrite the type but instead will correctly add the feature EXTRA with value + to its non-head daughter's HEAD:

(89)
```
mylang.add('head-comp-phrase
     := [ NON-HEAD-DTR.SYNSEM.LOCAL.CAT.HEAD.EXTRA + ].',
```

resulting in the following definition in the output file:

(90)
```
comp-head-phrase := basic-head-1st-comp-phrase & head-final-head-nexus &
[ NON-HEAD-DTR.SYNSEM.LOCAL.CAT.HEAD noun & [ EXTRA + ] ].
```

The Grammar Matrix currently has the following libraries: Word Order (Bender and Flickinger, 2005); Matrix Yes/No Questions (Bender and Flickinger, 2005); Coordination (Drellishak and Bender, 2005); Person, Number, Gender (Drellishak, 2009b); Agreement (Drellishak, 2009b); Case and Direct-Inverse (Drellishak, 2009b); Argument Optionality (Saleem, 2010); Morphotactics (O'Hara, 2008; Goodman and Bender, 2010); Tense and Aspect (Poulson, 2011b); Sentential Negation (Crowgey, 2013); Information Structure (Song, 2014); Lexicon (Bender and Flickinger, 2005; Trimble, 2014); Evidentials (Haeger, 2017); Nominalized Clauses (Howell et al., 2018); Clausal Modifiers (Howell and Zamaraeva, 2018); Valence Change (Curtis, 2018); Adnominal Possession (Nielsen, 2018); Clausal Complements (Zamaraeva et al., 2019). The earlier ones,

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[21] Matrix developers tend to avoid the term *module* familiar to programmers, because the nature of Matrix libraries is such that they depend on each other and interact, and therefore are not really modular (Bender et al., 2010b).

[22] This particular definition is just an example; a head complement rule need not look like this necessarily.

particularly the ones associated with Bender and Flickinger 2005, were meant as a scaffolding and were not necessarily based on typological surveys as described in Chapter 5.

My contribution described in the next chapters is adding a library to the Grammar Matrix. This means adding a new web page to the questionnaire, revising the core, and adding customization logic, all such that grammars which automatically come out of the system can parse sentences with constituent questions.

3.5 Summary

This concludes the technical background on the framework that I was using for my dissertation. I gave a brief tutorial on the HPSG theory of syntax; introduced the DELPH-IN JRF version of HPSG which I and my colleagues use for analysis and grammar engineering; and presented the Grammar Matrix, a grammar customization system of which my work is a part. The next chapter summarizes theoretical syntactic accounts of constituent questions, focusing in particular on the concepts which are most relevant to my analysis, and then reviews the relevant grammar engineering work.

Chapter 4

PREVIOUS HPSG ACCOUNTS OF CONSTITUENT QUESTIONS

This chapter is dedicated to (i) the existing theoretical HPSG analyses of constituent questions (§4.1); and (ii) to the existing implemented analyses on which I built my analysis of constituent questions presented in Chapter 6 (§4.2). In terms of theoretical analyses, the chapter focuses mostly on long-distance dependencies. While the typology of constituent questions also includes morphological marking and particles, the fact that question words can cross the clause boundary is undoubtedly the one that has attracted the most attention from syntacticians across frameworks. It also appears to be the fact which is the most challenging to formally model.

4.1 Theoretical HPSG accounts

Perhaps one of the most influential theoretical syntactic works for constituent questions, which long predates HPSG, is Ross 1967, where he discusses various apparent constraints on LDDs in English and at the same time develops Chomsky's (1957) concept of **movement** as it applies to English constituent questions, in detail. The data around which Ross (1967) had organized his discussion still serves as scaffolding to many constituent question analyses today, including some cross-linguistic ones. In the Minimalist Program (Chomsky, 1995), the concept of movement has remained crucial and influenced other theories of syntax including HPSG (in the sense that the inventors of constraint-based formalisms really wanted to have a theory *without* movement). The main idea of movement is that (i) some parts of a structure which are normally expected to appear in one place are missing from there; (ii) they appear in a different position instead; and (iii) there is still a way to trace them back to their usual position.

In HPSG, which is the framework adopted in my dissertation, movement does not play a role in analyses; there is only one structure per item, directly linked to the surface form. However the effect of certain operations is similar to that of movement in the sense that in the end there is structure-sharing between parts of the sentence. Where movement basically assumes that a constituent actually started out in some position and then moved to a different position, the HPSG analysis says that the same structure in the graph is reachable by more than one path.[1] Another crucial point is that in HPSG, phonologically empty trace elements can be completely eliminated on the lexical level (Pollard and Sag, 1994, p.379); instead, a feature structure for the element whose arguments are "missing" directly encodes that information.

4.1.1 Pollard and Sag (1994): An HPSG analysis of LDDs

Pollard and Sag (1994) adapted Gazdar's (1981) analysis of long-distance dependencies to HPSG. At the core of this analysis, there are three concepts: (i) nonlocal features; (ii) the Nonlocal Feature Principle (NFP); and (iii) the filler-gap construction, aka the head-filler schema. These three concepts can be mapped to three tiers of the analysis: (i) introducing the dependency (the "bottom" tier; nonlocal features); (ii) propagating the dependency ("middle"; the NFP); and (iii) filling the dependency ("top"; filler-gap).

Consider as a "teaser" the tree in example (92). Note how the SLASH value on *said* is not empty and furthermore it is identified with the local features of the subject of *are here*. The LDD has been introduced (I have not yet explained how). Now note that the nonempty value of SLASH is propagated up the tree from the daughters to the mother, up until the top V" node. At the top V" node, the dependency is discharged and the SLASH is empty.

(91) I forgot [which guests you said are here]. [eng] (Pollard and Sag, 1994, p.173)

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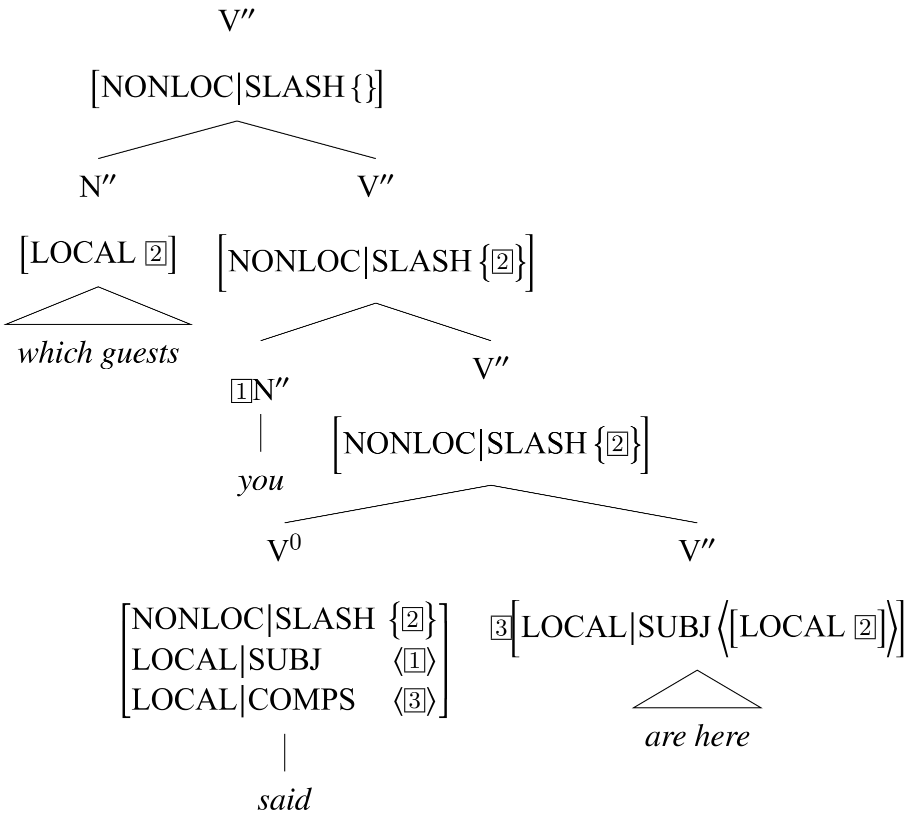
[1] Cf. "vertical sharing" in a movement-based account by Gračanin-Yuksek (2007).

(92)



Below I explain how the entire analysis works in Pollard and Sag 1994. Conceptually, this analysis is similar to what I later present in Chapter 6 as part of a cross-linguistic account of constituent questions, though there are differences which will be discussed in §4.2.1 and later in Chapter 6.

First, the NONLOCAL features. While LOCAL features comprise category (CAT) and content (CONT), essentially encoding the syntactic and semantic properties of the structure, and correspond somewhat to D-structure and LF in the Government and Binding theory,[2] NONLOCAL features' purpose is specifically an analysis of long-distance dependencies in the context of a lexicalist, constraint unification-based, and surface oriented theory. In a way, the HPSG's NONLOCAL features are a way to encode nonlocal dependencies locally (in HPSG every node has its own NONLOCAL substructure). This is motivated in Pollard and Sag 1994, p.163 primarily by the

[2] In HPSG, certain attributes of language *signs* typically have rough analogs in the Government and Binding theory, in the form in which it was in the early 1990s, e.g. as presented in Chomsky 1993. For example, the attributes PHON (phonology) and DTRS (daughters) correspond roughly to S-structure, while CAT (category) is roughly analogous to D-structure and CONT (content) to LF (logical form) (Pollard and Sag, 1994).

goal of avoiding the very notion of transformations (focusing instead on the notion of structure sharing). Later, it was further motivated by Bouma et al. (2001a) who suggested propagating nonlocal features from daugher to mother at every level of derivation is necessary to account for data from languages where long-distance dependencies are registered morphologically "along the extraction path" (see §4.1.2).

NONLOCAL features are set-valued.[3] Pollard and Sag (1994) posit three nonlocal features: SLASH, REL, and QUE. SLASH is used for all constituents which do not appear in their usual place, while REL and QUE are used specifically for relative clauses and constituent questions.[4] REL and QUE characterize what types of constituents can occur in the initial position in relative clauses and *wh*-questions, respectively.[5] Pollard and Sag (1994) give an analysis of topicalization, relying on SLASH, and an analysis of relative constructions, relying on SLASH and REL (and on the Nonlocal Feature Principle, and on the head-filler schema, as explained below). They do not provide an analysis of constituent questions beyond suggesting that the feature QUE will work similarly for constituent questions to how REL works for relative clauses. Most signs in the lexicon have empty nonlocal sets. Relative and interrogative pronouns have nonempty REL and QUE sets, respectively, and nonempty SLASH sets arise via **extraction** lexical rules. Such rules take terminal nodes as daughters and change the values of their valence as well as nonlocal lists. For example, a verb which was "looking for its complement" (had a nonempty COMPS list), upon undergoing a complement extraction rule, will have an empty COMPS list but a nonempty SLASH list, which will furthermore contain all the necessary information about the complement that is now "missing" from its usual place. As for subjects, Pollard and Sag (1994) assume that a subject extraction rule

[3] In DELPH-IN HPSG, these features are list-valued, as explained later in §3.2.1.

[4] Ginzburg and Sag (2000) (§4.1.3) later renamed QUE WH, to avoid ambiguity between polar and constituent questions.

[5] The distinction between REL and QUE is motivated in particular by the distributional differences with respect to 'pied-piping', e.g. as illustrated in (i).

(i) a. This is the farmer pictures of whom appeared in *Newsweek*.
    b. *Picture of whom appeared in *Newsweek*? [eng] (Pollard and Sag, 1994)

is only needed in complex sentences in English,[6] and because of that, somewhat counterintuitively, they posit a subject extraction lexical rule which applies to the clause-embedding verb rather than the verb which actually has its subject extracted. For example, in (92), the nonempty SLASH value is introduced by (93).[7]

(93)
$$\begin{bmatrix} \text{DTR} & \begin{bmatrix} \text{SUBJ} & \langle\ \text{Y}'' \rangle \\ \text{COMPS} & \left\langle \ldots, [\text{SUBJ}\ \ \langle\ \rangle], \ldots \right\rangle \end{bmatrix} \\ \text{SYNSEM} & \begin{bmatrix} \text{COMPS} & \left\langle \ldots, \left[\text{SUBJ}\ \left\langle [\text{LOCAL}\ \ \boxed{1}] \right\rangle\right], \ldots \right\rangle \\ \text{INHERITED}|\text{SLASH} & \{\boxed{1}\} \end{bmatrix} \end{bmatrix}$$

Conceptually, the point of the subject extraction rule is that it identifies the local substructure of a subject with an element in a SLASH set, thus giving rise to a LDD (because, as discussed below, whatever is in the SLASH set will be propagated in the derivation tree until it is realized in a head-filler construction). In terms of details though, the rule can take different forms, and Pollard and Sag's (1994) version of the rule is not exactly the same as the one that is in the ERG (see §4.2.1). The subject extraction rule from Pollard and Sag 1994, p.383, a simplified version of which is presented here as (93), is at play in licensing the *said* V^0 node. It is a lexical rule; previously (§3.1) we saw lexical rules taking a lexical entry with underspecified NUM feature as the daughter resulting in the mother structure where the value for NUM is specified to *sg* or *pl*, depending on the affix associated with the surface string. The subject extraction lexical rule takes as input a structure headed by a verb whose clausal complement has a nonempty SUBJ list and outputs a structure with an empty SUBJ list in that position but with the local information about the subject added to the SLASH list. In other words, the rule produces a structure which can syntactically be treated as if the clausal complement's subject was already attached but at the same time retains the information that it actually has not attached yet. Note once again how the

[6]Pollard and Sag (1994) do not actually include a section on constituent questions in their book, but they assume that simple questions like *Who left?* are licensed by the head-subject rule, just like declarative sentences. They do not discuss any details of that at all though. Later work (e.g. Ginzburg and Sag 2000) departs from that analysis.

[7]The format of the rule is adapted to clearly indicate what is the input (DTR) and what is the output (SYNSEM) of the lexical rule. Note also that the feature QUE is not present in this example; this is just because the focus of the example is on the SLASH dependency (as mentioned previously, Pollard and Sag (1994) do not provide examples

rule is concerned with the clausal complement-taking verb's SLASH, not the embedded verb's. This part will be different in the ERG (§4.2.1).

The Nonlocal Feature Principle (94) states:

(94) The value of each nonlocal feature on a phrasal sign is the union of the values on the daughters. (Pollard and Sag, 1994, p.162)

Note how in (92), assuming $\boxed{2}$ is the only nonlocal dependency (as in, all terminal nodes' SLASH sets in the tree either contain $\boxed{2}$ or are empty), all mother nodes' SLASH sets except for the very top one are indeed the union of the daughters'. In this case, this means they all must contain just $\boxed{2}$.

Finally the "top" is where the dependency is realized. For the SLASH dependencies, this is the filler-gap phrase structure rule, aka the head-filler schema. The filler-gap rule licenses a mother node whose daughters match the description of a "gappy" constituent (a constituent with a nonempty SLASH value) and a "filler" whose local features match this SLASH value. Pollard and Sag's (1994) head-filler schema is presented in (95).[8]

(95) X" → Y"[LOCAL $\boxed{1}$] V"[SLASH {$\boxed{1}$,...}]

This rule is what licenses the very top node in (92). Note how the left daughter's LOCAL features match what is oh the head daughter's (right) SLASH.

This section has described the basics of the HPSG LDD analysis, relying on the nonlocal SLASH feature which represents the dependency starting at the lexical level, a mechanism propagating nonlocal features in the derivation, and the filler-gap rule which ultimately realizes the dependency. As mentioned, example (92) does not illustrate the use of the feature QUE suggested by Pollard and Sag (1994) specifically for constituent questions but not exemplified in their work. The use of the feature QUE will be explained in the section dedicated to Ginzburg and

with QUE). The full analysis would use this feature, and I will give such an example later in §4.1.3 (114).

[8] An AVM representation of the Grammar Matrix filler-gap rule follows in (419).

Sag 2000 (§4.1.3), a detailed analysis of English interrogatives in HPSG.[9] That analysis relies on some concepts from another work, by Bouma et al. (2001a),[10] which I summarize in the next section.

4.1.2 A unified theory of complement, subject, and adjunct extraction (Bouma et al., 2001a)

Bouma et al. 2001a is an influential work in HPSG which suggested a number of mechanisms for LDD analysis aimed to improve the analysis in Pollard and Sag 1994. They address some of the criticisms offered by Hukari and Levine (1996) in their review of Pollard and Sag 1994, in particular the need for several extraction rules.[11] Bouma et al.'s (2001a) analysis features no valence reducing lexical rules at all.[12] Ginzburg and Sag (2000) base their analysis of English interrogatives on Bouma et al. 2001a; the ERG and subsequently the Grammar Matrix use a combination of analyses from Pollard and Sag 1994 and Ginzburg and Sag 2000, and in particular, while the ERG does use some of the mechanisms adopted by Ginzburg and Sag (2000) from Bouma et al. 2001a, the ERG still uses separate subject, object, and adjunct extraction rules, following Pollard and Sag 1994 in this respect.

Here, I review the aspects of Bouma et al. 2001a which are included in Ginzburg and Sag's (2000) analysis of interrogatives, although not all of them made their way into the ERG and subsequently the Grammar Matrix analyses. In particular, the Argument Realization Principle is important for understanding Ginzburg and Sag's (2000) analysis but it was not implemented in the ERG because of its nondeterministic aspects, which is the reason why the ERG still uses extraction rules. On the other hand, both Ginzburg and Sag 2000 and the ERG use the mechanism which Bouma et al. (2001a) call "SLASH amalgamation" and Ginzburg and Sag (2000) NONLOCAL

[9] QUE is called WH in Ginzburg and Sag 2000, though I will be calling it QUE because this is the term already adopted in the Grammar Matrix.

[10] Ginzburg and Sag 2000 relies on Bouma et al. 2001a despite the order of the publication dates.

[11] In addition to the subject extraction rule, the complete analysis by Pollard and Sag (1994) includes also the object extraction rule and the adjunct extraction rule.

[12] This is not to say that such rules could not be posited where necessary, especially where there is overt valence-changing morphology; Bouma et al. (2001a) suggest no such rules are needed for English LDDs.

amalgamation, but which is referred to in the DELPH-IN community and later in this dissertation as "lexical threading".[13]

Bouma et al. (2001a) further motivate and simplify the GPSG (Gazdar, 1981) and HPSG (Pollard and Sag, 1994) "middle" tier of the LDD analysis. At the core of the classic analysis of that tier is the observation that (i) the information about the long-distance dependency is encoded locally throughout the derivation path (the "middle" part of the LDD mechanism needs access to the local features of the extracted element at every step); and that (ii) extraction is furthermore registered lexically as selection for a "slashed" argument. Building on the critique of Pollard and Sag 1994 by Hukari and Levine (1996), Bouma et al. (2001a) further motivate the need to register nonlocal information at every step of the derivation by data from languages like Chamorro ([cha], Austronesian), in which verbs exhibit agreement with extracted arguments (96)–(97).

(96) Hayi f-um-a'gasi i kareta
who WH.SU-wash the car
'Who washed the car?' [cha] (Bouma et al., 2001a, p.4)

(97) Hayi si Juan ha-sangan-i hao [f-um-a'gasi i kareta]
who UNM Juan E3S-say-DAT you WH.SU-wash the car
'Who did Juan tell you washed the car?' [cha] (Bouma et al., 2001a, p.5)

Following Chung (1982, 1994), Bouma et al. (2001a) analyze the verb morphology in Chamorro as registering agreement with arguments that contain extracted elements, uniformly in main (96) and embedded (97) clauses. They note that in such a case, the subject extraction rule from Pollard and Sag 1994 (93) is not desirable; instead, it is possible and preferable to analyze all *wh*-subjects as extracted. Furthermore, they note that there is more uniformity in how subjects, objects, and adjuncts are extracted than is encoded in Pollard and Sag's (1994) analyses with separate extraction rules. They provide an analysis of subject, complement, and adjunct extraction without lexical rules, relying on the type *gap*, the Argument Realization Principle, and the SLASH amalgamation constraint. Of these, *gap* and SLASH amalgamation made their way into the analysis of LDD in the ERG (§4.2.1).

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[13]The metaphor is due to nonlocal features being incorporated by heads at the lexical level.

The type *gap* (98) identifies a structure's local feature values with the item in its SLASH set (98).

(98)
$$\begin{bmatrix} \textit{gap-synsem} & \\ \text{LOCAL} & \boxed{1} \\ \text{SLASH} & \left\{\boxed{1}\right\} \end{bmatrix}$$

Then, in combination with the above definition for *gap-synsem*, the Argument Realization Principle (100),[14] ensures that complements may appear either in COMPS or in SLASH, and that complements of type *gap* can only appear in SLASH.

(100)
$$\begin{bmatrix} \textit{word} & \\ \text{SUBJ} & \boxed{1} \\ \text{COMPS} & \boxed{2} \ominus \textit{list(gap-synsem)} \\ \text{DEPS} & \boxed{1} \oplus \boxed{2} \end{bmatrix}$$

(101)
$$\begin{bmatrix} \textit{word} & \\ \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{DEPS} & \left\langle \begin{bmatrix}\text{SLASH} & \boxed{1}\end{bmatrix}, \ldots, \begin{bmatrix}\text{SLASH} & \boxed{n}\end{bmatrix} \right\rangle \\ \text{BIND} & \boxed{0} \end{bmatrix} \end{bmatrix} \\ \text{SLASH} & \left(\boxed{1} \cup \ldots \cup \boxed{n}\right) - \boxed{0} \end{bmatrix}$$

Finally, the SLASH amalgamation principle (101) constrains a word's SLASH to be the union of its arguments' SLASHes,[15] which then allows phrases to inherit the SLASH value of the head daughter lexically, instead of directly gathering all the SLASH values of all involved elements in phrase structure rules. Consider the lexical entry for the verb *hates* from Bouma et al. 2001a (102):

---

[14] Bouma et al. (2001a) use the feature DEPS which is an important part of their unified analysis of arguments and adjuncts but it is not part of the Grammar Matrix and discussing its purpose would be orthogonal to the topic of this section. Here is a version of the ARP which does not contain DEPS, from Sag et al. 2003.

(99)
$$\begin{bmatrix} \textit{word} & \\ \text{SYNSEM} & \begin{bmatrix} \text{SPR} & \boxed{A} \\ \text{COMPS} & \boxed{B} \ominus \boxed{C} \\ \text{SLASH} & \boxed{C} \end{bmatrix} \\ \text{ARG-ST} & \boxed{A} \oplus \boxed{B} \end{bmatrix}$$

[15] The BIND feature will have nonempty values in e.g. *easy* adjectives.

$$(102)\quad \left[\begin{array}{ll} \textit{hates} & \\ \text{SUBJ} & \langle \textit{synsem} \rangle \\ \text{DEPS} & \left\langle \left[\begin{array}{ll}\text{LOCAL} & \text{NP}\\ \text{SLASH} & \boxed{1}\end{array}\right], \left[\begin{array}{ll}\text{LOCAL} & \text{NP}\\ \text{SLASH} & \boxed{2}\end{array}\right] \right\rangle \\ \text{SLASH} & \boxed{1} \cup \boxed{2} \end{array}\right]$$

This lexical entry can satisfy the ARP either as shown in (103) or as shown in (104).

$$(103)\quad \left[\begin{array}{ll} \textit{hates} & \\ \text{SUBJ} & \left\langle \boxed{3}\left[\begin{array}{ll}\text{LOCAL} & \text{NP}\\ \text{SLASH} & \boxed{1}\end{array}\right] \right\rangle \\ \text{COMPS} & \left\langle \boxed{4}\left[\begin{array}{ll}\text{LOCAL} & \text{NP}\\ \text{SLASH} & \boxed{2}\end{array}\right] \right\rangle \\ \text{DEPS} & \langle \boxed{3}, \boxed{4} \rangle \\ \text{SLASH} & \boxed{1} \cup \boxed{2} \end{array}\right]$$

$$(104)\quad \left[\begin{array}{ll} \textit{hates} & \\ \text{SUBJ} & \left\langle \boxed{3}\left[\begin{array}{ll}\text{LOCAL} & \text{NP}\\ \text{SLASH} & \boxed{1}\end{array}\right] \right\rangle \\ \text{COMPS} & \langle\ \rangle \\ \text{DEPS} & \left\langle \boxed{3}, \left[\begin{array}{ll}\textit{gap-synsem} & \\ \text{LOCAL} & \boxed{2}\\ \text{SLASH} & \left\{\boxed{2}\right\}\end{array}\right] \right\rangle \\ \text{SLASH} & \boxed{1} \cup \left\{\boxed{2}\text{NP}\right\} \end{array}\right]$$

The structure in (103) will be part of the analysis for (105) while the structure in (104) will be part of the analysis of (106).

(105) She hates this school. [eng]

(106) Which school does Kim think she hates? [eng] (Bouma et al., 2001a)

Moreover, there may be lexical entries which stipulate their arguments as gaps, such as one of the usages of the English *assure* (107).

(107) a. This candidate, they assured me to be reliable. [eng] (Bouma et al., 2001a)

b. *They assured me this candidate to be reliable. [eng] (Bouma et al., 2001a)

I will not review in detail how the three elements — the type *gap*, the ARP, and the SLASH amalgamation — play out in the lexical rule-free argument-adjunct unified analysis of LDDs suggested by Bouma et al. (2001a). What is relevant here is these three elements were adopted by Ginzburg and Sag (2000) in their analysis of English interrogatives to which I turn below. The purpose of the next section is mainly to explicate the use of the feature QUE which Pollard and Sag (1994) suggested but which Ginzburg and Sag (2000) developed into a detailed analysis — and on which I rely in my analysis presented in Chapter 6.

4.1.3 Ginzburg and Sag (2000): An analysis of English interrogatives

Ginzburg and Sag 2000 is a comprehensive HPSG account of English interrogatives. It covers various types of English questions including constituent and polar questions; single and multiple; canonical and reprise (echo). Their account of the wide variety of different English interrogatives is very detailed, and while it is a purely theoretical account, Flickinger's (2000) implementation of LDDs in the English Resource Grammar (§4.2.1) and by extension the Grammar Matrix and this dissertation are based on it in several ways.

Feature QUE, semantics, and LDDs

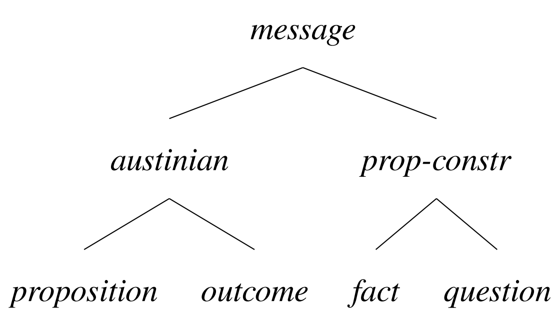
Pollard and Sag (1994) suggested the nonlocal feature QUE for constituent questions but did not give the actual analysis specific to such questions; Ginzburg and Sag (2000) do precisely that. QUE (which they call WH) is a set-valued feature — which now contains semantic parameters. Example (108) shows Ginzburg and Sag's (2000) lexical entry for the interrogative pronoun *who*.

(108)
$$\begin{bmatrix}\text{PHON} & \langle \textit{who} \rangle \\ \text{SYNSEM} & \begin{bmatrix}\text{LOCAL} & \begin{bmatrix}\text{CAT} & \text{NP} \\ \text{CONT} & \begin{bmatrix}\textit{param} & \\ \text{INDEX} & i \\ \text{RESTR} & \{\}\end{bmatrix} \\ \text{STORE} & \left\{ \boxed{1}\begin{bmatrix}\textit{param} & \\ \text{IND} & i \\ \text{RESTR} & \{\textit{person}(i)\}\end{bmatrix} \right\}\end{bmatrix} \\ \text{QUE} & \{(\boxed{1})\} \\ \text{REL} & \{\}\end{bmatrix} \\ \text{ARG-ST} & \langle\rangle\end{bmatrix}$$

Each *wh*-word introduces one parameter. That parameter is identified with the value of the element in the QUE set. This exact semantic formalism with the quantifier STORE is not used in my dissertation so there is no need to explain it in full detail; what is important here is that the index of the entity to which the pronoun is referring is identified with the element in the QUE set, for *wh*-words.

Ginzburg and Sag (2000) posit a semantic type hierarchy which allows them to encode the semantic differences between various kinds of utterances (109).

(109)



In terms of this type hierarchy, the CONTent value of all interrogative clauses is of type *question*. *Question* is in turn a subtype of *message*, another subtype of which is *proposition*. A *question*, exemplified in (111), has a set of parameters as well as another *message* inside it, this time a *proposition*. This is the proposition that is involved in the construction of the question. In addition to the assumptions put forth by Bouma et al. (2001a) presented in the previous section, a set of principles in Ginzburg and Sag's (2000) grammar ensure that (i) the interrogative clause's STORE value and its PARAMS set add up to be the head daughter's STORE; (ii) that the filler daughter has a nonempty QUE set, and the element in that set is included in the clause's semantic content; and (iii) the head daughter of the interrogative clause's CONT is the clause's PROP. This results in the following derivation (110) and the following semantic structure (111) for the English sentence *Who left?*:

(110) S

$$\begin{bmatrix} \text{QUE} & \{\} \\ \text{SLASH} & \{\} \\ \text{STORE} & \{\} \\ \text{CONT} & \begin{bmatrix} \textit{question} & \\ \text{PARAMS} & \{\boxed{3}\} \\ \text{PROP} & \boxed{4} \end{bmatrix} \\ \text{HEAD} & \boxed{0} \end{bmatrix}$$

NP

$$\begin{bmatrix} \text{LOCAL} & \boxed{2}\begin{bmatrix} \text{STORE} & \{\boxed{3}\} \end{bmatrix} \\ \text{QUE} & \{\boxed{3}\} \end{bmatrix}$$

who

S/NP

$$\begin{bmatrix} \text{HEAD} & \boxed{0} \\ \text{SUBJ} & \left\langle \boxed{1}\begin{bmatrix} \textit{gap} & \\ \text{LOCAL} & \boxed{2} \end{bmatrix} \right\rangle \\ \text{SLASH} & \{\boxed{2}\} \\ \text{QUE} & \{\} \\ \text{STORE} & \{\boxed{3}\} \\ \text{CONT} & \boxed{4}\begin{bmatrix} \textit{proposition} & \\ \text{SOA} & \boxed{5} \end{bmatrix} \end{bmatrix}$$

left

(111)
$$\begin{bmatrix} \textit{question} & \\ \text{PARAMS} & \left\{ \begin{bmatrix} \textit{param} \\ \text{INDEX } \boxed{1} \\ \text{RESTR } \{\textit{person}(\boxed{1})\} \end{bmatrix} \right\} \\ \text{PROP} & \begin{bmatrix} \textit{proposition} & \\ \text{SIT} & s \\ \text{SOA} & \begin{bmatrix} \text{QUANTS} & \langle\, \rangle \\ \text{NUCL} & \begin{bmatrix} \textit{leave-rel} \\ \text{LEAVER } \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

The SLASH dependency is introduced here lexically by the mechanism described in Bouma et al. 2001a, and the details of it are not important here as I will not be using this mechanism in Chapter 7. Suffice it to say that there is a SLASH dependency which is propagated in the tree and is realized on top by the filler-gap rule, as in example (92) from §4.1.1. What is new here is the semantics which is built up using the QUE feature. The value of QUE is introduced by the lexical entry for *who*. Note once more the identity between the element in QUE and the quantifier STORE. What this means is the appropriate semantics is encoded and the question word's parameter is now appropriately associated with the question message, due to QUE being a nonlocal feature. In fact, Ginzburg and Sag (2000) generalize Bouma et al.'s (2001a) SLASH amalgamation constraint to all nonlocal features; positing the Nonlocal Amalgamation Constraint (112).

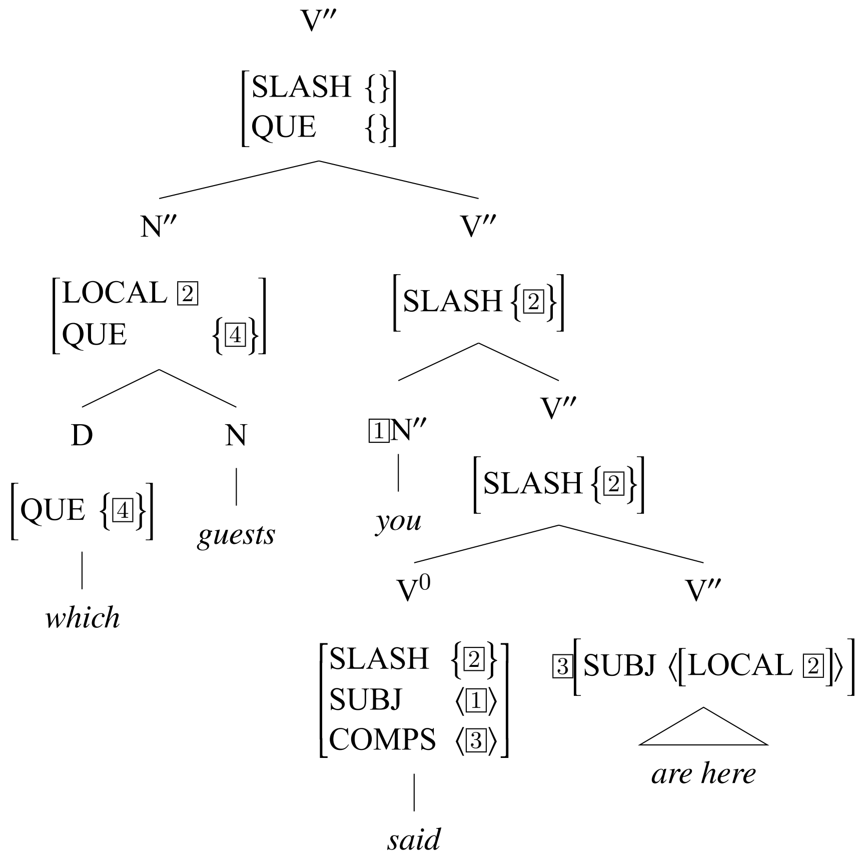
(112) For every nonlocal feature F, the word's value for F is the union of the values of its arguments. (Rephrased from Ginzburg and Sag 2000, p.211.)

The amalgamation of QUE will come to play later in example (114); meanwhile, the referent of *who* ends up encoded both as the argument of the verb *left* and as the question's parameter. The fact that this information is stored separately in the structure means, in particular, that a *wh* word can be a parameter of the matrix question and at the same time belong to the argument structure of the embedded clause (113).

(113) Who do you think left? [eng]

Now consider the analysis for the clausal complement (114) which was presented above as (92) without the QUE feature.

(114)



In addition to the SLASH dependency, this example now shows also the QUE dependency, which is an unbounded dependency between the top of the construction and the bottom of the filler daughter (115). This is the same dependency that Ross (1967) named "pied-piping" (§2.5.3).

(115) I wonder [[[whose cousin's] friend's] dog] ate the pastry. [eng] (Ginzburg and Sag, 2000, p.184)

The Nonlocal Amalgamation Constraint ensures that the QUE value is propagated within the filler daughter, up to the top of the construction where it is discharged by the filler-gap rule.

The top V" in (114) is licensed by a subtype of *interrogative clause* posited especially for fronted English subjects (116) which is also a subtype of the head filler phrase (95).

(116) *subj-int-cl*

$$\begin{bmatrix} \text{SUBJ} & \langle\rangle \\ \text{SLASH} & \{\} \\ \text{QUE} & \{\} \end{bmatrix} \rightarrow \begin{bmatrix} \text{LOCAL} & \boxed{1} \\ \text{QUE} & \textit{neset} \end{bmatrix} \; \mathbf{H}\begin{bmatrix} \text{SUBJ} & \left\langle \begin{bmatrix} \textit{gap} & \\ \text{LOCAL} & \boxed{1} \end{bmatrix} \right\rangle \\ \text{SLASH} & \{\boxed{1}\} \end{bmatrix}$$

It requires that the non-head daughter have a nonempty (*neset*) QUE set. This means only phrases containing a *wh*-word are suitable as filler daughters in this construction. Conversely, something needs to rule out *wh*-phrases as suitable non-head daughters of the subject-head rule, such that it is only the filler-gap rule that licenses sentences like *Who left?* (recall the argument from Bouma et al. (2001a) summarized in §4.1.2 on page 63).

The subject-head rule will not apply in this case because of a specially posited principle called the WH Subject Prohibition, which basically stipulates that the non-head daughter of a subject-head rule is QUE-empty.[16] What is essential for the reader is simply that, in questions about subjects, the *wh*-filler-gap rule should apply at the top tier of an LDD only when *wh*-subjects are present, and conversely, the head-subject rule should not apply in that case.

Note that there are two different semantic structures that Ginzburg and Sag's (2000) analysis assigns to (117).

(117) Who wondered who saw whom? [eng]

This has to do with the fact mentioned above, namely that a *wh*-word's parameter role is encoded separately from their argument structure role. As such, the parameters introduced by the second embedded *wh*-word in (117) (the *whom*) can belong either to the embedded (118)–(119) or to the main question (120)–(121) while in both cases arising from an argument of the embedded verb.[17]

[16] In §6.5.2, I demonstrate some challenges of generalizing this analysis to languages with *wh*-subjects intervening between the object and the verb (like Russian).

[17] The details of the mechanics of why and how exactly the parameters in Ginzburg and Sag 2000 are stored and retrieved are not essential as a background for my dissertation because I do not use this same semantic formalism. What is essential is the general claim that the two semantic interpretations exist and that Ginzburg and Sag's (2000) analysis captures the contrast.

(118)

$$
\begin{bmatrix}
\textit{question} \\
\text{PARAMS} & \left\{ \begin{bmatrix} \text{INDEX} & i \\ \text{RESTR} & \{\textit{person(i)}\} \end{bmatrix} \right\} \\
\text{PROP} & \begin{bmatrix}
\text{SIT} & s \\
\text{SOA} & \begin{bmatrix}
\text{QUANTS} & \langle\rangle \\
\text{NUCL} & \begin{bmatrix}
\textit{wonder-rel} \\
\text{WONDERER} & i \\
\text{Q-ARG} & \begin{bmatrix}
\textit{question} \\
\text{PARAMS} & \left\{ \begin{bmatrix} \text{INDEX} & j \\ \text{RESTR} & \{\textit{person(j)}\} \end{bmatrix}, \begin{bmatrix} \text{INDEX} & k \\ \text{RESTR} & \{\textit{person(k)}\} \end{bmatrix} \right\} \\
\text{PROP} & \begin{bmatrix}
\text{SIT} & t \\
\text{SOA} & \begin{bmatrix}
\text{QUANTS} & \langle\rangle \\
\text{NUCL} & \begin{bmatrix} \textit{see-rel} \\ \text{SEER} & j \\ \text{SEEN} & k \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

(119) Which (one) person wondered about the answer to the question: Who saw whom?

(120)
$$\begin{bmatrix} \textit{question} \\ \text{PARAMS} & \left\{ \begin{bmatrix}\text{INDEX} & i \\ \text{RESTR} & \left\{\textit{person(i)}\right\}\end{bmatrix}, \begin{bmatrix}\text{INDEX} & k \\ \text{RESTR} & \left\{\textit{person(k)}\right\}\end{bmatrix} \right\} \\ \text{PROP} & \begin{bmatrix} \text{SIT} & s \\ \text{SOA} & \begin{bmatrix} \text{QUANTS} & \langle\rangle \\ \text{NUCL} & \begin{bmatrix} \textit{wonder-rel} \\ \text{WONDERER} & i \\ \text{Q-ARG} & \begin{bmatrix} \textit{question} \\ \text{PARAMS} & \left\{\begin{bmatrix}\text{INDEX} & j \\ \text{RESTR} & \left\{\textit{person(j)}\right\}\end{bmatrix}\right\} \\ \text{PROP} & \begin{bmatrix}\text{SIT} & t \\ \text{SOA} & \begin{bmatrix}\text{QUANTS} & \langle\rangle \\ \text{NUCL} & \begin{bmatrix}\textit{see-rel} \\ \text{SEER} & j \\ \text{SEEN} & k\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

(121) Which person wondered who saw Kim? Which (possibly other) person wondered who saw Sandy? Which (possibly other) person wondered who saw Alex? ...

Ginzburg and Sag's (2000) analysis of question semantics had strong influence on how the ERG implements it (§4.2.1) and ultimately on how I implement it for the Grammar Matrix. However, there are differences.[18] The one which has most bearing on my analysis presented in Chapter 7 is that Ginzburg and Sag's (2000) *message* type hierarchy which encodes all the various types of utterances (109), is not used, and neither are the question parameters in the form they are presented in Ginzburg and Sag 2000. *message* types were originally part of the Grammar Matrix and

[18] In general, DELPH-IN JRF uses a different semantic formalism than Ginzburg and Sag (2000), and as such could not be used to directly implement their analysis, but certain analogous concepts and mechanisms can be and were implemented.

other DELPH-IN grammars, but they were eliminated from there due to lack of scalability,[19] and so I do not use it. This means, in particular, that the contrast described above is not captured in my analysis and accounting for it is future work (see also §4.2.1).

In situ questions

Ginzburg and Sag's (2000) analysis of *in situ* question phrases focuses on English questions which are not constituent questions, such as echo questions and the like. *In situ* question phrases which are part of a sentence which is ultimately licensed by the head-filler rule (117) are licensed in Ginzburg and Sag 2000 by head-subject or head-complement rules. Ginzburg and Sag's (2000) analysis posits duplicate lexical entries for *wh*-words, one entry with a nonempty QUE-set, for fronted question phrases, and one with an empty QUE-set, for *in situ* words (p. 250). For example, the first and the second *who* in (117) will have a nonempty QUE set but the third one will have an empty one. That *in situ* question words have empty QUE sets helps Ginzburg and Sag (2000) model, in particular, the fact that certain modifiers can occur only with fronted *wh*-words (122) but not with the *in situ* ones (123).

(122) Who the hell do you think they visited? [eng] (Ginzburg and Sag, 2000, p. 229)

(123) *Who visited who the hell? [eng] (Ginzburg and Sag, 2000, p. 229)

Further details of the analysis are beyond the scope of this dissertation (since I do not cover questions other than constituent), but at a high level, it involves a unary phrase structure rule which turns a head-subject phrase into a question (125)–(126) if the quantifier STORE is nonempty at the point the head-subject phrase applied.[20]

(124) Tracy saw WHO?! [eng] (Ginzburg and Sag, 2000, p.255)

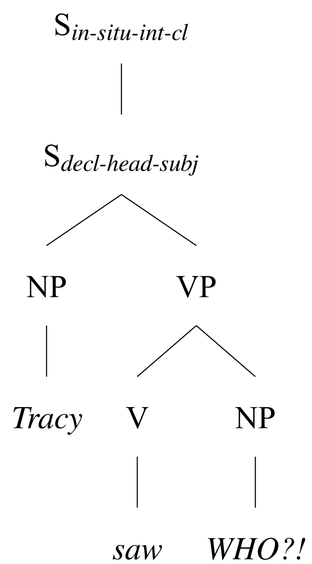
[19] A (very) informal record of the DELPH-IN decision can be found here: `http://moin.delph-in.net/FeforMessageDemise`. Unfortunately it lacks detail but Emily M. Bender (p.c.) recalls that it was not clear exactly which linguistic elements merited their own 'message'. Messages also noticeably cluttered representations. See also `https://delphinqa.ling.washington.edu/t/beware-of-the-slippery-slope-of-messages/209/7`.

[20] The full version of the rule can be found in Ginzburg and Sag 2000, p.282. (125) is an abridged version.

(125) *in-situ-int-cl*

$$\begin{bmatrix}\text{CONT} & \begin{bmatrix}\textit{question} \\ \text{PARAMS } \boxed{2} \text{ PROP } \boxed{1}\end{bmatrix}\end{bmatrix} \rightarrow \mathbf{H}\begin{bmatrix}\text{CONT } \boxed{1} \\ \text{STORE} \neq \boxed{3} \;\&\; (\boxed{3} \cup \boxed{2})\end{bmatrix}$$

(126)



In such constructions, the QUE set of the *in situ* question phrase is empty. However, for actual constituent questions which are *in situ* (so, not in English), Ginzburg and Sag (2000) suggest that such words do have a nonempty QUE value, as illustrated by their analysis of questions in Iraqi Arabic ([acm]; Afro-Asiatic) (127)–(128).

(127) Mona shaafat meno
Mona saw whom
'Who did Mona see?' [acm] (Ginzburg and Sag, 2000, p.290)

(128)

$$
\begin{array}{c}
\mathrm{S} \\
\begin{bmatrix}
\text{QUE} & \{\} \\
\text{CONT} & \begin{bmatrix} \textit{question} & \\ \text{PARAMS} & \{\boxed{2}\} \\ \text{PROP} & \boxed{1} \end{bmatrix}
\end{bmatrix} \\
| \\
\mathrm{S} \\
\begin{bmatrix}
\text{QUE} & \{\boxed{2}\} \\
\text{CONT} & \boxed{1}\begin{bmatrix}\textit{proposition}\end{bmatrix}
\end{bmatrix} \\
\triangle \\
\textit{Mona shafaat meno} \\
\text{`who did Mona see'}
\end{array}
$$

Ginzburg and Sag (2000) suggest the analysis in (128) as an alternative to the analysis for the same data by Johnson and Lappin (1999), in which they propose an extraction + filler-gap derivation, symmetric to the one shown earlier for (110), simply with the head daughter in front of the filler daughter (so, assuming a different, symmetric version of the filler-gap rule). In Chapter 6, I adopt Ginzburg and Sag's (2000) suggestion to model the *in situ* question forming cross-linguistically but later conclude that the complications of that analysis in the context of flexible word order make Johnson and Lappin's (1999) option look more appealing and worth further exploration.

4.1.4 Sag et al. 2003

Sag et al. 2003 was written as an HPSG textbook but in practice has been serving a role that is larger than just a pedagogical tool. It has helped train several generations of aspiring grammar engineers; it also described theoretically several ideas which are not found directly in Pollard and Sag 1994, the most relevant to this dissertation being allowing multiple elements on the SLASH-list.[21] Sag et al. (2003) offer an analysis of the English *easy* adjectives relying on the ARP and on

[21] Sag et al. (2003) actually call SLASH GAP; I call it SLASH here to avoid confusion with the type *gap*.

the idea that lexical entries can stipulate their arguments as containing at least one gap (p. 452). Sag et al. (2003) still constrain the head daughter of the filler-gap rule to have exactly one element in its SLASH, however —a constraint that I depart from in my analysis presented in Chapter 6.

4.1.5 Interim Summary

This section gave an overview of theoretical work which influenced the kind of grammar engineering that I am doing in this dissertation. In particular, I described an analysis of LDDs originating from Pollard and Sag 1994 relying on nonlocal features, their propagation in the tree, and the realization of the dependency via the filler-gap rule. I also explained how feature QUE is used to compose interrogative semantics and presented additionally some important features of the analysis of English interrogatives by Ginzburg and Sag (2000). Finally, I described the usage of SLASH list longer than one element, in the context of Sag et al.'s (2003) analysis of English *easy* adjectives (found also in the ERG). The next section summarizes the existing grammar engineering analyses which implement some of these concepts and on which I directly build, or which otherwise directly relate to this work.

4.2 Previous and related grammar engineering work

The grammar engineering landscape includes multiple projects carried out in various formalisms. In addition to DELPH-IN projects,[22] there are other HPSG-based formalisms with varying properties, including ALE (Penn, 2000), LIGHT (Ciortuz, 2002; Ciortuz and Saveluc, 2012), Alpino (Bouma et al., 2001b; Van Noord et al., 2006, focusing on Dutch), and Enju (Miyao and Tsujii, 2008, focusing on probabistic disambiguation). CoreGram (Müller, 2015) is a grammar engineering project similar to the Grammar Matrix but couched within ALE rather than the DELPH-IN formalism. The LFG (Kaplan and Bresnan, 1982) engineering consortium analog is ParGram (Butt and King, 2002).

The two grammar engineering projects most relevant to this work are the English Resource

[22] `http://moin.delph-in.net/`

Grammar (Flickinger, 2000, 2011) and the Grammar Matrix (Bender et al., 2002; Bender and Flickinger, 2005; Bender et al., 2010b). The Grammar Matrix has already been introduced above (§3.4), and so below I focus on the specific components of this system on which I directly build. Apart from the ERG and the Grammar Matrix, this work was also informed by the Zhong grammar of Chinese languages (Fan, 2018) and particularly by the unpublished analyses developed by Emily M. Bender for her grammar engineering graduate level course.[23]

4.2.1 The English Resource Grammar

The English Resource Grammar (Flickinger, 2000, 2011) is a broad-coverage implemented grammar of English written in DELPH-IN JRF, and it served, along with the German Grammar (Müller and Kasper, 2000; Crysmann, 2003) and the Japanese Jacy grammar (Siegel et al., 2016), as the foundation for the Grammar Matrix, meaning many of the analyses which were thought to be cross-linguistically applicable were either adapted or taken directly from the ERG.[24]

There are a number of differences between the ERG (and in many cases, generally between the DELPH-IN JRF of which the ERG is the biggest artifact) and the accounts of LDDs by Pollard and Sag (1994) and Ginzburg and Sag (2000) (§4.1.1). There are several reasons for this. First, the ERG represents independent research in its own right; second, the ERG started being developed roughly in the same time period when the foundations of HPSG were being published; third, the ERG is a concrete implementation rather than a purely theoretical analysis.

First of all, what is posited in theoretical accounts as principles is implemented in the ERG and in other DELPH-IN grammars as constraints on types. In other words, the principles are part of the type hierarchy, not a separate part of the grammars. For example, to implement something like the Head Feature Principle, a type such as (129) is defined which copies the head values from the appropriate daughter to the mother node, and then the phrase structure rules which are understood to follow the principle inherit from that type. This will ensure all feature-value pairs appropriate

[23] `http://courses.washington.edu/ling567/`

[24] Throughout this document, I am citing Flickinger 2000 and Flickinger 2011 for any analyses which can traced back to and are found in the ERG files, whether or not they are explicitly described in either paper.

for the HEAD portion of the structure as well as the type of the HEAD value will be structure-shared between the mother and the daughter which is in turn identified with the HEAD-DTR portion.

(129)
$$\begin{bmatrix} \textit{headed-phrase} & \\ \text{SYNSEM|LOCAL|CAT|HEAD} & \boxed{0} \\ \text{HEAD-DTR|LOCAL|CAT|HEAD} & \boxed{0} \end{bmatrix}$$

This illustrates how principles are in practice implemented in DELPH-IN JRF.

The ERG uses *diff-lists* as the feature value for SLASH and QUE rather than sets. Guy Emerson explains in Zamaraeva and Emerson (in press):

> "While set-valued features are often used in HPSG, unification of sets is not guaranteed to produce a unique result (Pollard and Moshier, 1990; Moshier and Pollard, 1994). So that unification always produces a unique result, the DELPH-IN JRF does not allow set-valued features, which means that features like SLASH must be list-valued rather than set-valued."

As explained in §3.2.1, the formalism that the ERG and the Grammar Matrix use does not natively define any relational constraints (including operators such as ⊕ (append) or ⊖ (list/set subtraction)).

In the ERG (Flickinger, 2000) and subsequently in the Grammar Matrix (Bender et al., 2002), most lexical types such as verbs, nouns, and determiners inherit from basic supertypes which implement SLASH amalgamation (e.g. *basic-one-arg, basic-two-arg* (130), etc). Another type introduced by Bouma et al. (2001a), *gap-synsem* (131), is needed to constrain some types to include nonempty SLASH values initially (at the "bottom" tier of the derivation). In the ERG, *gap* is used in extraction rules (134)–(135).

(130)
$$\begin{bmatrix} \textit{basic-two-arg-lex-item} & \\ \text{ARG-ST} & \left\langle \begin{bmatrix} \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{1}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{2}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{3}\ ! \rangle \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{4}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{5}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{6}\ ! \rangle \end{bmatrix} \end{bmatrix} \right\rangle \\ \text{SYNSEM|NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{1}, \boxed{4}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{2}, \boxed{5}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{3}, \boxed{6}\ ! \rangle \end{bmatrix} \end{bmatrix}$$

(131) $\begin{bmatrix} \textit{gap} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{1} \\ \text{NON-LOCAL}|\text{SLASH} & \langle ! \ \boxed{1} \ ! \rangle \end{bmatrix} \end{bmatrix}$

Furthermore, the Argument Realization Principle (99) is not implemented in the ERG, and it uses instead a combination of lexical threading (§4.1.2), like in Ginzburg and Sag 2000, and extraction rules, like in Pollard and Sag 1994. While the main reason Bouma et al. (2001a) suggested lexical threading was getting rid of the extraction rules, the ERG found lexical threading helpful even without the benefit of getting rid of the rules, in particular an elegant analysis of the English *easy* adjectives.

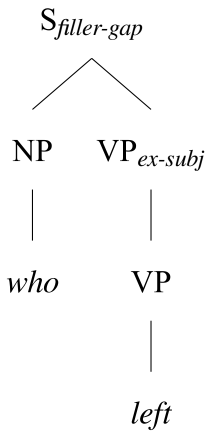
My analysis of constituent questions presented in this dissertation is indebted to the ERG in at least two ways: (i) The Grammar Matrix core (§3.4) was "distilled" from the ERG, and so many of the features and types that currently are in the Matrix core in fact originated from the ERG (Flickinger, 2000; Bender et al., 2002); (ii) For the analyses of semantics of various types of sentences, I was often consulting the ERG as a gold standard. This includes the semantics of questions as well as the semantics of sentences containing adpositions and adverbs, certain types of which I added to the Matrix (§6.1.2).

Of the types which originated from the ERG, the most relevant to this work is the *basic-filler-rule* (133) and the extraction rules including *basic-extracted-subj* (134), *basic-extracted-comp* (135), and *extracted-adj* (136).[25] The phrasal types which I describe in Chapter 6 are mostly their subtypes. An ERG derivation for the English sentence *Who arrived?*, for example, will involve the subject extraction and the filler-gap rule, as shown in (132).[26]

[25]Incidentally, all these types are not strictly speaking core, because they will not be used in a grammar of a language which never dislocates any constituents. However many languages do that, and generally in practice there are cases when the division between core and non-core types in the Matrix files is not fully maintained.

[26]This is a simplified derivation without lexical rules. To see the actual derivation, the reader can use the demo website for ERG `http://delph-in.github.io/delphin-viz/demo/`.

(132)



Compared to the derivation illustrating Ginzburg and Sag's (2000) analysis (110), derivation (132) features an explicit subject extraction rule. The rest of the syntactic machinery is basically the same.

The *basic-filler-rule* in the ERG identifies one daughter's SLASH with another daughter's LOCAL value (133); the order of the daughters (which one is the head daughter) is achieved by having the subtype of the *basic-filler-rule* which is intended to license a particular type of construction inherit additionally from an appropriate headed rule type.

(133)

$$\begin{bmatrix} \textit{basic-filler-phrase} \\ \text{SYNSEM}|\text{NON-LOCAL}|\text{SLASH } \textit{0-dlist} \\ \text{ARGS} \left\langle \begin{bmatrix} \text{SYNSEM} \begin{bmatrix} \text{LOCAL} & \boxed{0} \\ \text{NON-LOCAL}|\text{SLASH} & \textit{0-dlist} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{SYNSEM}|\text{NON-LOCAL}|\text{SLASH} \begin{bmatrix} \textit{1-dlist} \\ \text{LIST}|\text{FIRST } \boxed{0} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

The *basic-extracted-subj* phrase identifies the element on the SLASH list (the gap) with the subject (134) while (135) does the same for the complement.

(134)

$$\begin{bmatrix} \textit{basic-ex-subj} & \\ \text{SYNSEM}|\text{LOCAL}|\text{CAT}|\text{VAL} & \begin{bmatrix} \text{SUBJ} & \langle\,\rangle \\ \text{SPR} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} \begin{bmatrix} \text{VAL} \begin{bmatrix} \text{SUBJ} & \left\langle \begin{bmatrix} \textit{gap} \\ \text{LOCAL } \boxed{0} \begin{bmatrix} \textit{local} \\ \text{CONT}|\text{HOOK}|\text{INDEX } \textit{ref-ind} \end{bmatrix} \end{bmatrix} \right\rangle \\ \text{COMPS} & \textit{olist} \end{bmatrix} \\ \text{MC} \quad \textit{na} \end{bmatrix} \\ \text{NON-LOCAL}|\text{SLASH}|\text{LIST } \langle \boxed{0} \rangle \end{bmatrix} \\ \text{C-CONT} & \begin{bmatrix} \text{RELS} & \langle !\ !\rangle \\ \text{HCONS} & \langle !\ !\rangle \\ \text{ICONS} & \langle !\ !\rangle \end{bmatrix} \end{bmatrix}$$

(135)
$$\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{basic-ex-comp}}\\
\text{SYNSEM} & \left[\begin{array}{ll}\multicolumn{2}{l}{\textit{canonical-synsem}}\\ \text{LOCAL|CAT} & \left[\begin{array}{ll}\text{VAL} & \left[\begin{array}{ll}\text{SUBJ} & \boxed{0}\\ \text{SPR} & \boxed{1}\\ \text{COMPS} & \boxed{2}\end{array}\right]\\ \text{MC} & \boxed{3}\end{array}\right]\end{array}\right]\\
\text{HEAD-DTR} & \left[\begin{array}{ll}\text{SYNSEM} & \left[\begin{array}{ll}\text{LOCAL|CAT} & \left[\begin{array}{ll}\text{VAL} & \left[\begin{array}{ll}\text{SUBJ} & \boxed{0}\\ \text{SPR} & \boxed{1}\\ \text{COMPS} & \left\langle \left[\begin{array}{l}\textit{gap}\\ \text{NON-LOCAL|SLASH } \boxed{4}\end{array}\right] \oplus \boxed{2} \right\rangle\end{array}\right]\\ \text{MC} & \boxed{3}\end{array}\right]\\ \text{NON-LOCAL|SLASH} & \boxed{4}\end{array}\right]\end{array}\right]\\
\text{C-CONT} & \left[\begin{array}{ll}\text{RELS} & \langle ! \; ! \rangle\\ \text{HCONS} & \langle ! \; ! \rangle \\ \text{ICONS} & \langle ! \; ! \rangle\end{array}\right]
\end{array}\right]$$

Finally the extracted adjunct rule essentially says that what is on its SLASH list can modify the head daughter (136).

(136)
$$\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{ex-adjunct-phrase}}\\
\text{SYNSEM} & \left[\begin{array}{ll}\text{NON-LOCAL|SLASH} & \left\langle ! \left[\begin{array}{ll}\text{CAT|HEAD|MOD} & \left\langle \left[\begin{array}{ll}\text{LOCAL} & \left[\begin{array}{ll}\multicolumn{2}{l}{\textit{intersective-mod}}\\ \text{CAT} & \left[\begin{array}{ll}\text{HEAD} & \boxed{0}\\ \text{VAL} & \boxed{1}\end{array}\right]\end{array}\right]\end{array}\right] \right\rangle\end{array}\right] ! \right\rangle\end{array}\right]\\
\text{HEAD-DTR|SYNSEM} & \left[\begin{array}{ll}\multicolumn{2}{l}{\textit{canonical-synsem}}\\ \text{LOCAL} & [\ \textit{local}\\ \text{CAT} & \left[\begin{array}{ll}\text{HEAD} & \boxed{0}\\ \text{VAL} & \boxed{1} \left[\begin{array}{ll}\text{SUBJ} & \left\langle \left[\begin{array}{l}\textit{synsem-min}\\ \text{NON-LOCAL|SLASH} \ \langle ! \; ! \rangle\end{array}\right] \right\rangle\end{array}\right]\end{array}\right]\\ \text{NON-LOCAL|SLASH} & \langle ! \; ! \rangle\\ \text{MODIFIED} & \textit{notmod}\end{array}\right]
\end{array}\right]$$

I use all of these types, most of them modified to some degree, in the analyses presented in Chapter 6. The modifications have to do with the requirement to serve a wider range of languages, particularly languages with multiple fronting.

Another important concept which comes from the ERG is the **sentential force** feature (SF). It is a feature appropriate for *events*, and its possible values include *prop*osition and *ques*tion, as well as a type which underspecifies between them, *prop-or-ques*. This feature is part of the semantic representation (MRS), and it is set to *ques* in particular by interrogative clauses.

The ERG has a hierarchy of interrogative clauses inspired by Ginzburg and Sag 2000; subsequently, the Grammar Matrix posits a type *interrogative-clause* (137) which I use for my analysis when I posit a *wh-ques-phrase* as a subtype of *interrogative-clause* (§6.3, example (204)).

(137) $\begin{bmatrix} \textit{interrogative-clause} & \\ \text{SYNSEM|LOCAL|CONT|HOOK} & \boxed{1}\begin{bmatrix}\text{INDEX|SF} & \textit{ques}\end{bmatrix} \\ \text{HEAD-DTR|SYNSEM|LOCAL|CONT|HOOK} & \boxed{1} \\ \text{C-CONT|HOOK} & \boxed{1} \end{bmatrix}$

Note how this rule identifies the semantic contribution of the phrase (C-CONT) with that of the head daughter's semantic HOOK. This is true of all *head-compositional* phrases in the ERG and consequently the Grammar Matrix. This means, in particular, that if a structure is [SF *prop*], it can never be the head daughter of an *interrogative-clause* because the daughter's semantics is then not unifiable with the mother's. If it is [SF *prop-or-ques*] however, it can.

The SF feature is used in the ERG and subsequently in the Grammar Matrix instead of Ginzburg and Sag's (2000) *messages* (111) to model the distinction between declarative, interrogative, and imperative semantics. The possible values for SF are *prop* for 'proposition' or *ques* for 'question' (along with a few other values serving e.g. the imperative constructions). These are atomic; no further structure is appropriate for them. The main disadvantage of this from the point of view of modeling *wh*-questions for the Grammar Matrix is the inability to treat *wh*-words as question parameters of the right clauses in complex sentences. For example, the English sentence (138) is a polar question which embeds another question. The embedded questions is about a referent which is the subject of a clause which is itself a complement of the embedded verb *seem*.

(138) Does Kim know who seems to have arrived? [eng][27]

The version of the ERG which still had *messages* assigned a fairly elaborate MRS for (138), as shown in Figure 4.1. In this MRS, there are various *messages* (the *m* relations) which are linked to different event (*e*) variables though there is no direct correspondence to Ginzburg and Sag's (2000) PARAMS feature.[28] In principle though, those *m(essage)* relations are where the feature would be.

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[27] Thanks to Guy Emerson to suggesting this particular example as illustrative.

[28] Emily M. Bender (p.c.) recalls that at some point she did start implementing the PARAMS feature in the ERG but that work never made it into the ERG releases.

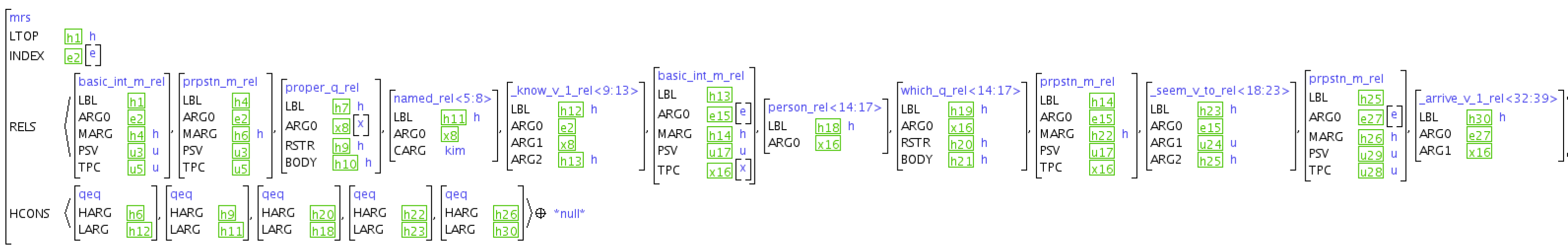

Figure 4.1: An MRS provided by the ERG revision 1143 to the sentence *Does Kim know who seems to have arrived?*

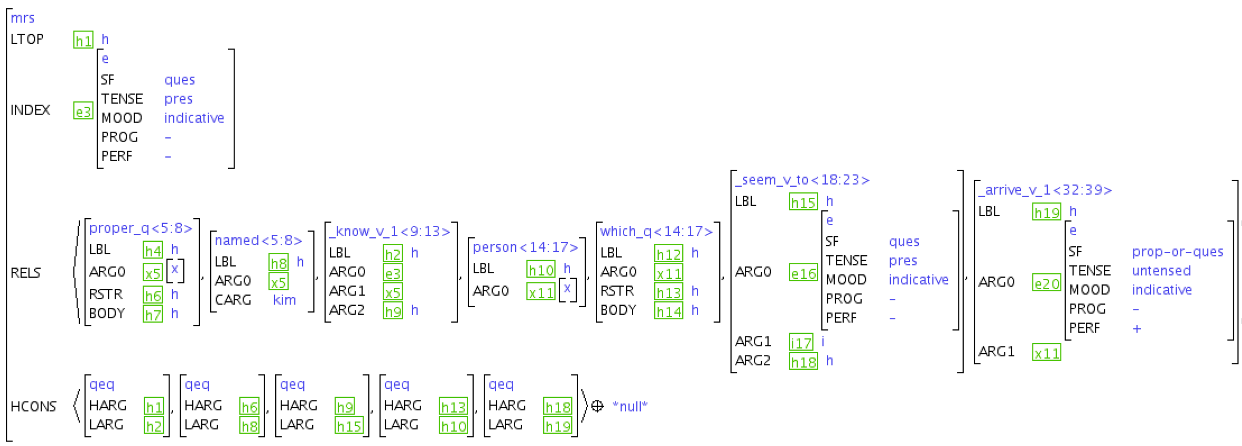

Figure 4.2: An MRS provided by the ERG-2018 to the sentence *Does Kim know who seems to have arrived?*

In the ERG-2018,[29] the same sentence gets a shorter MRS structure (Figure 4.2). This structure is different from the one in Figure 4.1 in several ways (they are separated by about 12 years of development) but what is relevant here is that there are no more *m(essage)* relations; instead, the SF feature is specified for each event. There are two questions in the sentence, as before (the second one is now underspecified between question and proposition), but the relations that represent the word *who* (*which person*) could no longer be linked to either one. The variable *x11* is only a semantic role in the _arrive_v predication.

Head-subject and head-complement structures are [SF *prop-or-ques*] in the ERG and in the Grammar Matrix. This means such structures can be treated as intonation questions, but, unless further work is done, it leads to licensing sentences like (139).

(139) *I ask Kim arrived. [eng]

Unless additional work is done on the analysis, (139) will be licensed by a Matrix-derived grammar which specifies *ask* as a question-embedding verb. *Kim arrived*, because it would be licensed by the head-subject rule, is [SF *prop-or-ques*] and can be embedded by *ask* which constrains its

[29] Available via `svn checkout http://svn.delph-in.net/erg/tags/2018`

complement to be [SF *ques*].[30] It is not possible to say, in DELPH-IN JRF, that the verb embeds [SF *ques*] but not [SF *prop-or-ques*] clauses because *ques* is a subtype of *prop-or-ques* and as such unifies with it. I present a partial solution to this problem in §6.2.

4.2.2 Other DELPH-IN grammars

BURGER (Osenova, 2010) is a Matrix-based grammar of Bulgarian ([bul]; Indo-European). Bulgarian is a Slavic language and it is similar to Russian in that it has multiple fronting in constituent questions (§2.5.2).[31] BURGER does not cover multiple constituent questions but does have an account of single questions as well as relative clauses for which it required some revisions to Matrix core types which my work ultimately also required, such as relaxing the QUE constraints on phrase structure rules such as the subject-head rule so as to allow *wh*-words in non-fronted positions (§6.5.2). Furthermore, BURGER does not necessarily employ extraction and head-filler rules to license questions. Instead, a question like (140) will be licensed by a regular subject-head rule, without extraction. The question semantics is achieved by identifying the SF value of the verb with that of its subject (141).[32] It is not clear to me how to generalize this analysis to long-distance dependencies where it appears one must have a filler-gap rule.

(140) Кое куче лаеше?
Koe kuche laeshe
which.NOM dog.NOM bark.PST
'Which dog was barking?' [bul] (BURGER test suite)

(141)
$$\begin{bmatrix} \textit{main-verb-lex} & \\ \text{SYNSEM|LOCAL|CONT|HOOK|INDEX|SF} & \boxed{0} \\ \text{ARG-ST|FIRST|SYNSEM|LOCAL|CONT|HOOK|INDEX|SF} & \boxed{0} \end{bmatrix}$$

[30] In the ERG, this problem is avoided using a fairly elaborate solution which relies on some special properties of English subjects; at present, I did not try to adapt that solution to the Grammar Matrix cross-linguistic context. The solution is informally discussed here: `https://delphinqa.ling.washington.edu/t/complementizers-and-embedded-questions/475/30?u=olzama`

[31] There are also differences, in particular with respect to optionality of fronting. Bulgarian requires that all question phrases obligatorily front (Rudin, 1988, *inter alia*).

[32] This is a departure from the semantic analysis adopted in the Grammar Matrix, as this requires giving SF values to non-event variables (e.g. referents).

RRG, the Russian Resource Grammar (Avgustinova and Zhang, 2009), has not provided me with a lot of material as of yet because it does not cover questions and overall focuses more on lexical coverage than syntactic. I would like to integrate my work with this grammar in the future, however, to make use of the morphological analyzer and the rich lexicon.

Jacy (Siegel et al., 2016) is a DELPH-IN grammar of Japanese; Zhong (Fan, 2018) is a DELPH-IN grammar of Mandarin [cmn] and Cantonese [yue] Chinese (Sino-Tibetan).[33] I consulted both Jacy and Zhong when I was modeling question particles (§6.4).

4.2.3 Analyses used for LING567 at University of Washington

Emily M. Bender put together instructions for how to model constituent questions for a grammar engineering course taught annually at University of Washington.[34] The instructions include analyses for second position clitics (intended for polar questions) and two analyses for *wh*-questions, one for English and one for an abstract *in situ* language (§2.5.5).

Second position question clitics are analyzed as modifiers that attach to the right of the word they modify,[35] and insist that that word be the initial thing in the sentence. Bender comments that there is no claim that the proposed analysis is necessarily comprehensive but that it has worked for Russian and other languages, in the context of the grammar engineering class. While the second position clitics in LING567 were intended for polar questions, this strategy is used to form *wh* questions as well, e.g. in Malagasy (Potsdam, 2004). I directly used this analysis in my analysis presented in §6.7.2.

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[33] Jacy originally stood for "JApanese in Cooperation with YY", YY being a technology company. Jacy is not usually spelled as an acronym, partly because the work on the grammar long survived YY. Zhong is for the first character of *Zhōngwén* which means 'Chinese'.

[34] `http://courses.washington.edu/ling567/2017/lab6.html`

[35] Clitics attaching to the first phrase (rather than the first word) also exist but are not covered in this analysis.

4.2.4 Other Grammar Matrix libraries

My work builds directly on the analyses that already exist in the Grammar Matrix. In addition to the Matrix core which mainly comes from an earlier version of the ERG, there are multiple libraries which made my work possible and informed the new analyses I added to various degrees.

4.2.5 Libraries which support interacting phenomena

In terms of libraries which provide me with the ability to test constituent question analyses on sentences that contain other syntactic phenomena as well, I rely first and foremost on the basic word order library (Bender and Flickinger, 2005; Fokkens, 2014) which provides a treatment for basic word order which relies on the notion of head-initial and head-final phrase structure rules and constrains the valence lists so as to block unwanted ambiguity, as explained regarding the head-subject rule example (86) in §3.4. This library also provides the noun-determiner order and the auxiliary order support. The next most important library for this work is the lexicon which was in the Grammar Matrix customization system from the start (Bender and Flickinger, 2005) and which was further expanded and improved by Matrix developers, most notably Drellishak (2009b), and which interacts with the case library added by Drellishak (2009b). All of these libraries required some modifications in order to support constituent questions, which will be mentioned where appropriate in Chapter 7.

Another library on which I heavily rely in this work is the morphology and morphotactics library (O'Hara, 2008; Goodman and Bender, 2010; Goodman, 2013). It allows the user to specify various lexical rules which furthermore are organized into position classes. The position classes can be specified to take all or only some of lexical types as input. The orthographies associated with the lexical rule types are added as lexical rule type instances. The library also offers functionality to make special flags available in the questionnaire for lexical rules, which are then only used internally but are ultimately translated into appropriate HPSG feature-value pairs, such as the *ques* value for the SF feature on the customization side, if the user specifies a lexical rule which is part of an interrogative paradigm (§2.8). The user does not specify a value for the SF feature directly; rather, the user choice is interpreted this way by the customization system.

I use a number of other Matrix libraries to a smaller extent, mainly to be able to include in the test suites specific examples from specific languages with whichever phenomena happen to be present in the sentences in addition to constituent question-related phenomena (see Chapter 8). These libraries include adnominal possession (Nielsen, 2018), valence change (Curtis, 2018), tense, aspect, and mood (Poulson, 2011a), and coordination (Drellishak and Bender, 2005). It is not crucial to understanding this work to know how they are organized.

4.2.6 Libraries which have analyses directly interacting with constituent questions

Some of the phenomena currently supported by the Grammar Matrix are directly related to constituent questions in terms of the syntactic mechanisms involved. They include polar questions (Bender and Flickinger, 2005), clausal complements (Zamaraeva et al., 2019), and information structure (Song, 2014).

The **polar questions** library (Bender and Flickinger, 2005) supports several kinds of yes/no matrix questions: (i) intonation, by default (the SF feature in simple clauses is underspecified between proposition and question); (ii) morphological marking (question semantics is added to the verb which goes through the lexical rule that the user specified for this purpose); subject-auxiliary inversion (a set of appropriate phrase structure rules and a lexical rule which turns an auxiliary into an inverted auxiliary is emitted by the customization system if the user checks this box); and particles. Previously the library simply asked the user to enter the spelling for a particle. The customization system would then add a complementizer subtype for it. I substantially extend the functionality with respect to particles (§6.7).

The library for **clausal complements** is primarily my own work (Zamaraeva et al., 2019). The library is organized as follows. The user may specify complementation "strategies", and each will be associated with one clause-embedding verb type in the grammar. The complements of such verbs can then be specified with respect to various features, via the questionnaire, which will then be properly interpreted by the customization system. With this work, I add the distinction between proposition-embedding and question-embedding verbs to this library (§6.2).

Some of the aspects of my analysis of clausal complements ended up being revised in the context of this dissertation as it turned out they did not generalize well. The most relevant bit here is the INIT head feature.[36] Originally, the clausal complements library would constrain the head complement rules to be INIT − or + in the case the language has free word order, but the question particle or complementizer can only appear strictly before or after its complement. That does not generalize to ditransitive clauses, however. For examples like (142), we need first the head-complement rule to apply and then the complement-head rule.

(142)	Иван	Маш-е	дал	книг-у
	Ivan	Mash-e	dal	knig-u
	Ivan.NOM	Masha-DAT	give.PST.3SG	book-ACC
	'Ivan gave a book to Masha.' [rus]			

But because INIT was a feature of heads, a (headed) rule can't just check that the head daughter has that property without taking on the property for the mother. So, licensing (142) would not be possible if the complement-head rule mother were constrained to be INIT −, as it would be under the original clausal complements library analysis. A better and indeed a simpler analysis is to constrain the Complement Head Rule to be HEAD *+nv*,[37] which is also in line with the traditional HPSG approach to use disjunctive HEAD types to constrain phrase structure rules. I implement this change as part of this work.

The Grammar Matrix **information structure** library (Song, 2014) provides analyses for various ways of marking topic, focus, and contrast found in the world's languages. It uses filler-gap (133) and extraction (134) rules (see §4.2.1) for topicalization and modifier-like particles for focus marking. This makes this library highly relevant to my constituent questions library and ideally there would be a high degree of integration between the two. In reality I have not yet achieved this much desirable integration because of the relatively high complexity of the information structure library and the fact that it did not fully support all word orders, particularly free

[36] Recall that a head feature is a feature appropriate for the type *head*, and that all head features are by default passed up from head daughter to mother, in HPSG.

[37] *+nv* is a disjunctive type for nouns and verbs; a structure that is of type *noun* will unify with it, and so will a structure of type *verb*.

word order which I used in my Russian development grammar (§8.3). As of now, it is possible that some combination or user choices may lead to superfluous filler-gap rules in the grammar or to a conflict in the specification of the subject extraction rule customized by both libraries.

4.3 Summary

In this chapter, I talked about the theoretical foundations to which my analysis relates and presented some DELPH-IN grammar engineering work on which my dissertation directly builds. The next chapter describes the general methodology of my work.

Chapter 5

METHODOLOGY: TEST-DRIVEN DEVELOPMENT AND EVALUATION ON HELD-OUT LANGUAGE FAMILIES

Adding libraries to the Grammar Matrix has a fairly established methodology (Bender et al., 2010b). Here I describe the methodology in general so that the reader can better understand the principles which were guiding my library design and development (Chapters 6–7). In Chapter 8, I describe how exactly I carried out the testing and evaluation methodology.

5.1 The goal of Matrix library development

The goal of creating a new library for the Grammar Matrix is adding testable support for a new syntactic phenomenon. For example, with this dissertation, I add support for constituent questions, which means that the user should now be able to automatically obtain from the system a grammar which can pair sentences containing constituent questions with syntactic and semantic representations, for a range of languages. In particular, the semantic representations should be well-formed and standard for the Minimal Recursion Semantics formalism (§3.2.2). In other words, the MRS structure for sentences from different languages which mean more or less the same thing will often be similar.[1] The exact shape of the syntactic structure is less crucial so long as it helps construct the correct semantic (MRS) structure while correctly modeling grammaticality. Central to the methodology and to the goals of the Grammar Matrix system as a project is that these

[1]This does not always have to be the case though. For example, the MRS for the Korean sentence (i) should probably have a predication for possibility whereas its English equivalent does not have one (assuming (i) is the best translation for the English *I can eat glass*).

(i)	na-neun	yuri-leul	meok-eul	suga	iss-ta
	I-TOP	glass-ACC	eat-PROSPECTIVE	POSSIBILITY	have-DECL

‘I can eat glass.’
(Lit.: ‘The possibility of my eating glass exists.’) [kor] (Provided by Emily Proch Ahn.)

grammars and analyses are tested on diverse natural language data, both during the development (giving rise to something like *test-driven development* (§5.7)) and after the development is frozen, for evaluation.

5.2 Typological literature review and illustrative languages

To achieve the goal of adding support for a new phenomenon to the Grammar Matrix system, any library developer starts with language data along with any existing analyses, usually aggregated from typological overviews such as Shopen 2007 and any other, often syntactic, literature which gives examples of how the phenomenon manifests itself in the world's languages. This typological and syntactic literature review allows the developer to identify *illustrative languages* which will guide the library development starting with the web questionnaire (in fact, the questionnaire is more or less a summary of the typological literature on the phenomenon), and aggregate sentences from those languages into *test suites*. At the same time, the developer notes various typological characteristics of each illustrative language, such as basic word order, case system, etc. This allows the developer to model the illustrative languages in the Grammar Matrix web questionnaire, which yields baseline *specifications* for them.

5.3 Languages as specifications + test suites

For the purposes of testing the Grammar Matrix customization system, languages can be represented by a pairing of a specification (set of typological choices, lexical entries, and morphological rules) that can be customized and a test suite of sentences which the grammar can be run on. This concept makes it convenient to add *artificial*, or *pseudo-* languages to the testing pool.

5.4 Pseudolanguages

While the new library questionnaire design is guided by illustrative languages, usually the developer wants to test additional combinations of choices that are made available to the user which are not necessarily present in the illustrative languages or, more importantly, which it is not possible to express in the illustrative languages within the scope of what the Matrix can do. In other words, pseudolanguages make it possible to map out the space of possible analyses provided by the library and also to focus on testing specific parts of the customization system while potentially abstracting away from other parts. Pseudolanguages are merely specifications that correspond to some particular ways of filling out the web questionnaire, paired with test suites which illustrate what the grammar of this pseudolanguage should and should not generate (parse). The goal is to only include pseudolanguages which make sense typologically, although in principle, because they are not real language data, there is a danger here of including something that does not actually exist.[2] Example (143) illustrates a pseudolanguage[3] where subject-auxiliary inversion is grammatical in embedded clauses (unlike in English where it is only grammatical in main clauses).

(143) I wonder what do the dogs chase? [pseudolanguage1]

Such a pseudolanguage is needed to test whether such typological possibility, which I make available in my new constituent questions library questionnaire, works as expected. This pseudolanguage uses English words; that is convenient when a quick association with a phenomenon found in English is desired, and in general improves readability. In other cases, pseudolanguages might use code words like *noun* or *tverb* (144). This second option helps avoid bias when reading the test suites but may make it harder to remember or understand what the sentence is supposed to mean (though in each case, the meaning can and should be accessed via the MRS).

(144) noun1 tverb noun2 [pseudolanguage2]

5.5 A complete pseudolanguage example

For a complete example, consider a language characterized by *obligatory single fronting of the question phrase in main clauses* as well as SVO word order and no determiners, no case marking,

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[2]In practice, I experienced the opposite: I had thought interrogative paradigms were likely to be the same for polar and constituent questions in one language, and I was wondering whether including an analysis for separate paradigms, which I developed and tested with a pseudolanguage (§6.8), was meaningful. In the evaluation stage, I did come across a language that does have separate paradigms (§8.5.7).

[3]Incidentally, (143) is possible in some varieties of English but here it is intended to illustrate a pseudolanguage.

no person distinction, and no auxiliaries.[4] Such a pseudolanguage may be illustrated by the following test suite (145):

(145)
```
cat sleeps
*sleeps cat
cat sees house
*cat house sees
who sleeps?
*sleeps who?
what cat sees?
*cat sees what?
*cat what sees?
cat sleeps in house
where cat sleeps?
*cat sleeps where?
*where sleeps cat?
*cat where sleeps?
cat sees cat in house.
what cat sees in house?
*cat sees what in house?
```

and by the following grammar specification obtained with the Grammar Matrix web questionnaire (146):

[4]Pseudolanguages in the Matrix often purposefully minimize complexity so that an analysis for a particular phenomenon can be tested "on its own", with minimal interaction with other phenomena.

(146)
```
version=32
section=general
language=wh-svo-sg-oblig-min
section=word-order
word-order=svo
has-dets=no
has-aux=no
section=person
person=none
section=case
case-marking=none
section=wh-q
front-matrix=single
matrix-front-opt=single-oblig
section=lexicon
  noun1_det=imp
    noun1_stem1_orth=cat
    noun1_stem1_pred=_cat_n_rel
  noun2_det=imp
    noun2_stem1_orth=house
    noun2_stem1_pred=_house_n_rel
  noun3_name=wh
  noun3_inter=on
  noun3_det=imp
    noun3_stem1_orth=who
    noun3_stem1_pred=_person_n_rel
    noun3_stem2_orth=what
    noun3_stem2_pred=_thing_n_rel
  verb1_valence=intrans
    verb1_stem1_orth=sleeps
    verb1_stem1_pred=_sleep_v_rel
  verb2_valence=trans
    verb2_stem1_orth=sees
    verb2_stem1_pred=_sees_v_rel
  adv1_name=wh-loc
    adv1_stem1_orth=where
    adv1_stem1_pred=_place_n_rel
  adv1_inter=on
    normadp1_stem1_orth=in
    normadp1_stem1_pred=_in_p_rel
  normadp1_order=before
```

The specification is input to the customization system which outputs a grammar; the grammar can then parse the test suite, and the grammarian can inspect the results and see what bearing they have on her hypothesis.[5]

5.6 *Language test suites*

Language test suites consist of grammatical and ungrammatical sentences from a particular language (real or artificial) which illustrate primarily the phenomenon for which library support is being added. The methodology I follow suggests using at least several illustrative languages (for example, five) and systematically mapping out the space of typological possibilities which is covered by the artificial (pseudo)languages, of which there are usually several dozen. It is not always possible to actually test out all of the questionnaire combinations exhaustively because there may be thousands of them; in such cases, combinations which occur more often in typological literature usually take priority. To compile a test suite for an illustrative language, the Matrix developer usually searches the descriptive grammar or uses native speaker expertise if available. The test suite focuses on exemplar sentences for the phenomenon for which the Matrix developer is adding support and often also contains sentences illustrating basic sentence structure. Sentences containing constituent questions along with other phenomena are included "as is" if these other phenomena are already covered by the Grammar Matrix. In cases when example constituent questions from a descriptive grammar contain phenomena which are not being modeled and are not already present in the Grammar Matrix, the developer may have to simplify/modify the sentences. In such cases, it is ideal to get judgments on the resulting modified sentences from a native speaker; unfortunately that is not always possible to do. The expected practice is to clearly indicate the provenance of each example.

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[5]Since the specification is elicited via the web questionnaire and the "results" here mean a sentence was either assigned a meaningful semantic representation or not, such results can be informative for any linguist, regardless of their theoretical preferences. In practice, it may currently be easier to use the system if one is familiar with HPSG.

5.7 Test-driven development

A Matrix developer who wishes to add support to the system for some syntactic phenomenon will always start with the existing version of the system, which can be considered *baseline*. Baseline grammars obtained from the Grammar Matrix will parse some sentences from the language but normally not the ones which exhibit phenomenon for which the support is yet to be added. At the same time, a baseline grammar usually already tests a lot of what constitutes the scaffolding for the new library. For example, all languages need word order specifications as well as a minimal lexicon. It therefore makes sense to start with this baseline system (and the grammars that it can output) and with a test suite which has all the sentences that one ultimately wants to be covered,[6] and incrementally build support for the new phenomenon while constantly testing what effect each addition had. Each illustrative and pseudolanguage specification is customized by the current version of the customization system and then the output grammar is run on the test suite. If any grammatical sentences are not parsed or any ungrammatical ones are parsed, the developer investigates and either "fixes the problem" in the customization system (which will, at the initial stages, mean including the initial analysis for the phenomenon being modelled!) or concludes the test suite should be modified because there is a mistake there or because treating the sentence correctly is beyond the scope of the project for an independent reason. Once the developer is happy with the structures which the customization system assigns (or correctly fails to assign) to each sentence in a test suite, the pairing of the test suite and the corresponding MRS structures can be considered a **regression test** (§5.9). Such tests can be all run for each modification to the customization system. This way, the developer can ensure that the previous state of the customization system is not negatively altered by any new addition. This is loosely parallel to the concept of *test-driven development* in software engineering (Beck, 2003)[7] where first tests are written and then code is added to the program until all tests pass.

[6] Of course in practice the developer starts with some set of sentences and may add to it later.

[7] Beck (2003) is often credited for "rediscovering" the concept of test-driven development. He made the term popular as well as the practice. The concept probably long predates his book although there is no other canonical citation.

One of the reasons to work in a test-driven fashion is also that it helps break the work into smaller, tractable chunks. It is usually not realistic to first draw complete HPSG analyses on paper and fully commit to them, and then implement those analyses in one go (along with customization logic, which would have also been drafted on paper)—and only then evaluate them on test suites from various languages. Test-driven development is thus also a strategy for incremental analysis.

Finally, test-driven development in the Matrix context is also data-driven development, since tests are linguistic data (sentences). This is another reason why this practice became established in Grammar Matrix development; it reflects the philosophy of starting from data and prioritizing semantic representations as the result of the analysis.

5.8 Methodology for developing library parts

Each library has a web questionnaire associated with it, some lexical and phrasal types which provide the general analysis and support for the phenomenon, integrated into the already existing type hierarchy, and some programmed logic which customizes those types into a specific grammar given a language specification as defined above. The most central feature of the methodology of developing all three parts is that it is data-driven; the developer starts with a test suite of sentences and works on the system until the coverage over the test suite is satisfactory. Each component however has its own features that bear on the specifics of the methodology, as discussed in this section.

5.8.1 Web questionnaire

At the surface, the web questionnaire is a menu of choices which allows the user to specify a language along some typological dimensions (as well add lexical entries and morphological rules). The questionnaire serializes those choices as text and outputs a machine-readable specification. The customization system can then create a grammar from that specification. At the same time, the questionnaire is also a summary of typological and sometimes theoretical syntactic literature, because the choices which the questionnaire exposes represent typological combinations attested in the literature. Thus adding a new subpage to the questionnaire is both programmatic and linguistic-analytical work. The programmatic part involves writing a new web page using special syntax developed for the Grammar Matrix by Drellishak (2009b) which interfaces with HTML and JavaScript. The analytical part of the work has to do with mapping typological literature to a set of menu choices which are meaningful in the context of DELPH-IN HPSG in general and the Grammar Matrix in particular. It is essentially about how to turn the space of possibilities that the system can output into a set of questions that can be asked of the linguist. Along the way there are design decisions related to what is presented on which page. For example, question particles are relevant to both polar and constituent questions but those are separate libraries in the Matrix and separate web pages in the questionnaire. A design decision that I made here was to contain all specification of particles in the Polar Questions web page and to enrich it with some user choices regarding constituent questions. Other examples include presenting a phenomenon as a set of "strategies" (blocks of inter-related choices) as was done, for instance, in the coordination (Drellishak and Bender, 2005), negation (Crowgey, 2013), clausal modifiers (Howell and Zamaraeva, 2018), and clausal complements (Zamaraeva et al., 2019) libraries.

5.8.2 Type hierarchy and core analyses

As explained in §3.4, the Grammar Matrix consists of a "core" grammar included in all grammars it produces, and a set of libraries. The core types are or at least should be stored in the file called `matrix.tdl`.[8] Any new library is expected to use the Grammar Matrix core type hierarchy (§3.4) as much as possible. In other words, any new type added by the developer will fit in the overall hierarchy, and it is best if it does not duplicate any constraints where it can use an existing supertype.

Some types added in the context of a new library may be core, if they are expected to be used in any grammar which covers the phenomenon in question (and if all languages are expected to evince the phenomenon in question). For example, any grammar which covers constituent questions will

[8] In practice it is possible that a type which is not strictly speaking core ends up in `matrix.tdl`, and vice versa, a type that should be there is stored elsewhere in the system. This does not necessarily lead to undesirable behavior (so long as the customization logic ensures that the right set of types is added to the grammar) but is nonetheless wrong from the conceptual point of view.

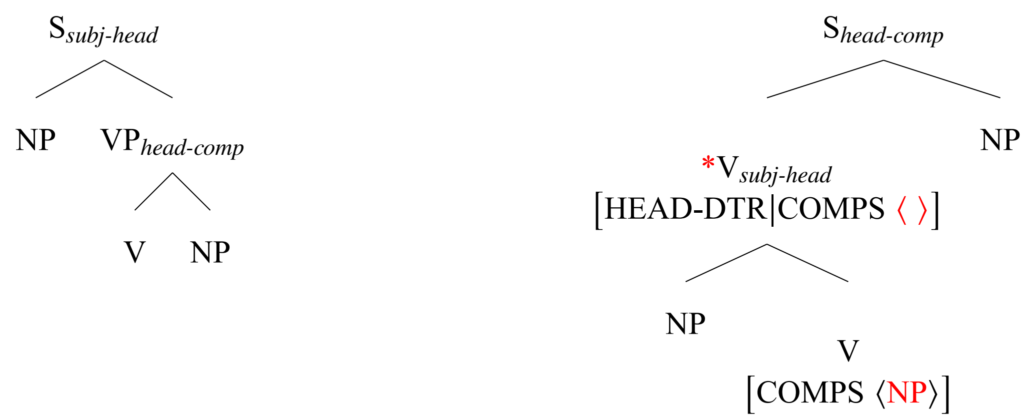
use the QUE feature (§3.1), and so the types which ensure appending or propagating QUE are parts of the core (and live in `matrix.tdl`). On the other hand, the YNQ feature, for example, is only used in languages with second position clitics and so it is not necessary for it to be in the core. To summarize, the newly added types should be well integrated into the existing hierarchy (not duplicating any constraints) and ideally in line with other analyses in DELPH-IN HPSG.

5.8.3 Customization

In principle, programming the customization should start with first fully drafting the logic which takes as input a language specification and outputs customized types with existing sets of constraints as supertypes. Using Bender and Flickinger 2005 as an example, the developer might start with the task of programming customization for word order given the basic head-subject and head-complement rule types and their supertypes, as well as the *head-final* and the *head-initial* phrase types (87). The customization logic with respect to this portion of the grammar then is simple to draft and implement: if the language is specified as SV, then the head-subject rule is customized to have the *head-final* parent; if the language is VS, the *head-initial* parent. But even in such a simple case, some additional constraints play a role, such as the empty vs. nonempty COMPS list to ensure high vs. low subject attachment to avoid spurious parses in SVO and OVS orders (147a)–(147b).

(147)

a. b.



Because of the range of combinatorically possible language specifications which cover not only basic word order but other phenomena as well, in practice customization is often programmed in the test-driven fashion, using a limited number of choice combinations (specifications) and focusing on a small number of natural language specifications and test suites. Ideally any *ad hoc* solutions and artifacts of incomplete or misguided analyses are eradicated or at least improved at the editing/review stage, when the developer documents the logic that was implemented and can notice if some of it does not make sense and would only be working by accident or is doing duplicate work and can be removed.[9]

5.9 Regression testing with illustrative and pseudolanguage test suites

As explained above, throughout the process of adding new types or new customization logic to the system, the developer tests any modifications to the system with respect to a number of illustrative and pseudolanguages. This process is called *regression testing*, and the Grammar Matrix has a regression testing system associated with it (Bender et al., 2007). Pairings of language specifications and test suites are stored along with the *gold* semantic representations in the MRS

[9] I can testify to this: I found multiple spurious constraints which my customization logic was adding to some of the types, when I was writing Chapter 7 of this dissertation.

formalism. In principle, the developer could even hand-craft the gold standard although in practice this is usually not done and a new test is stored only once the Grammar Matrix can actually produce a set of gold MRS for a given test suite given a language specification. Once such a test is stored, it can be run at any point, which means a grammar will be created by the current version of the customization system and the resulting MRSs will be compared with the stored gold results. If the results are identical, the developer can be reassured that the newly added modifications did not interfere with the previous analyses in any negative way; in other words, the system still produces correctly behaving grammars for all other languages which had been tested before (if all existing tests were run).

5.10 Evaluation with held-out language families

After all of the previous stages are completed and all the development is frozen, the developer performs evaluation on 'held-out' languages. This is always the final stage in adding a library to the Grammar Matrix (apart from any associated writing/documentation).

The goal of the evaluation stage is to assess how the Grammar Matrix system, with the newest additions to it, is doing with respect to modeling the given phenomenon in a random set of languages. Due to time constraints, the number of languages for evaluation has traditionally been 5. Each language must come from a language family which was not already used for this library, so, each evaluation language will be from a different language family and one not represented in the illustrative languages, nor in the typological review. This does not mean however that the developer has never heard of the language before or has not seen examples of other phenomena from this language at some point.

For each held-out language, the developer puts together a test suite focused on the phenomenon for which the developer is adding support (with some other phenomena inevitably also present) and then fills out the questionnaire. This way, the developer can assess how well her analyses constructed for development languages and informed by typological literature generalize, and how well the analysis for the newly supported phenomenon interacts with the existing analyses for other phenomena.

5.11 Documentation

Each Grammar Matrix library has a corresponding documentation page on the DELPH-IN wiki.[10] There is no unified format for this, but the goal is to explain informally what the library is covering, what the limitations are, and how to fill out the questionnaire properly. References to the literature used in development are usually provided to some extent. Usually but not always, there are also publications associated with the libraries (e.g. Bender and Flickinger, 2005; Drellishak, 2009a; Poulson, 2011a; Howell et al., 2018; Zamaraeva et al., 2019) as well as Master's and PhD theses, like the present work.

5.12 Summary

This chapter described the general methodology of adding a new library to the Grammar Matrix. In this dissertation, I closely followed the process described above. The analyses presented next in Chapter 6 were developed as illustrative, using the test-driven methodology. The new questionnare and customization are summarized in Chapter 7. The details about the testing are presented in Chapter 8.

[10] `http://moin.delph-in.net/MatrixDocTop`. At the time of this writing, the DELPH-IN wiki was in the process of migrating from `moin.delph-in.net` to `https://github.com/delph-in/`.

Chapter 6

ILLUSTRATIVE ANALYSES FOR CONSTITUENT QUESTIONS

This chapter presents HPSG analyses which illustrate the support I add to the Grammar Matrix for a range of phenomena associated with constituent questions. The chapter is organized around data from "illustrative languages" (§5.2). I use five illustrative languages: English, Japanese, Russian, Yukaghir, and Chukchi. Additionally, the reader will see several artificially constructed datasets and pseudolanguage specifications, where I was not able to use a real language (mostly due to time constraints but, in some cases, because I do not know whether such languages exist but still want to hypothesize a combination of some typological dimensions and see what an analysis for such a language would look like). In this chapter, I use English as the illustrative language in more than one section: for the analysis of question words, complex clauses, and fronting. In the case with question words and complex clauses, such analyses are intended to work for all languages and were tested with all illustrative languages, not only English. Admittedly, the two illustrative languages that I myself speak are both Indo-European (English and Russian). I do not speak any of the other languages presented here. For languages I do not speak, I did my best to not alter examples from the literature or, where I had to alter them, to consult native speakers; I clarify this in footnotes where needed. Even with unaltered examples, when one does not speak the language, the view on the grammar is of course rather narrow, limited to the few examples that were considered. With such a view, it would not be appropriate to make claims about any language as a whole. But remember that this work assumes the method of *fragments* (Montague, 1974), implying that a fragment is meaningful so long as it is fully formalized and extendable (or revisable), and that ultimately the goal of these illustrative grammars is to model a range of typological possibilities, not so much to present individual grammars from a language expert's perspective. The goal of this chapter is primarily to set the scene for the discussion of the library in Chapter 7; without discussing analyses for individual languages first, the description of the library would likely be hard to relate to for readers who are not themselves Grammar Matrix developers. This chapter presents the analyses for individual languages separately so as to make clear how the analyses themselves work. The next chapter then presents how these analyses as well as other possible analyses are obtained automatically from the Grammar Matrix system.

6.1 Question phrases and lexical items. Illustrative languages: English, Russian (Indo-European)

Question words occur in all languages and are usually necessary to form a constituent question (Dryer, 2013b). I use English as the illustrative language for an exposition in this chapter, but indeed any language could be used, and all of the illustrative and artificial languages which are included in this work use this analysis of question words and phrases.

The range of question words I cover in the new constituent questions library for the Matrix includes question pronouns (148)–(150), question determiners (151), and question adverbs (152).[1]

(148) **What** did you do? [eng]

(149) **Who** did you see? [eng]

(150) **Who** saw **whom**? [eng]

(151) In **which** city do you live? [eng]

(152) **Where** did you go? [eng]

When laying out this chapter, I wanted to present lexical types separately from phrasal types, because of the importance of lexical types in a lexicalist framework such as HPSG. I therefore had to decide whether to present the lexical types for question words first (before any full sentence analyses are presented) or last. I decided to present them first, so that in the later sections, the reader can refer back to the lexical types whenever they wonder how exactly the lexical types are involved in the analyses. However this means that in this section, the reader has to assume an analysis at the phrasal level. Because I used English as the illustrative language here, the reader

[1] Question verbs, which only occur in some languages, are also covered and presented separately in §6.9.

can always assume an analysis like in the English Resource Grammar, which was briefly presented in §4.2.1 and which is available via the web demo.[2] I will provide sample simplified trees from the ERG, however the focus of the below sections is on the semantic contribution of the lexical types which is best seen in the MRS figures. The details of how such semantic representations are constructed by the syntax follow in the later sections focusing more on the phrasal types.

Question pronouns

In the analysis I present here, the main function of all question words, including pronouns, is to ensure the sentence containing the word has a semantic structure which reflects a question about the constituent to which the word refers. Recall from §4.1.3 that this is done by introducing a QUE dependency. The QUE dependency helps model the distribution of question words and their correlation with question semantics in several ways: in constraining the filler of the filler-gap rule to being a constituent that contains a question word; in triggering the phrase structure rule that produces question semantics when an *in situ wh*-word is present; and in modeling pied-piping (§2.5.3). In addition, the MRS representation of the sentence (§3.2.2) must include an appropriate quantifier (conventionally coded as which_q_rel in the DELPH-IN formalism) binding the right variable.

Consider a lexical type for *wh*-pronouns, *wh-pronoun-noun-lex* (153).[3]

---

[2]`http://delph-in.github.io/delphin-viz/demo/`.

[3]This analysis is based on one proposed by Emily M. Bender for her grammar engineering course.

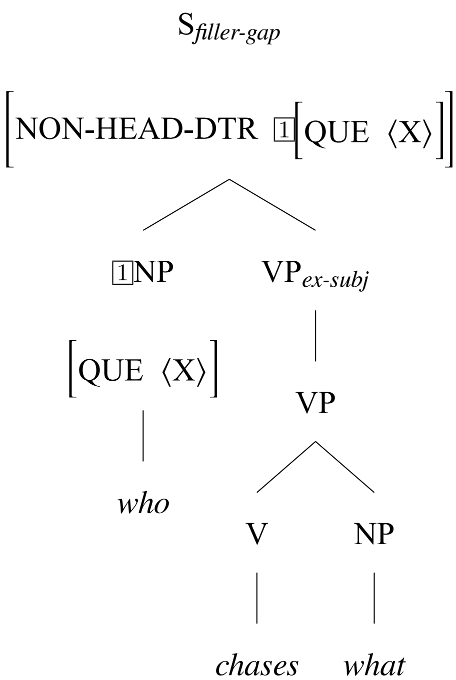
(153)
$$\begin{bmatrix} \textit{wh-pronoun-lex} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{MOD} & \langle\,\rangle \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{LTOP} & \boxed{5} \\ \text{INDEX} & \boxed{4} \end{bmatrix} \\ \text{RELS}|\text{LIST} & \left\langle \boxed{3}\begin{bmatrix} \text{LBL} & \boxed{0} \\ \text{ARG0} & \boxed{1}\,[\textit{ref-ind}] \end{bmatrix}, \begin{bmatrix} \textit{quant-relation} & \\ \textbf{PRED} & \text{which\_q\_rel} \\ \text{RSTR} & \boxed{2} \end{bmatrix} \right\rangle \\ \text{HCONS}|\text{LIST} & \left\langle \begin{bmatrix} \text{HARG} & \boxed{2} \\ \text{LARG} & \boxed{0} \end{bmatrix} \right\rangle \\ \text{ICONS}|\text{LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \\ \text{LKEYS}|\text{KEYREL} & \boxed{3}\begin{bmatrix} \text{LBL} & \boxed{5} \\ \text{ARG0} & \boxed{4} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \textbf{QUE}|\textbf{LIST} & \langle\boxed{1}\rangle \\ \text{REL}|\text{LIST} & \langle\,\rangle \\ \text{SLASH}|\text{LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

This type is like a personal pronoun, except its RELS (relations) list contributes a *which*-quantifier instead of an existential one, and it has a nonempty QUE-list so as to introduce a long-distance dependency, as explained in §4.1.3.[4] Like personal pronouns, this type does not allow determiners or complements, does not itself serve as a specifier or a modifier, and has a quantifying relation in its semantics that is properly linked to the noun predication. Assuming an analysis like in the ERG (154), this lexical entry will give rise to the NP node in the derivation for e.g. the English *who chases what?*, if it is used in an English grammar with the corresponding orthography. I present my version of the analysis later in §6.3.

---

[4]Note that QUE is of type *append-list* (§3.2.1). Using append lists instead of difference lists for nonlocal features is an infrastructural change that I introduce to the system, which will be discussed later in §7.11.1 and §7.11.2. Here, all that matters for the example is that there is an element on the QUE list, so that a long-distance dependency is introduced.

(154)



The sample semantic structure that the question pronoun type enables is shown in Figure 6.1. The main event (chasing) has two arguments which are linked to *which person* and *which thing* (*person* and *thing* relations were supplied by the user; the quantifier comes from (153)).

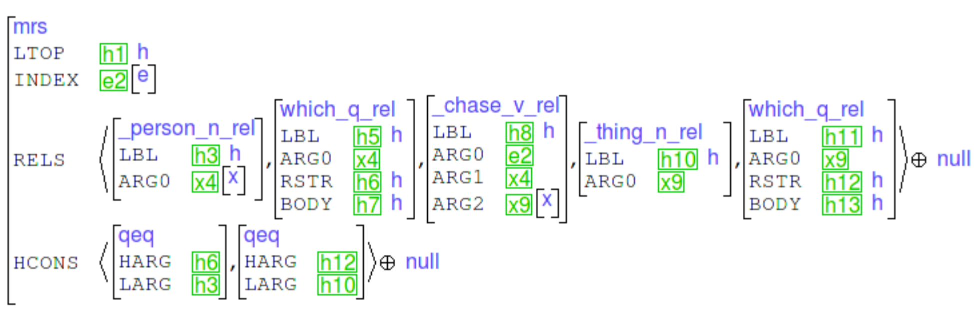


Figure 6.1: The semantic structure for the sentence *Who chases what*.

Question determiners

Question determiners (155)–(157) quantify nouns while creating a question about these nouns. Semantically, they need therefore to introduce quantifiers; syntactically, they may agree with the noun in case/number/gender (157) or not (158).

(155) **Which** person chases **which** thing? [eng]

(156) In **which** city do you live? [eng]

(157)

В	**какой**	Иван	приехал	город?
V	**kakoi**	Ivan	priehal	gorod?
IN	which.SG.ACC	Ivan.NOM	arrive.PAST.3SG	town.SG.ACC

'In which town did Ivan arrive?" [rus]

(158)

Иван	**сколько**	читает	книг?
Ivan	**skolko**	chitaet	knig?
Ivan.NOM	how.many	read.PRES.3SG	book.PL.PARTITIVE

"How many books is it that Ivan is reading?" [rus]

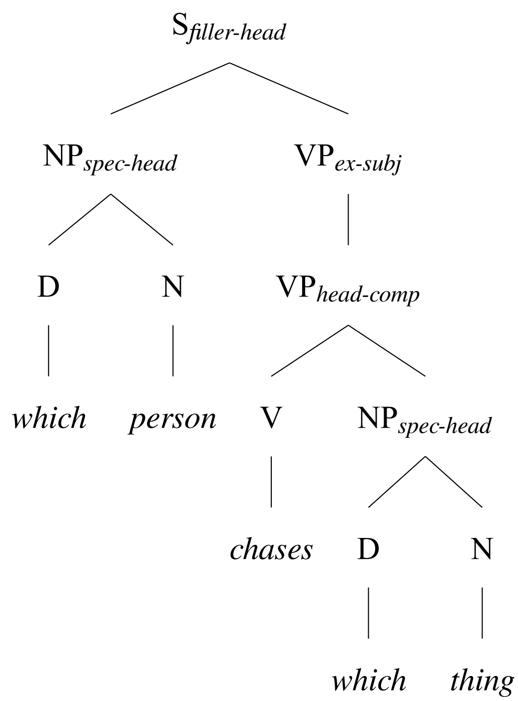
I introduce the following core type which inherits most of its constraints from the already existing Matrix *basic-determiner-lex* supertype. In addition to those, this subtype for question determiners has a nonempty QUE list, the sole element of which is linked to the SPEC's element's index (159), introducing the dependency for the referent of the noun which the determiner quantifies.[5]

[5] The SPEC feature (Pollard and Sag, 1994) is used in HPSG to allow determiners to select for certain properties of nouns to which they serve as specifiers. Compare this to the SPR feature which is used by nouns to select for specifiers.

(159)
$$
\begin{bmatrix}
\textit{wh-determiner-lex} & \\
\text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{det} & \\ \text{MOD} & \langle\,\rangle\end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\,\rangle \\ \textbf{SPEC} & \left\langle \begin{bmatrix} \text{LOCAL.CONT.HOOK} & \begin{bmatrix}\text{LTOP} & \boxed{0} \\ \text{INDEX} & \boxed{1}\end{bmatrix}\end{bmatrix}\right\rangle \\ \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix}\end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix}\text{LTOP} & \boxed{5}\\ \text{INDEX} & \boxed{4}\end{bmatrix} \\ \text{RELS|LIST} & \langle \boxed{3} \rangle \\ \text{HCONS|LIST} & \left\langle\begin{bmatrix}\textit{qeq} & \\ \text{HARG} & \boxed{2} \\ \text{LARG} & \boxed{0}\end{bmatrix}\right\rangle \\ \text{ICONS|LIST} & \langle\,\rangle\end{bmatrix}\end{bmatrix} \\ \text{LKEYS|KEYREL} & \boxed{3}\begin{bmatrix}\textit{quant-relation} & \\ \textbf{ARG0} & \boxed{1} \\ \text{RSTR} & \boxed{2}\end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \textbf{QUE|LIST} & \langle\boxed{1}\rangle \\ \text{REL|LIST} & \langle\,\rangle \\ \text{SLASH|LIST} & \langle\,\rangle\end{bmatrix}\end{bmatrix}
\end{bmatrix}
$$

Assuming an analysis like in the ERG, the semantic structure that the question determiner type enables looks similar to the one for question pronouns (Figure 6.1), although while the pronoun supplies both the quantifier relation and the noun relation from a limited set (_person_n_rel/_thing_n_rel), the which_q_rel relation will now be supplied by the determiner lexical type (159), and the noun relation will be supplied by the quantified noun lexical entry, e.g. _city_n_rel for (156). A sample derivation for (155) is given in (160). The semantic structure for (160) is the same as in Figure 6.1.

(160)



6.1.1 Adverbs (question and not)

To account for sentences like (152), I need a lexical type for non-scopal adverbs. The Grammar Matrix core already implements the distinction between non-scopal (161) and scopal (162) modifiers (Flickinger, 2000, 2011; Crowgey, 2013; Trimble, 2014).[6]

(161) Every dog barked **loudly**. [eng]

(162) That athlete **probably** won every medal. [eng]

The idea is that the interaction between *every* and *probably* allows for two readings: in (162), one reading has to do with the probability of winning each medal independently while the other with the probability of winning all of them as a set. In terms of implementation, this difference is at the level of the MRS (§3.2.2), specifically at the level of quantifier scope (hence the name scopal vs. non-scopal). Non-scopal modifiers share their *labels* (LBL; "handles" which link predications

[6]The first example (161) comes from the DELPH-IN wiki: `http://moin.delph-in.net/ErgSemantics/Design`; the second example (162) was suggested to me by Emily M. Bender.

to particular nodes in the scopal tree (Copestake et al., 2005)) with the heads they modify, and so there is no room for quantifiers to scope in between; the case is different with scopal modifiers (e.g. clausal modifiers).

The only adverbs already in the Grammar Matrix were the ones for the clausal modifiers library (Howell and Zamaraeva, 2018) and the ones used to express negation (Crowgey, 2013); both are scopal. *Wh*-adverbs do not allow for ambiguity like in (162). Therefore I add a new supertype and a new lexical type for non-scopal adverbs like temporal adverbs (163).[7] Note that historically, non-scopal modifiers were called *intersective* in the Grammar Matrix, hence the *intersective-mod* type on the MOD list.[8]

(163)
$$
\begin{bmatrix}
\textit{adverb-lex-item} & \\
\text{SYNSEM} & \begin{bmatrix}
\text{LOCAL} & \begin{bmatrix}
\text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix}
\textit{adv} & \\
\text{MOD} & \left\langle \begin{bmatrix}
\textit{intersective-mod} & \\
\text{LOCAL} & \begin{bmatrix}
\text{CAT|HEAD } \textit{verb} & \\
\text{CONT|HOOK} & \begin{bmatrix} \text{CLAUSE-KEY} & \boxed{3} \\ \text{LTOP} & \boxed{2} \end{bmatrix}
\end{bmatrix}
\end{bmatrix} \right\rangle
\end{bmatrix} \\
\text{VAL} & \begin{bmatrix}
\text{SPR} & \langle\, \rangle \\
\text{SPEC} & \langle\, \rangle \\
\text{SUBJ} & \langle\, \rangle \\
\text{COMPS} & \langle\, \rangle
\end{bmatrix}
\end{bmatrix} \\
\text{CONT} & \begin{bmatrix}
\text{RELS|LIST} & \left\langle \begin{bmatrix} \text{LBL} & \boxed{2} \\ \text{ARG0} & \textit{event} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{1} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \boxed{0} \\ \text{ARG0} & \boxed{1} \\ \text{LBL} & \boxed{4} \end{bmatrix}, \begin{bmatrix} \text{ARG0} & \boxed{1} \\ \text{RSTR} & \boxed{5} \end{bmatrix} \right\rangle \\
\text{HOOK|LTOP} & \boxed{2} \\
\text{HCONS|LIST} & \left\langle \begin{bmatrix} \textit{qeq} & \\ \text{HARG} & \boxed{5} \\ \text{LARG} & \boxed{4} \end{bmatrix} \right\rangle
\end{bmatrix}
\end{bmatrix}
\end{bmatrix} \\
\text{LKEYS|KEYREL} & \begin{bmatrix}
\text{PRED} & \boxed{0} \\
\text{ARG0} & \boxed{1}\begin{bmatrix}\textit{ref-ind}\end{bmatrix} \\
\text{LBL} & \boxed{2}
\end{bmatrix}
\end{bmatrix}
$$

Furthermore, I add subtypes for location (in time and space) and manner adverbs as well as *wh*- and non-*wh*-adverbs (164).

---

[7]A simpler type would be needed for non-temporal adverbs; I do not consider it here.

[8]This use of *intersective* in the Matrix is not precise, but fixing this issue is out of scope of my dissertation. See `http://moin.delph-in.net/ErgSemantics/Design` for the related DELPH-IN discussion.

(164)

$$
\begin{array}{c}
\textit{adverb-lex-item} \\
\begin{array}{cccc}
\textit{loc-adv-lex-item} & \textit{manner-adv-lex-item} & \textit{wh-adv-lex-item} & \textit{non-wh-adv-lex-item}
\end{array}
\end{array}
$$

All these types (165)–(168) ultimately serve as supertypes for the user-defined, customized adverb lexical items.

(165)

$$
\begin{bmatrix}
\textit{non-wh-adverb} \\
\text{SYNSEM} \begin{bmatrix} \text{LOCAL} & \begin{bmatrix}\text{CONT} \begin{bmatrix}\text{RELS|LIST} \left\langle \text{X, Y,} \begin{bmatrix}\text{PRED exist\_q\_rel}\end{bmatrix} \right\rangle \end{bmatrix}\end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix}\text{QUE|LIST } \langle\ \rangle\end{bmatrix} \end{bmatrix}
\end{bmatrix}
$$

(166)

$$
\begin{bmatrix}
\textit{wh-adverb} \\
\text{SYNSEM} \begin{bmatrix} \text{LOCAL} \begin{bmatrix}\text{CONT} \begin{bmatrix}\text{RELS|LIST} \left\langle \text{X,} \begin{bmatrix}\text{ARG0 } \boxed{0}\end{bmatrix}, \begin{bmatrix}\textit{quant-relation} \\ \text{PRED which\_q\_rel}\end{bmatrix} \right\rangle \end{bmatrix}\end{bmatrix} \\ \text{NON-LOCAL|QUE|LIST } \langle \boxed{0} \rangle \end{bmatrix}
\end{bmatrix}
$$

(167)

$$
\begin{bmatrix}
\textit{loc-adv-lex-item} \\
\text{SYNSEM|LOCAL|CONT|RELS|LIST } \left\langle \begin{bmatrix}\text{PRED loc\_nonsp\_rel}\end{bmatrix} \right\rangle
\end{bmatrix}
$$

(168)

$$
\begin{bmatrix}
\textit{manner-adv-lex-item} \\
\text{SYNSEM|LOCAL|CONT|RELS|LIST } \left\langle \begin{bmatrix}\text{PRED manner\_nonsp\_rel}\end{bmatrix} \right\rangle
\end{bmatrix}
$$

For example, a given adverb can be both location and *wh-*, as in the English example (152), or it can be location and non-*wh*, etc. The types for question (166) and non-question (165) adverbs differ in that the non-question one specifies its quantifier relation to be exist_q_rel while the question adverb has the which_q_rel quantifier. The question adverb (166) has a nonempty QUE-list and also links the semantics of the element on that list to its second predication, making a LDD possible in which the referent is the time/location etc., of the event.

The semantics that adverb types are contributing can be seen in Figure 6.2. Note the main (sleeping) event index, *e2*, which is also the first argument of the special relation, loc_nonsp_rel. Note further how this relation has also a second argument which is linked to a noun phrase (in

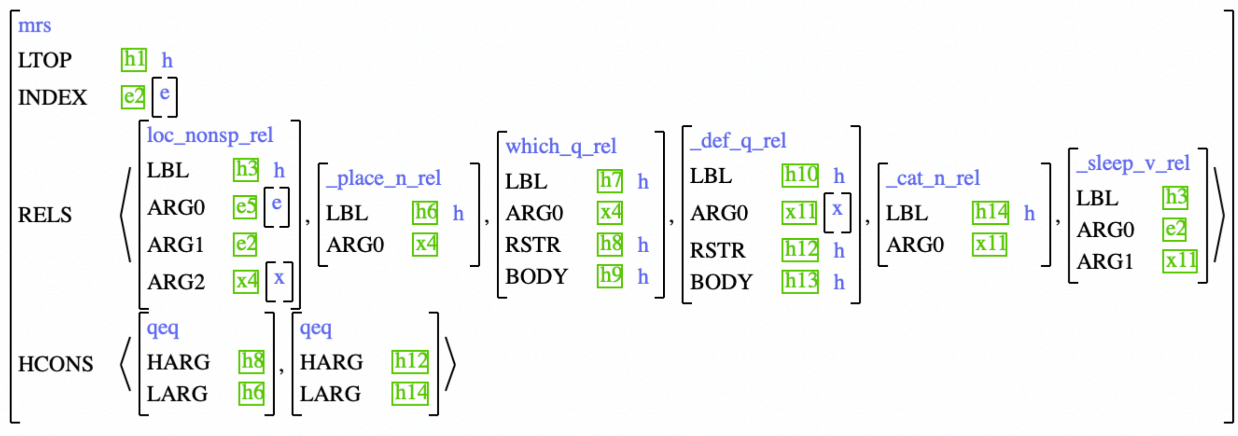


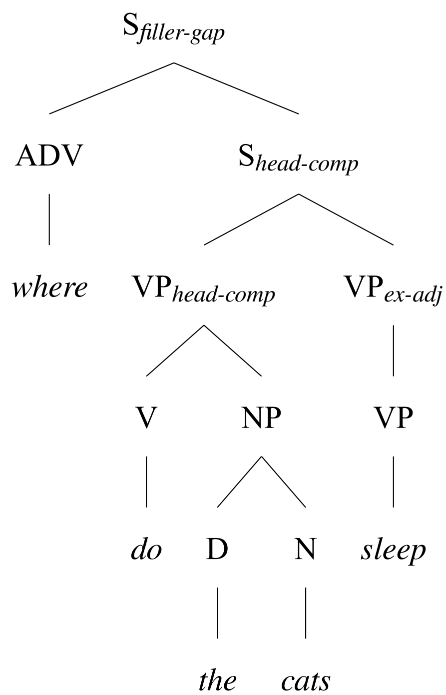
Figure 6.2: The semantic structure for the sentence *Where do the cats sleep*.

this case, a *wh*-phrase). The mechanics of these links is contributed by *adverb-lex-item* while the specifics, such as the relations' names, come from further subtypes *adverb-lex-item* and, in the case of the place relation, from the web questionnaire. This loc_nonsp_rel relation's name, inherited from the English Resource Grammar (Flickinger, 2000), means that something is happening in some location — either in time or space. It comes from the instance of (167). There is an additional relation with predicate value _place_n_rel which comes from user specification (via the questionnaire). The user-supplied specification is pulled into the type by the Lexicon customization system function which I added for adverbs; the function basically knows where to look for the PRED value supplied by the user and inserts that string in the right place in the code for the subtype. This way (167) and (168) can be used by the customization logic as supertypes for user-specified adverb types (see §7.2).

In the ERG, the semantic representation like in Figure 6.2 is obtained via the derivation in (169). In terms of using an extracted adjunct rule and a filler-gap rule, the derivation is similar to what I will present later in §6.3.[9]

[9]I do not discuss the analysis of subject-auxiliary inversion though.

(169)



6.1.2 Adpositions: A non-question lexical type

Question sentences with PP constructions (170) require a lexical type for adpositions in the grammar. Such a type was not present in the Grammar Matrix previously.

(170) **In** which city do you live? [eng]

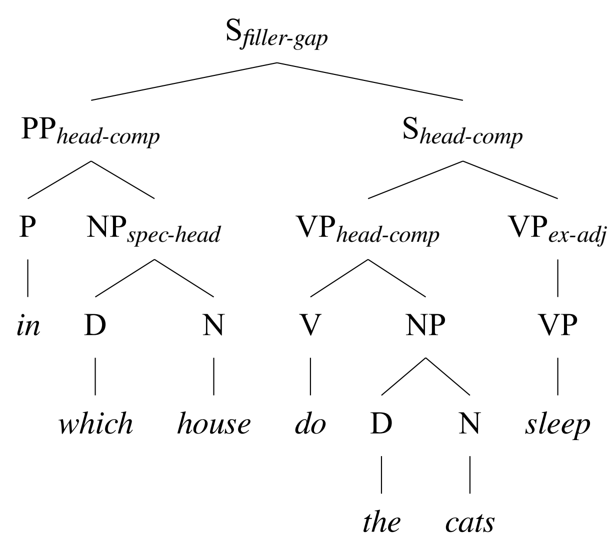
Consider a lexical type presented in (171).

(171)

$$
\begin{bmatrix}
\textit{norm-adposition-lex} & \\
\text{SYNSEM} & \begin{bmatrix}
\text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{adp} & \\ \text{MOD} & \left\langle \begin{bmatrix} \textit{intersective-mod} & \\ \text{LOCAL} & \begin{bmatrix} \text{CAT|VAL|SPR} & \textit{cons} \\ \text{CONT|HOOK|INDEX} & \boxed{5} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \\
\text{VAL} & \begin{bmatrix} \text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \left\langle \boxed{3} \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{VAL|SPR} & \langle\,\rangle \end{bmatrix} & \\ \text{CONT|HOOK|INDEX} & \boxed{0} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK|INDEX} & \boxed{5} \\ \text{RELS|LIST} & \left\langle \begin{bmatrix} \text{PRED } \boxed{2} \\ \text{ARG0 } \textit{event} \\ \text{ARG1 } \textit{event-ot-ref-ind} \end{bmatrix} \right\rangle \\ \text{HCONS|LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}
\end{bmatrix} \end{bmatrix} \\
\text{NON-LOCAL} & \textit{non-local-none} \\
\text{LKEYS|KEYREL} & \begin{bmatrix} \textit{arg12-ev-rel} \\ \text{PRED } \boxed{2} \\ \text{ARG1 } \boxed{5} \\ \text{ARG2 } \boxed{0} \end{bmatrix}
\end{bmatrix} \\
\text{ARG-ST} & \langle \boxed{3} \rangle
\end{bmatrix}
$$

The point of this type is that it has an object-like argument (the VALence feature COMPS) and that it itself can modify other structures (the HEAD feature MOD) and in particular, it can therefore serve as an extracted adjunct, as illustrated by (172).

(172)



A sample semantic structure which the core adposition type provides is shown in Figure 6.3. This structure is provided by the semantic relations list (CONT|RELS) and the identities which are stipulated between the complement's INDEX, the modified structure's INDEX, and the adposition's own semantic ARGuments, ARG1 and ARG2. Note the index *e2*: this is the main verb event's semantic index, and it is the first semantic argument of the adposition which means *in*. Its second semantic argument is the object NP *which house*.

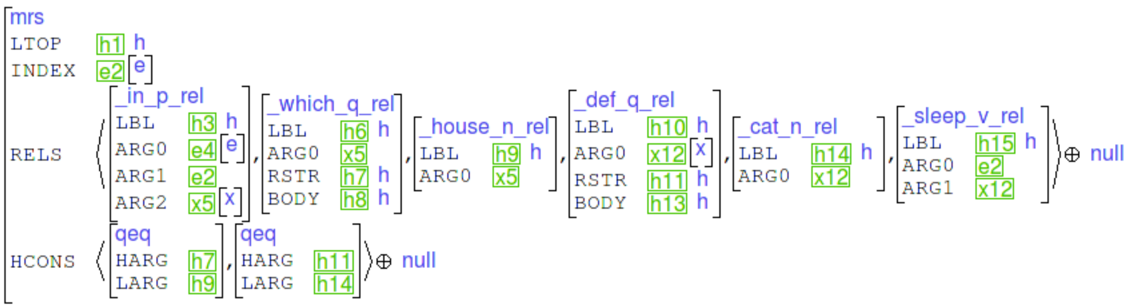


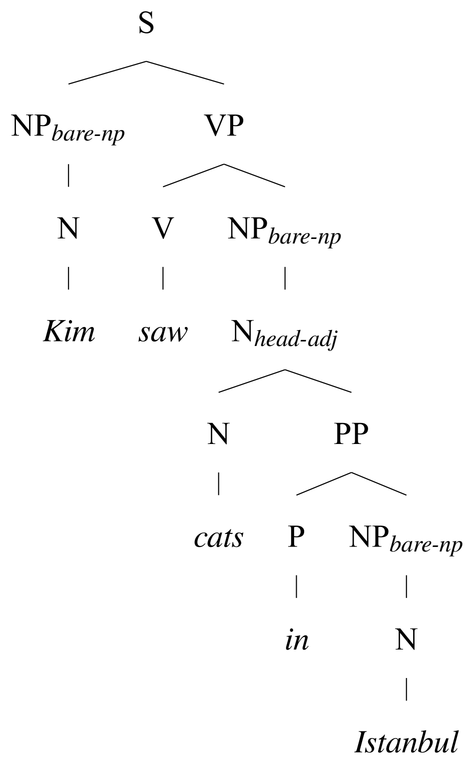
Figure 6.3: The semantic structure for the sentence *In which house do the cats sleep*.

Consider now cases where the PP modifies not a verb but a noun, like in one of the possible readings of (173) indicated by the square brackets.

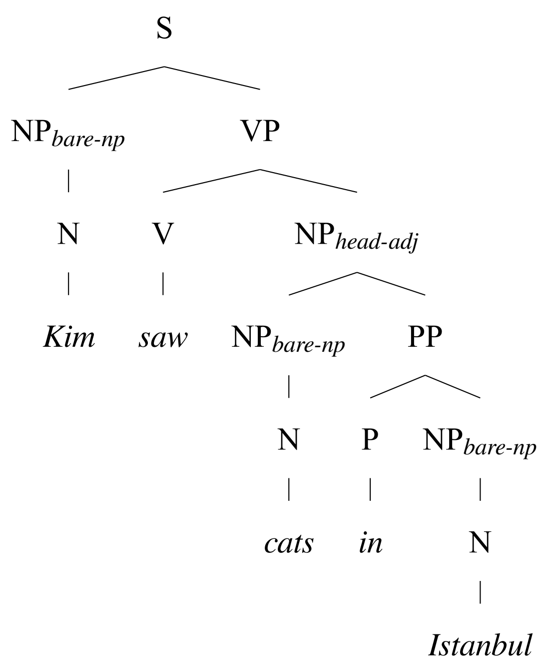
(173) Kim saw [cats in Istanbul]. [eng]

In such cases, the question arises, whether the adposition must attach low (174) or high (175) with respect to the NP (if only for the simple reason that having two trees yielding the same semantics would be meaningless).

(174)

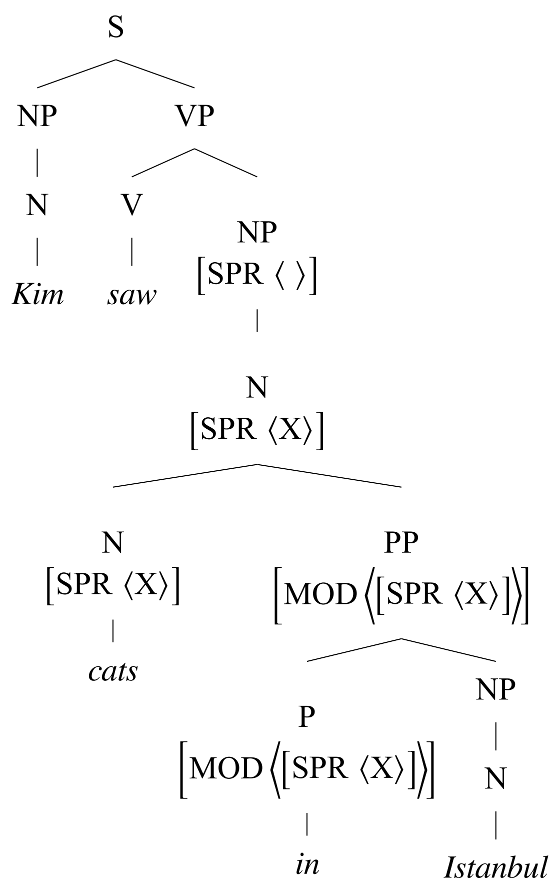


(175)



I assume, following Bender et al. (2005) and the ERG (Flickinger, 2000, 2011), that adpositions must modify the noun before the determiner attaches to the modified noun — hence the nonempty (*cons*) SPR constraint on the MOD;[10] it means the structure could not be a noun phrase. So, for the English sentence (173), (177) should be ruled out and only (176) should be allowed by the grammar. This is not an arbitrary choice; Bender et al. (2005) argue that, given data from Turkish, modifiers need to be able to outscope determiners.[11]

(176)

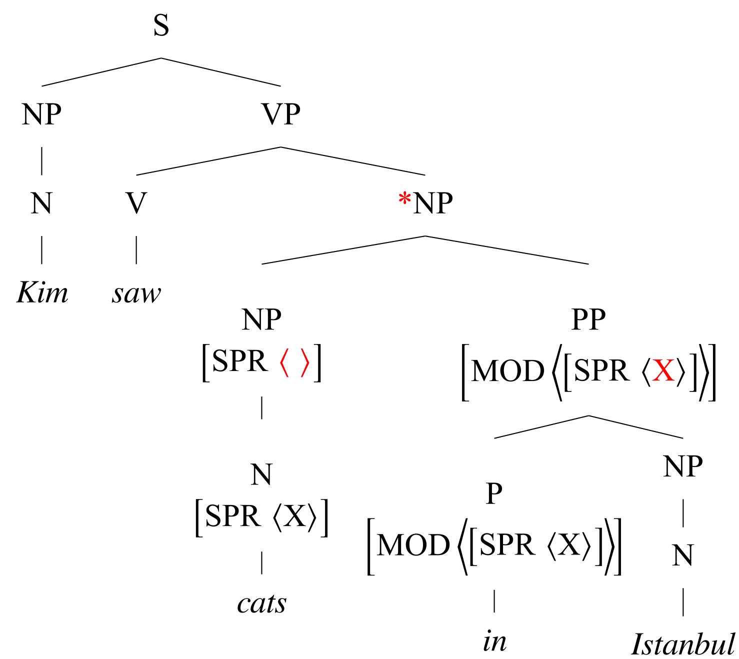


[10]*Cons* is a list of one or more elements in the DELPH-IN formalism (77).

[11]The example Bender et al. (2005) use is (i):

(i) olası bir sonuç
probable one outcome
'one probable outcome' [tur]

(177)



Adpositions do not introduce any nonlocal dependencies and therefore their NON-LOCAL feature is of type *non-local-none* (178).[12]

(178) $$\begin{bmatrix} \textit{non-local-none} & \\ \text{SYNSEM|NON-LOCAL} & \begin{bmatrix} \text{SLASH|LIST} & \langle\,\rangle \\ \text{QUE|LIST} & \langle\,\rangle \\ \text{REL|LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix}$$

In the context of this work I did not model the distinction between pre- and post- modifiers in the questionnaire so a grammar of English output by the system will admit both (179) and (180), for example. This contrast can be modeled in the future with the POSTHEAD feature which is already part of the Matrix core, following the ERG (Flickinger, 2000, 2011).

(179) a tunnel under the city [eng]

(180) *an under the city tunnel [eng] (Hegedus, 2016)

Finally, pied-piping is discussed later in §6.3.5 and §6.5.3. This concludes the overview of lexical types I include in my analysis of constituent questions.

---

[12]This core type was already present in the Matrix.

6.1.3 Interim summary

The previous section described my analysis for question words as a part of the constituent questions library for the Grammar Matrix. The main purpose of these types is to introduce a dependency between the event and the referent of the question word by virtue of having nonempty QUE-list (as explained in §4.1.3). So far, most examples I gave came from English, assuming an analysis similar to that in the ERG (§4.2.1), however the same analysis will be used for all languages in the context of the actual analysis I implement for the Grammar Matrix.

6.2 Constituent questions in complex clauses. Illustrative language: English (Indo-European)

Perhaps one of the most interesting things about constituent questions is the fact that they can include long-distance dependencies. Data which most clearly illustrate the unbounded nature of fronting (that question phrases can cross several clause boundaries) necessarily has complex clauses (181).

(181) Who do you think Kim believes Sandy saw? [eng]

This means that, in order to model constituent questions in the Matrix, I need to rely on an analysis of clausal complements, which is what I discuss in this section.

As a starting point for modeling the differences between clause-embedding verbs like *think, know*, and *wonder* (182)–(185), I add verb subtypes which specify the sentential force SF feature (§4.2.1) on the verb's complement (186)–(187).

(182) I know who arrived. [eng]

(183) *I think who arrived. [eng]

(184) I ask who arrived. [eng]

(185) *I ask Kim arrived. [eng]

Verbs like *ask* will be of type (186); verbs like *think* of type (187); verbs like *know* will have two lexical entries, one of each type.

(186) $\begin{bmatrix} \textit{question-embedding-verb} \\ \text{SYNSEM|LOCAL|CAT|VAL|COMPS} \left\langle \begin{bmatrix} \text{SF} & \textit{ques} \end{bmatrix} \right\rangle \end{bmatrix}$

(187) $\begin{bmatrix} \textit{proposition-embedding-verb} \\ \text{SYNSEM|LOCAL|CAT|VAL|COMPS} \left\langle \begin{bmatrix} \text{SF} & \textit{prop} \end{bmatrix} \right\rangle \end{bmatrix}$

This provides proper semantics for grammatical sentences; however the SF constraint is not enough to rule out ungrammatical sentences like (185), so, this analysis goes only part of the way and should be considered merely auxiliary in the context of modeling constituent questions in the system.

In the Grammar Matrix, following the ERG (Flickinger, 2000), modeling such differences cannot be done solely in terms of the semantic SF feature, because simple clauses formed by head-subject and head-complement rules are going to be [SF *prop-or-ques*] (as explained in §4.2.1). This means any structure licensed by a head-subject or a head-complement rule will unify with the complement of a proposition-embedding verb as well as a question-embedding verb. The SF feature is still important because after the structure is unified with the clausal complement of a particular verb, it will no longer be underspecified and will contribute to the correct semantics of the whole clause. But additional work is needed to rule out ungrammatical sentences.[13] To summarize, under this analysis, it is possible to model embedded questions to a degree, but the purpose of the analysis is not to demonstrate the contrast between different clause-embedding verbs, and the analysis is limited with respect to this contrast.

6.3 Single obligatory fronting of question phrases. Illustrative language: English (Indo-European)

Question phrase fronting is one of the most salient syntactic characteristics of constituent questions. In this dissertation, I offer analyses for two illustrative languages, English and Russian, both Indo-European, both featuring question phrase fronting.

[13] In the current implementation of my analysis, some of these ungrammatical sentences will be ruled out thanks to the WH feature which tracks whether there is any *wh*-word in any position in the sentence (§277,§6.7.3). But such use of this feature is perhaps not sufficiently motivated; for one thing, it will only rule out embedding constituent questions but not polar questions; it also will rule out grammatical sentences which contain *wh*-words but which are not questions themselves.

English is a language which obligatorily fronts one question phrase (188)–(193).

(188) Who saw what? [eng]

(189) What did Kim see? [eng][14]

(190) *Kim saw what? [eng]

(191) *Who what saw? [eng]

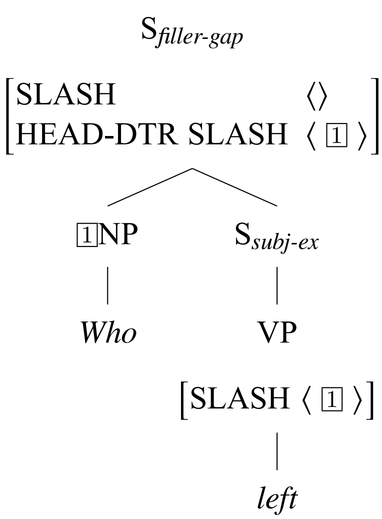
(192) Who do you think Kim saw? [eng]

(193) *Do you think who Kim saw? [eng]

Recall from §4.2.1 that an analysis for (194) in the ERG looks like (132) repeated here as (195). The SLASH dependency is introduced by the subject extraction rule (the "bottom" level of the LDD analysis (§4.1.1)); the dependency is ultimately realized by the filler-gap rule (the "top" level of the analysis).

(194) Who left? [eng]

(195)



[14]I do not cover English subject-auxiliary inversion in this work. The way English does subject-auxiliary inversion seems typologically rare, with this kind of auxiliary only showing up in special constructions such as questions. Ilja Seržant (p.c.) pointed me also to some German and Norwegian dialects which do something similar in anaphoric use (*Magst du das? Ja, das tue ich.* ('Are you going to eat? Yes, I am.')). The code which accompanies this

With respect to the “bottom” and the “top” levels of the LDD, (195) basically represents the analysis which I adopt for such languages for the Grammar Matrix. Most of the lexical and phrasal types, with the exception of *wh-ques-phrase* were already available to me in the Matrix core.

6.3.1 Extraction rules

Following the ERG (Flickinger, 2000, 2011) (§4.2.1), my analysis of the “bottom” of the SLASH dependency for languages like English relies on separate *extraction rules*: subject extraction, complement extraction, and adjunct extraction. All of these types use the type *gap* (196), but unlike Bouma et al. (2001a), Ginzburg and Sag (2000), and the ERG (Flickinger, 2000, 2011), I do not use SLASH amalgamation (lexical threading; §4.1.2).

The subject extraction, the complement extraction, and the adjunct extraction phrase structure rules are presented in (197)–(199). The subject extraction rule takes as its head daughter a verb-headed structure with a nonempty SUBJ list and introduces a nonlocal SLASH dependency with the LOCAL value of the subject, while making the actual SUBJ list empty (saturated). The complement extraction rule shortens the complements list (COMPS) by one element, and the adjunct extraction rule essentially says that what is on its SLASH list can modify the head daughter. All these types were reviewed in §4.2.1.

(196)
$$\left[\begin{array}{ll} \textit{gap} & \\ \text{SYNSEM} & \left[\begin{array}{ll} \text{LOCAL} & \boxed{1} \\ \text{NON-LOCAL}|\text{SLASH}|\text{LIST} & \langle \boxed{1} \rangle \end{array}\right] \end{array}\right]$$

(197)
$$\left[\begin{array}{ll} \textit{extracted-subj-phrase} & \\ \text{SYNSEM} & \left[\begin{array}{ll} \text{LOCAL}|\text{CAT}|\text{VAL}|\text{SUBJ} & \langle\, \rangle \\ \text{NON-LOCAL}|\text{SLASH}|\text{APPEND} & \left\langle \boxed{0}\,, \left[\text{LIST}\ \langle \boxed{1} \rangle\right] \right\rangle \end{array}\right] \\ \text{HEAD-DTR}|\text{SYNSEM} & \left[\begin{array}{ll} \text{LOCAL}|\text{CAT}|\text{VAL}|\text{SUBJ} & \left\langle \left[\begin{array}{l} \textit{gap} \\ \text{LOCAL}\ \boxed{1} \end{array}\right] \right\rangle \\ \text{NON-LOCAL}|\text{SLASH} & \boxed{0} \end{array}\right] \end{array}\right]$$

---

dissertation will output grammars specified for subject-auxiliary inversion via the questionnaire, which does make that option available; the English development grammar with which I tested my analyses does include it. But the

(198)
$$\begin{bmatrix} \textit{extracted-comp-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\mid\text{CAT}\mid\text{VAL}\mid\text{COMPS} & \boxed{0} \\ \text{NON-LOCAL}\mid\text{SLASH}\mid\text{APPEND} & \left\langle \boxed{1}, \left[\text{LIST}\ \langle \boxed{2} \rangle\right] \right\rangle \end{bmatrix} \\ \text{HEAD-DTR}\mid\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\mid\text{CAT}\mid\text{VAL}\mid\text{COMPS} & \begin{bmatrix} \text{FIRST} & \begin{bmatrix} \textit{gap} & \\ \text{LOCAL} & \boxed{2} \end{bmatrix} \\ \text{REST} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL}\mid\text{SLASH} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

(199)
$$\begin{bmatrix} \textit{extracted-adj-phrase} & \\ \text{SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT}\mid\text{HEAD} & \boxed{1} \\ \text{CONT}\mid\text{HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC}\mid\text{SLASH}\mid\text{LIST} & \left\langle \begin{bmatrix} \text{LIST} & \left\langle \begin{bmatrix} \text{CAT}\mid\text{HEAD}\mid\text{MOD} & \left\langle \begin{bmatrix} \text{LOC} & \begin{bmatrix} \textit{intersective-mod} & \\ \text{CAT}\mid\text{HEAD} & \boxed{1} \\ \text{CONT}\mid\text{HOOK} & \boxed{2} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \\ \text{MODIFIED} & \textit{hasmod} \end{bmatrix} \\ \text{HDR}\mid\text{SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT}\mid\text{HEAD} & \boxed{1} \\ \text{CONT}\mid\text{HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC}\mid\text{SLASH} & \langle\ \rangle \\ \text{MODIFIED} & \textit{notmod} \end{bmatrix} \end{bmatrix}$$

In the sense that they introduce a SLASH dependency, I use these types exactly as they were in the ERG and as they were originally in the Matrix core.[15] The main difference between the ERG analysis and my analysis with respect to these rules is that I use append lists instead of difference lists (§3.2.1). Append lists are discussed in more detail in §7.11.1–§7.11.2. For the purposes of this section, it does not matter whether difference lists or append lists are used for nonlocal features, the result is the same.

6.3.2 *Propagating nonlocal features*

The "middle" level of the HPSG analysis of LDD is concerned with how the nonlocal feature values such as SLASH are propagated up the derivation tree. Note that, while both subject (197)

subject-auxiliary analysis is a work in progress and was implemented minimally, simply to support the extraction and fronting in the real English examples. Presenting the analysis here would not serve much purpose. For a fully functional and well-tested analysis of English subject-auxiliary inversion, see the ERG (Flickinger, 2000, 2011).

[15]There is one difference which I introduced by mistake and which remains in the system as of the time of this writing. As of the time of this writing, *extracted-adj-phrase* constrains the head daughter to be LIGHT +, which

and complement (198) extraction rules use the type *gap* (196), they also explicitly put the extracted element on the SLASH list. In the ERG (§4.2.1), this was different, as the ERG follows Bouma et al. 2001a in implementing the nonlocal amalgamation (lexical threading) mechanism, which means there is no need to explicitly mention the SLASH value on the mother in e.g. the extraction rules such as (197). In other words, in terms of the "middle" tier of the LDD mechanism, my analysis departs from the ERG. In particular, I do not use lexical threading (§4.1.2).

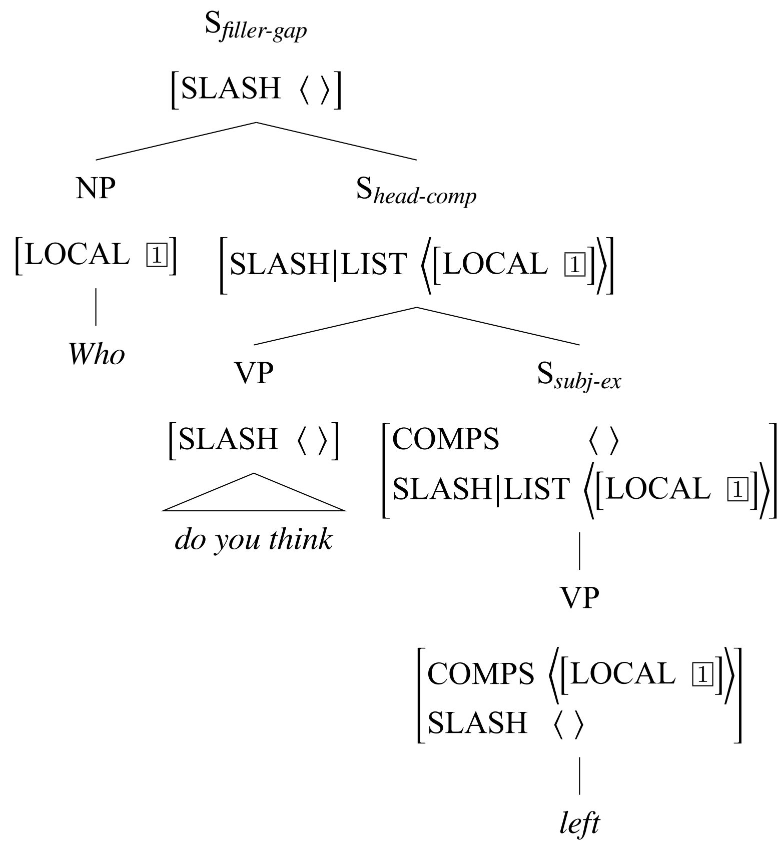
Under my analysis, the nonlocal feature values are propagated explicitly on the phrasal level. This choice is further explained in the section about multiple fronting languages (§6.5); the infrastructural changes to the Grammar Matrix system related to this choice are summarized in §7.11.2. In the meantime, consider two supertypes (200)–(201) which I posit to implement such propagation. Most phrasal types, such as subject-head and complement-head, as well as adjunct-head, inherit from (200) under my analysis. This means the nonlocal features of both daughters (ARGS) will be appended to create the mother's nonlocal lists. Lexical and other unary rules (except extraction rules) inherit from (201), which means the mother simply inherits the daughter's features. In combination with the extraction rules as presented above in (197)–(198) and with the filler-gap rule presented as (203) in §6.3.3, I have the analysis of obligatory single fronting as in (195) as well as in (202).

(200)
$$\begin{bmatrix} \textit{binary-non-local-phrase} & \\ \text{ARGS} & \left\langle \begin{bmatrix} \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH} & \boxed{1} \\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH} & \boxed{4} \\ \text{REL} & \boxed{5} \\ \text{QUE} & \boxed{6} \end{bmatrix} \end{bmatrix} \right\rangle \\ \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH}|\text{APPEND} & \langle \boxed{1}, \boxed{4} \rangle \\ \text{REL}|\text{APPEND} & \langle \boxed{2}, \boxed{5} \rangle \\ \text{QUE}|\text{APPEND} & \langle \boxed{3}, \boxed{6} \rangle \end{bmatrix} \end{bmatrix}$$

means it must be a word, e.g. a word without complements, a V rather than a VP. While this accidentally leads to some expected and desirable behavior in some development grammars, it prevents other grammars from working correctly, as discussed in §8.5.9 on p. 343. The LIGHT feature is not shown in (199), but when this issue is addressed, the type should probably propagate the LIGHT value from daughter to mother.

(201) $$\begin{bmatrix} \textit{unary-non-local-phrase} & \\ \text{DTR}|\text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix}\text{SLASH} & \boxed{1}\\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3}\end{bmatrix} \\ \text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix}\text{SLASH} & \boxed{1}\\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3}\end{bmatrix} \end{bmatrix}$$

(202)



6.3.3 The filler-gap phrase

Following the ERG (Flickinger, 2000, 2011) (§4.2.1), my analysis of the "top" of the SLASH dependency relies on the *filler-gap* phrasal type. Example (203) shows the version of the type which works, as a supertype, for the presented analysis of English as well as other single-fronting languages. This type was already available for me to use in the Matrix core.[16]

(203) $$\begin{bmatrix} \textit{filler-gap-phrase} & \\ \text{SLASH} & \langle\ \rangle \\ \text{ARGS} & \left\langle \boxed{1}\ , \begin{bmatrix}\text{SLASH|LIST}\ \ \langle\boxed{1}\rangle\end{bmatrix} \right\rangle \end{bmatrix}$$

This phrasal type discharges the SLASH dependency. However, for an analysis of constituent questions, QUE dependencies are also important (§4.1.3). To discharge also the QUE dependency, I add to the Matrix core a subtype of the filler-gap phrase, the *wh-ques-phrase*. The *wh-ques-phrase* (204) is a subtype of *filler-gap-phrase* (203) and *interrogative-clause* (137). As such, it constrains the structure's sentential force to *ques* and licenses structures where an argument or an adjunct had been extracted and dislocated. I only posit a head-final version of phrase as sentence initial position of question phrases is typical (Dryer, 2013b) and I only had that option represented in the languages I tested the analysis on (including held-out languages, §5.10), but of course a head-initial version could be posited if needed. Apart from the constraints provided by its supertypes, the phrase specifies some category information, valence information on the head daughter, and the fact that the non-head daughter (the extracted constituent) is a question phrase by requiring it to have a nonempty QUE value (204).

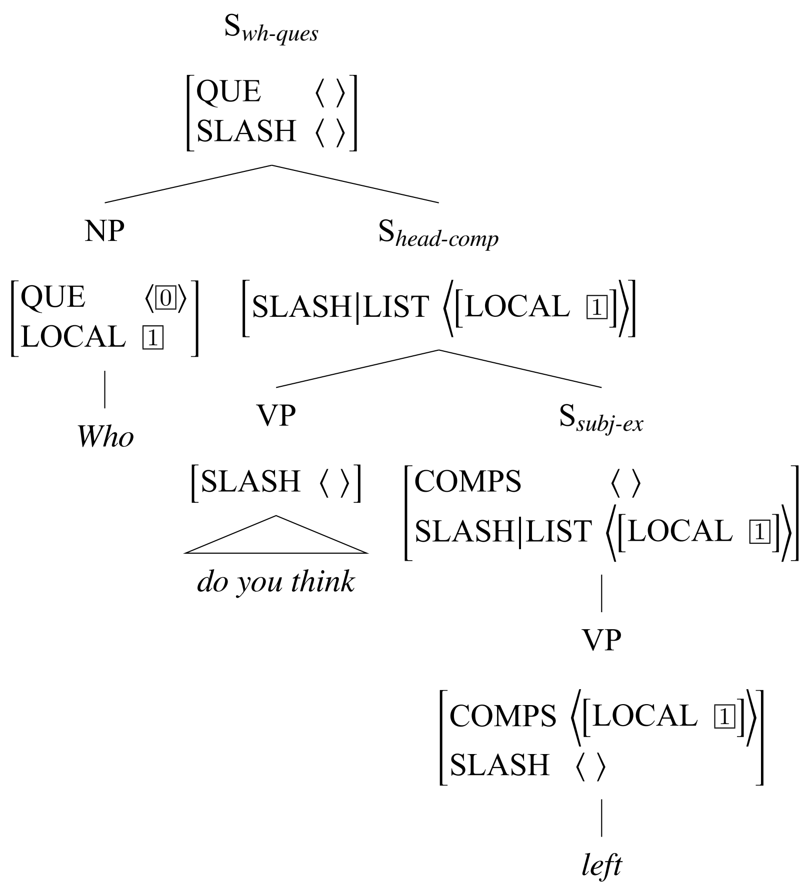
[16] Except it was stated in difference list terms; see §7.11.2. Note also that the filler-gap type is not really "core"; not all languages front constituents. This is an example of an inconsistency between the concept of the "core" and the implementation.

(204)
$$\left[\begin{array}{ll}
\textit{wh-ques-phrase} & \\
\text{SYNSEM} & \left[\begin{array}{ll}
\text{LOCAL} & \left[\begin{array}{ll}
\text{CAT} & \left[\begin{array}{ll}\text{HEAD} & \textit{verb}\\ \text{MC} & \textit{bool}\\ \text{VAL} & \boxed{0}\end{array}\right]\\
\text{CONT|HOOK|INDEX|SF} & \textit{ques}
\end{array}\right]\\
\text{NON-LOCAL} & \left[\begin{array}{ll}\text{QUE|LIST} & \langle\,\rangle\\ \text{SLASH|LIST} & \boxed{2}\end{array}\right]
\end{array}\right]\\
\text{HEAD-DTR|SYNSEM} & \left[\begin{array}{ll}
\text{LOCAL|CAT} & \left[\text{VAL}\ \boxed{0}\left[\begin{array}{ll}\text{SUBJ} & \langle\,\rangle\\ \text{COMPS} & \langle\,\rangle\end{array}\right]\right]\\
\text{NON-LOCAL|SLASH|LIST} & \left[\begin{array}{ll}\text{FIRST} & \boxed{1}\\ \text{REST} & \boxed{2}\langle\,\rangle\end{array}\right]
\end{array}\right]\\
\text{NON-HEAD-DTR|SYNSEM} & \left[\text{LOCAL}\ \boxed{1}\left[\text{NON-LOCAL|QUE|LIST}\ \langle \textit{ref-ind}\rangle\right]\right]
\end{array}\right]$$

Note that the *wh-ques-phrase* “zeroes out” the QUE-list on the mother regardless of how many QUE-elements were on either daughter. In Ginzburg and Sag’s (2000) analysis, the assumption was that all *in situ* question words have empty QUE sets, and so there could never be a situation when the QUE-list of the head daughter would be nonempty. In my analysis, *contra* Ginzburg and Sag (2000), all question words have nonempty QUE-lists (§6.1). With respect to languages like English, the main benefit of this assumption is that there is then no need for duplicate lexical entries for question words that can appear *in situ* (the pros and cons of this assumption for my analysis of multiple fronting are discussed in §6.5). But under this analysis, it is not possible to assume that the head daughter’s QUE list is empty, and so *wh-ques-phrase* must either pass up the head daughter’s value or discharge all of the values. Passing up nonempty QUE values from the head daughter would mean some other rule would then have to discharge them, even though there are no more fronted elements. For this reason, in my analysis, *wh-ques-phrase* discharges all QUE values of both daughters.

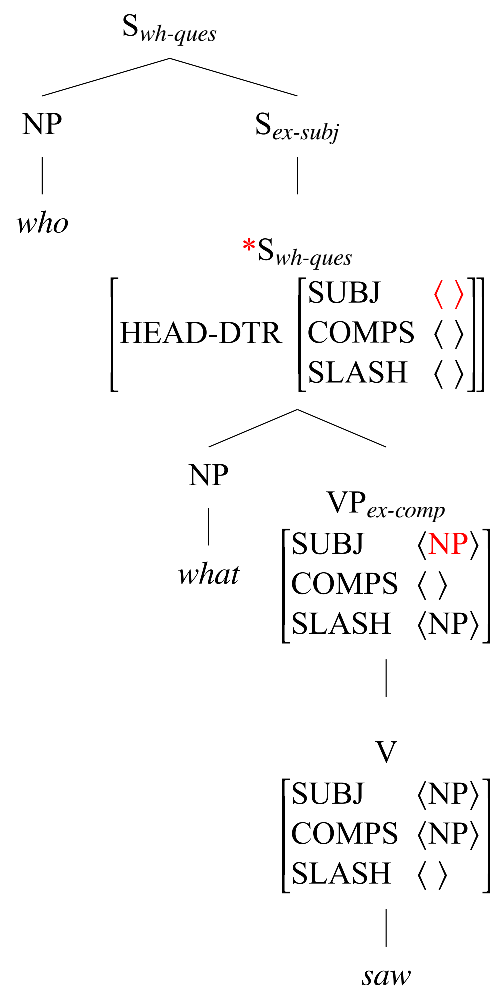
A more detailed visualization of the analysis shown in (202) is presented in (205), with the instance of *wh-ques-phrase* rather than its *filler-gap* supertype. With *wh-ques-phrase*, sentences like **Kim do you think left* are not admitted because *Kim* would have an empty QUE list; the analysis of topicalization is beyond the scope of my work but it would involve a different subtype of the *filler-gap* phrase.

(205)



Note that while the *wh-ques-phrase* (204) shows the SLASH list explicitly in terms of FIRST and REST, the length of its head daughter's SLASH list is strictly 1 and the mother's SLASH list is strictly empty. Later in §6.5, only a slight change to the type as presented here will accommodate multiple question phrase fronting. For single-fronting languages, this constraint on the length of the SLASH list in combination with the constraint that the valence (VAL) lists all be empty ensure that only one argument can be extracted. For them to be both extracted low in the tree would require the SLASH list to be longer than 1 (which is prohibited), but also, the *wh-ques* rule as stated cannot apply if either subject or object are still on the valence list. Note that, if it were not for the VAL constraint, the *wh-ques* phrase would subtract an element from the SLASH list making it again available for extraction and then for filling the gap, multiple times, as illustrated in (206).

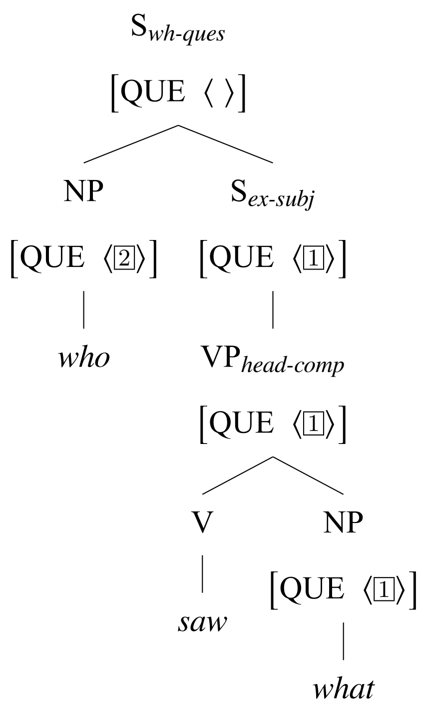
(206)



6.3.4 Multiple questions

Another thing to consider here is how to license multiple question sentences like *Who saw what?* (188). Recall that in Ginzburg and Sag (2000), the *in situ wh*-words have empty QUE sets (§4.1.3) and so the head-complement rule constrains its non-head daughter to be QUE empty which does not mean it could not be a *wh-* word; what it means is, it must be an *in situ* word. My analysis is different (so is the analysis in the ERG). I do not posit any additional lexical entry for *what*, and therefore must allow the head-complement rule to take *wh*-phrases as non-head daughters. This does not cause any issue given that the filler-gap rule zeroes out the QUE-list (204); it does not matter how many *wh*-words are in the head daughter structure, so long as they are complements or adjuncts. The sentence (188) is then analyzed simply as (207).

(207)



The subject-head rule however needs to say that its non-head daughter is not a *wh*-word (208).

(208) $$\begin{bmatrix} \textit{subj-head-phrase} \\ \text{HEAD-DTR}|\text{SYNSEM}|\text{CAT}|\text{VAL}|\text{SUBJ}\ \langle \boxed{1} \rangle \\ \text{NON-HEAD-DTR}\ \boxed{1}\begin{bmatrix}\text{NON-LOCAL}|\text{QUE}\ \langle\ \rangle\end{bmatrix} \end{bmatrix}$$

This is in order to ensure that sentences with *wh*-subjects are analyzed only via the filler-gap rule, not also via the subject-head rule (see the argument from Bouma et al. (2001a), §4.1.2, p. 96).

6.3.5 Pied-piping

Recall from Chapter 2 that Ross (1967) called “pied-piping” the phenomenon where the language requires (209a)–(209b) or allows (210a)–(210b) that a fronted *wh*-word be extracted not on its own but along with the noun that it serves as a specifier for (209a) — or the adposition for which it serves as the complement (210a).

(209) a. Which book did you read? [eng]

b. *Which did you read book? [eng]

(210) a. In which house do the cats sleep? [eng]

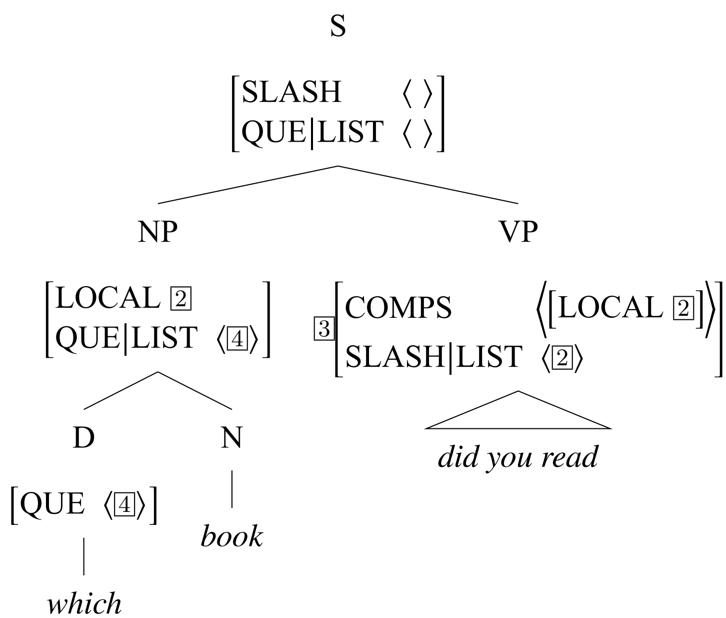
b. Which house do the cats sleep in? [eng]

Recall now from §4.1.3 that the nonlocal feature QUE introduces a LDD at the level of the question word. It is a nonlocal feature, and so it is passed up the derivation tree like other nonlocal features, thanks to phrasal types inheriting from types like (200) and (201). Combined with the SLASH LDD analysis presented above in §6.3.1, this yields (212) as well as appropriate trees for sentences with deeper nested noun phrases like (115) repeated here as (211).

(211) I wonder [[[whose cousin's] friend's] dog] ate the pastry. [eng] (Ginzburg and Sag, 2000, p.184)

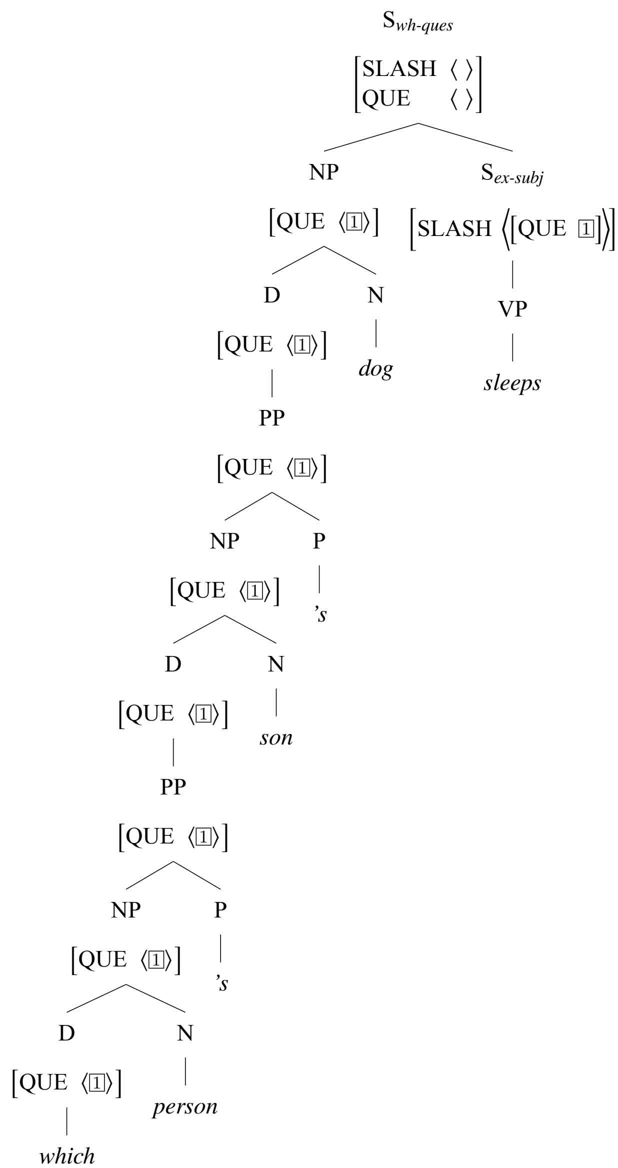
At the same time, sentences like (209b) are ruled out because there is no determiner extraction rule in the grammar; only subjects, objects, and adjuncts can be extracted (§6.3.1).

(212)



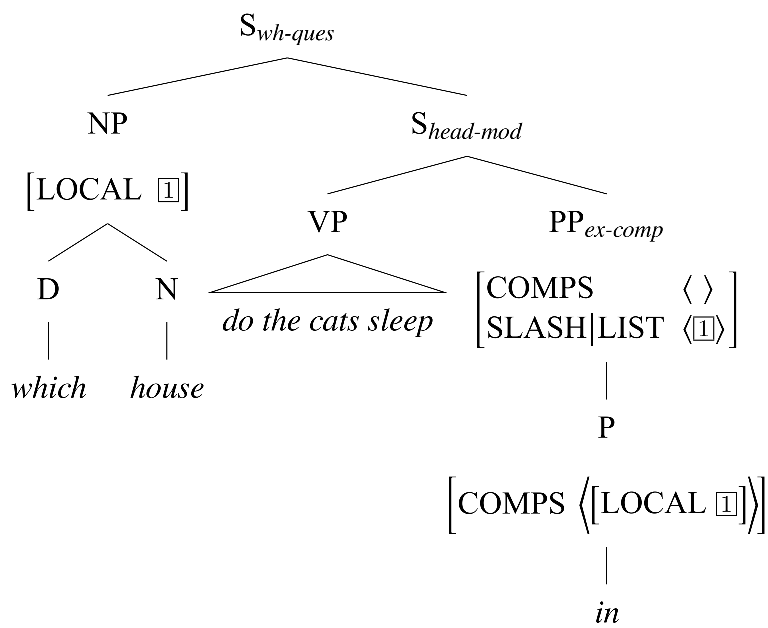
Given the lexical types for question words as presented in §6.1 (all question words have a nonempty QUE value), there is nothing else that needs to be done to yield (212) or a similar tree for (211), assuming an appropriate analysis of the English noun phrase, in particular of adnominal possession. I use the analysis provided for the Grammar Matrix by Nielsen (2018) and present a sample derivation in (213) (see §7.10.3 for the documentation of the minor fixes I introduce there).

(213)



Furthermore, the optional pied-piping of adpositions (210a)–(210b) follows automatically from the analysis of complement extraction as presented in §6.3.1. Since any complement can be extracted by the complement extraction rule as presented in (198), a noun complement can be extracted from an adposition's COMPS list and then the sentence can be realized as filler-gap construction (214).

(214)



6.3.6 Interim summary

This section presented a fragment analysis of English focused on licensing long-distance questions (§2.4). The core of the analysis is essentially the same as in the ERG (Flickinger, 2000, 2011)[17] and it relies on extraction rules, a subtype of the filler-gap rule, and lexical entries for question words which have nonempty QUE values, for precise application of the filler-gap rule and for pied-piping. My analysis, unlike the ERG, does not use lexical threading, a choice which I motivate in the section dedicated to multiple fronting analysis (§6.5). The summary of customization for other similar languages is presented in §7.5. The next section presents an analysis fragment of an *in situ* language, Japanese.

6.4 In situ questions. Illustrative language: Japanese (Japonic)

In Japanese, an SOV language, question phrases remain *in situ* (215)–(216).

(215) Dare ga kuru no?
who NOM come Q
'Who will come?' [jpn] (Miyagawa, 1987)

---

[17]The ERG is a broad coverage grammar and covers a lot more than my Matrix development English fragment.

(216) Mary-wa [John-ga **nani-o** yonda to] itta-no?
Mary-TOP John-NOM **what**-ACC read that said-Q
'What did Mary say that John read?' [jpn] (Pesetsky, 1987)

Example (216) presents a long-distance question; the question word here is the parameter of the matrix clause. But unlike in fronting languages, the question word does not front and remains in the embedded clause in the canonical object position.

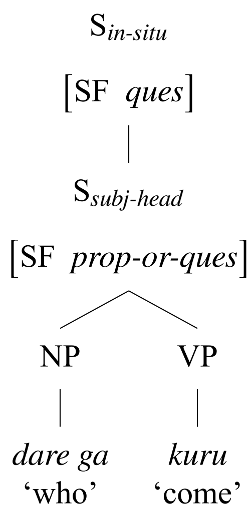
The *in-situ-ques* type presented below as (217) is a unary phrase structure rule which turns propositions into questions; Ginzburg and Sag (2000) have a version of this rule in their analysis (see example (128)). Under the analysis presented here,[18] examples like (215) and (216) are analyzed using the *in-situ-ques* type (217), which is a unary rule and a subtype of *interrogative-clause* (137). This unary rule projects a declarative structure with a nonempty QUE-list to a QUE-empty interrogative structure (217)–(218).

(217)
$$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}|\text{LIST} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0} \begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}|\text{LIST} & \langle \textit{ref-ind}, \ldots \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

---

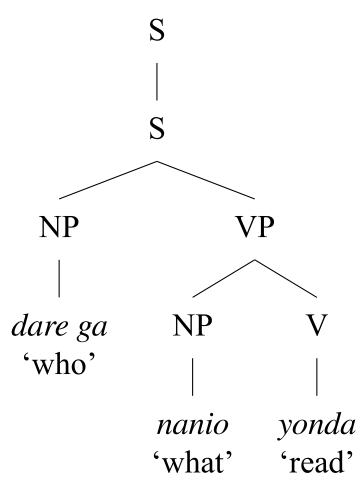
[18]The basic version of the *in situ* phrase intended for Matrix grammars was first written in DELPH-IN HPSG by Emily M. Bender for her grammar engineering class. `http://courses.washington.edu/ling567/2017/lab7.html`

(218)



Note that, just like the *wh-ques-phrase* (204), this unary phrase structure rule does not care how many elements were on the head daughter's QUE list and zeroes out the list on the mother. This allows for a clause with multiple question phrases to be included in one question sentence, with only one application of this phrase structure rule (219).

(219)

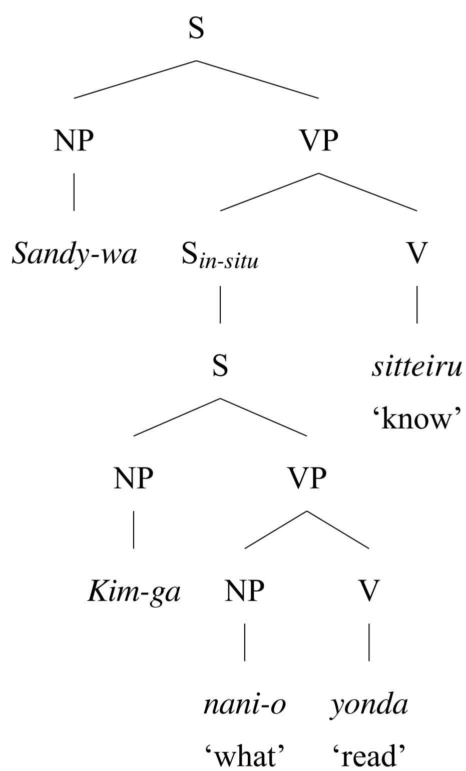


Finally, my analysis of *in situ* questions in Japanese allows for ambiguity in sentences like (220). This ambiguity is presented in (221a) and (221b) and is desirable, assuming (220) has two readings.

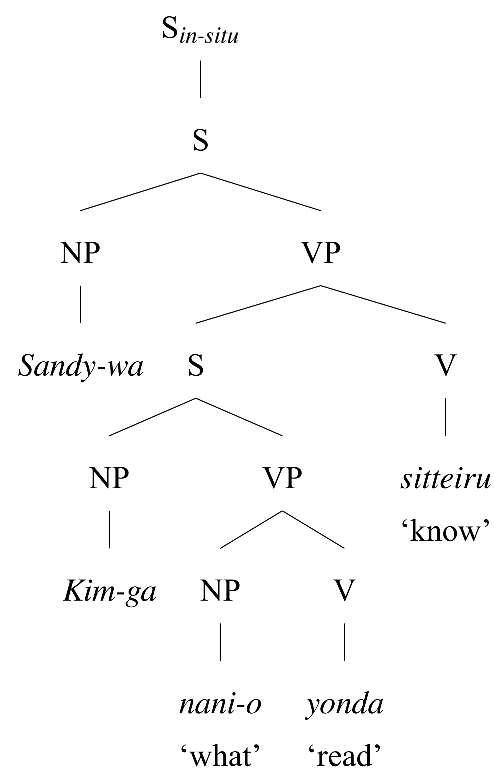
(220) Sandy-wa Kim-ga nani-o yonda sitteiru
Sandy-TOP Kim-NOM what.ACC read know
'Sandy knows what Kim reads/Does Sandy know what Kim reads?' [jpn] (Constructed by me based on examples from Pesetsky (1987).[19])

(221)

a.



b.



This section presented a fragment of a Japanese grammar that covers polar and constituent questions, relying on the *in situ* phrase structure rule. Japanese question particles are discussed later in §6.7.1. The summary of customization for other *in situ* languages is presented in §7.5.

[19]I asked a Japanese native speaker to comment on this constructed example. The speaker confirmed the sentence was possible albeit it would sound better with particles; she confirmed also the two possible readings. I give the analysis here for the sentence without particles to illustrate the role of the *in situ* phrase structure rule clearer. The analysis is similar with particles.

6.5 Multiple optional fronting of question phrases. Illustrative language: Russian (Indo-European)

Russian exhibits multiple question phrase fronting (222),[20] including in LDD constructions (223)–(224), although LDD *wh*-questions may be infrequent.[21]

(222) Когда кто кого видел?
Kogda kto kogo videl?
when who.NOM who.ACC see.PST
'When did which person see which other person?' [rus][22]

(223) И кто ты думаешь будет третьим?
I kto ty dumaesh budet tretjim?
And who.NOM 2SG.NOM think.2SG.PRES be.3SG.FUT third.INSTR
'And who do you think will be the third [in the group]?' [rus] (Galikhin, 2017, loc.246)[23]

(224) ?Когда кто кого ты точно знаешь, что видел?
Kogda kto kogo ty tochno znaesh (chto) videl?
when who.NOM who.ACC 2SG for.sure know (that) see.PST
'What are the sets of times and persons such that one person saw another at a certain time, such that you know this set of facts for sure?' [rus]

Multiple adjunct fronting appears either impossible (225) or rare, (227) being the only example I have found so far in the Russian National Corpus.[24]

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[20] Parts of this section were published as Zamaraeva and Emerson (in press).

[21] Some literature contends that they are not possible, or possible only with subjunctive clauses (Antonenko, 2008; Stepanov and Stateva, 2006; Bailyn, 2005) but I observed myself producing such constructions and have found multiple examples in my chat archives. See especially example (223).

[22] To remind the reader, unless stated otherwise, the Russian examples are constructed by me. Long-distance questions in Russian are not easy but they seem to be possible, according both to my judgments and to the fact that examples can sometimes be found in books and on the web. Where my constructed examples seemed possible but difficult, I marked them by the question mark (?). I suspect they could be difficult due to processing reasons but still entirely possible under the right circumstances in speech.

[23] Note the future tense in the embedded clause in this example; it indicates clearly that this is a long-distance question and not a parenthetical use of 'think', which could be a likely interpretation if the embedded verb were in the past tense.

[24] I have seen example (226) somewhere on the web but was unable to recover the source; in (226), it is possible to argue that the combination of 'where' and 'when' may be idiomatic and the sentence simply means the speaker does not know the rules of punctuation, and then there is no constituent question there. In (227), however, the

(225) ??Когда где мы купили эти книги?
??*Kogda gde* my kupili eti knigi?
when where 1PL.NOM buy.PAST.1PL this.PL.ACC book.PL.ACC
Intended: 'When [and] where did we buy these books?' [rus]

(226) Я не знаю, где когда ставить запятые
Ya ne znayu, gde kogda stavit zapyatye
1SG NEG know.PRES.1SG where when put.INF comma.ACC.PL
'I don't know when and where to put commas.' [rus]

(227) Издание DP. ru выпустило инфографику обо всех
DP. ru vypustilo infografiku obo vseh kvartirah
DP. ru publish.PAST infographic.ACC of all.PREP apartment.PREP
квартирах Достоевского (где когда жил, где что написал)
Dostoevskogo (*gde* *kogda* zhil, gde chto napisal)
Dostoyevsky.GEN (where when live.PAST, where what write.PAST)
'DP.ru published an infographic about all Dostoevsky's apartments (where he lived when, where he wrote what) [rus] (Oborin, 1987, RNC)

Finally, fronting appears optional in that the question phrase is not necessarily in the left periphery (228), and adjuncts can appear in any position with respect to the arguments (229)–(231). The order of the arguments is also flexible (232), although the canonical order is with the subject preceding the object.

(228) Ты где работаешь?
Ty *gde* rabotaesh?
2SG where work.2SG
'Where do you work?' [rus][25]

(229) Кто кого когда видел?
Kto *kogo* *kogda* videl?
who.NOM who.ACC when see.PST
'Who saw whom when?' [rus]

'where' and 'when' definitely refer to locations in space and time.

[25]This very common Russian sentence was pointed out to me by John F. Bailyn in personal communication. Bailyn thinks the subject in this sentence is also fronted and the fronting of the *wh*-word is obligatory.

(230) Кто когда кого видел?
Kto kogda kogo videl?
who.NOM when who.ACC see.PST
'Who saw whom when?' [rus]

(231) Когда кто кого видел?
Kogda kto kogo videl?
when who.NOM who.ACC see.PST
'When did which person see which other person?' [rus]

(232) Кого кто видел?
kogo kto videl?
who.ACC who.NOM see.PST
'Which person saw which other person?' [rus]

6.5.1 Multiple fronting

My analysis of Russian relies on the same machinery as my analysis of English, namely the extraction rules which introduce the SLASH dependencies and the filler-gap rule (§6.3).[26] The main difference in how these rules are stated for Russian is that, to model multiple fronting, multiple application of the filler-gap rule is allowed, and extraction rules can apply one after another (233). This section discusses this multiple application of extraction and filler-gap rules. In addition, to model Russian fronting as optional, I also use the *in situ* phrase introduced in the previous section (§6.4); the analysis of optional fronting is discussed in the next section (§6.5.2).[27]

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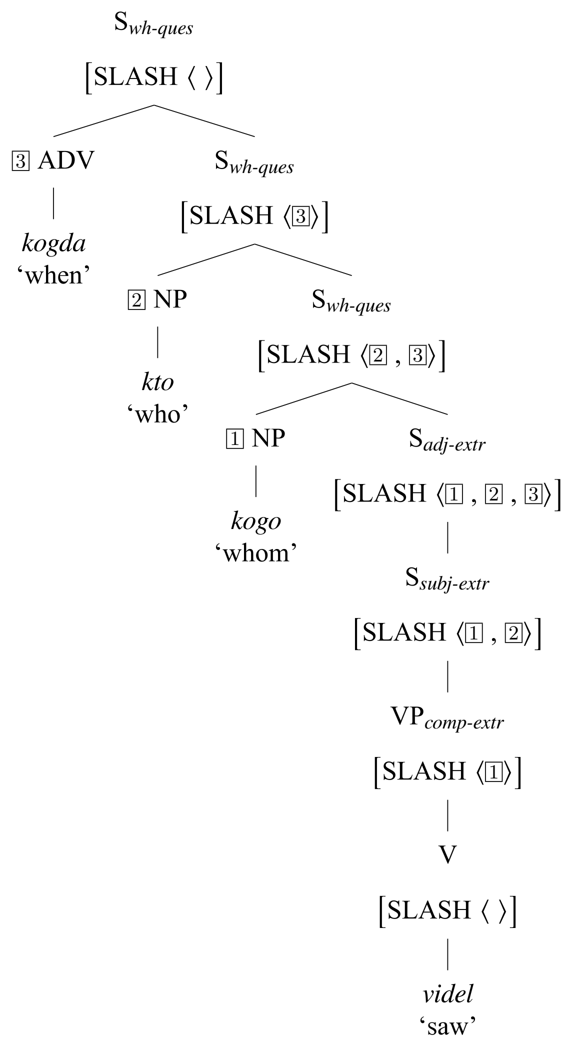
[26] All analyses for all languages rely on question words with the nonempty QUE value.

[27] As explained in §2.5.3, superiority effects are not discussed. Russian does not show strong superiority effects, however other languages with multiple fronting do, for example Bulgarian (Bošković, 2002).

(233)



The derivation (233) for the Russian sentence (231) illustrates how the SLASH values first are appended, one after the other, as the extraction rules apply, and then are realized, in the same order, by the *wh-ques-phrase*. All of the extraction rules and the *wh-ques* filler-gap rule need to look slightly different than in the section about English (§6.3), in order for this analysis to work. In particular, it requires the subject extraction (234) and the complement extraction (235) rules to be stated as follows.

(234)
$$\begin{bmatrix} \textit{extracted-subj-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT|VAL|SUBJ} & \langle\ \rangle \\ \text{NON-LOCAL|SLASH|APPEND} & \left\langle \boxed{0}, \begin{bmatrix}\text{LIST } \langle \boxed{1} \rangle\end{bmatrix} \right\rangle \end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT|VAL|SUBJ} & \left\langle \begin{bmatrix} \textit{gap} \\ \text{LOCAL } \boxed{1}\end{bmatrix}\right\rangle \\ \text{NON-LOCAL|SLASH} & \boxed{0}\end{bmatrix}\end{bmatrix}$$

(235)
$$\begin{bmatrix} \textit{extracted-comp-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT|VAL|COMPS} & \boxed{0} \\ \text{NON-LOCAL|SLASH|APPEND} & \left\langle \boxed{1}, \begin{bmatrix}\text{LIST } \langle \boxed{2} \rangle\end{bmatrix} \right\rangle \end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT|VAL|COMPS} & \begin{bmatrix} \text{FIRST} & \begin{bmatrix} \textit{gap} \\ \text{LOCAL } \boxed{2}\end{bmatrix} \\ \text{REST} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL|SLASH} & \boxed{1}\end{bmatrix}\end{bmatrix}$$

Recall that in §6.3, the mother substructures of the same rules had the length of the SLASH list strictly 1 (single fronting), implying that the daughter's SLASH was empty to start with. Here, instead the length of the daughter's list can be anything, and the mother's substructure appends a new element to the existing, possibly nonempty list. This formulation makes multiple extraction as in (233) possible. This formulation is also what motivates two systemic changes in the Grammar Matrix: the switch from difference lists to append lists and abandoning lexical threading.

The necessity to routinely append nonlocal feature lists like this motivated the switch from difference lists to append lists in the Grammar Matrix. Recall from §3.2.1 that appending difference lists is cumbersome; having to do so leads to engineering errors.[28] Append lists allow for simple, much less error-prone programming syntax (APPEND ⟨ x, y ⟩). This notation is not only easy to write but also to read, making it easier to reason about the grammar and the system as a whole. This is why not only my analysis of Russian but the entire Grammar Matrix system now uses append lists instead of difference lists. The summary of the infrastructural changes is presented in §7.11.1.

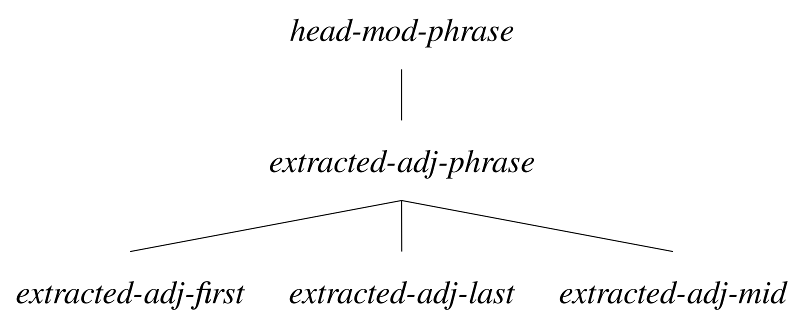
As for lexical threading, recall from §4.1.2 that it is the notion that heads "amalgamate" their

[28] But it can be done; see the ERG (Flickinger, 2000, 2011) and also Crysmann 2015, the latter being an analysis of multiple LDDs using difference lists.

arguments' nonlocal feature values. So, under the lexical threading assumption, there would be no need for a rule like subject extraction (234) to explicitly say anything about its mother's SLASH list, given the type *gap* (196). The SLASH list is then propagated via the head, without the need to stipulate any additional constraints at the level of phrase structure rules. Note that what this means in the context of extraction is that the extraction rules do not actually combine or extend SLASH lists but merely specify that a particular position in the list is nonempty. While not a problem for single-fronting languages, in languages with multiple fronting, particularly where adjuncts can intervene between arguments (230), this presents certain difficulties.

The problem is, if (under the lexical threading assumption) all that extraction rules can do is specify that a (specific) position on the list is not empty while the order of the list is determined by the lexical entry (which knows nothing about its adjuncts), then several adjunct extraction rules are needed to account for examples (229)–(231). There would have to be a hierarchy of adjunct extraction rules as shown in (236). One rule would allow for extracting an adjunct either before the arguments, one after the arguments, and one in between the arguments. This would account for (231) and (229).

(236)



(237)
$$\begin{bmatrix} \textit{extracted-adj} \\ \text{SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC|SLASH|APP} & \left\langle \boxed{3}, \begin{bmatrix} \text{LIST} & \left\langle \begin{bmatrix} \text{CAT|HEAD|MOD} & \left\langle \begin{bmatrix} \text{LOC} & \begin{bmatrix} \textit{intersective-mod} \\ \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \\ \text{MODIFIED} & \textit{hasmod} \end{bmatrix} \\ \text{HDR|SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC|SLASH} & \boxed{3} \\ \text{MODIFIED} & \textit{notmod} \end{bmatrix} \end{bmatrix}$$

Example (237)[29] shows the rule that would be used to extract an adjunct after any arguments, the *extracted-adj-last* in (236), accounting for (231), as shown in (233). Because SLASH is of type *append-list*, there are no issues with placing the extracted adjunct at the specified position on the mother's SLASH, but the order of the arguments put on the SLASH list is determined at the level of the lexical entry, and, in order for any extracted adjuncts to be inserted at some specific position, there would have to be an analogous phrase structure rule for *extracted-adj-first* (238) and *extracted-adj-mid* (not shown).

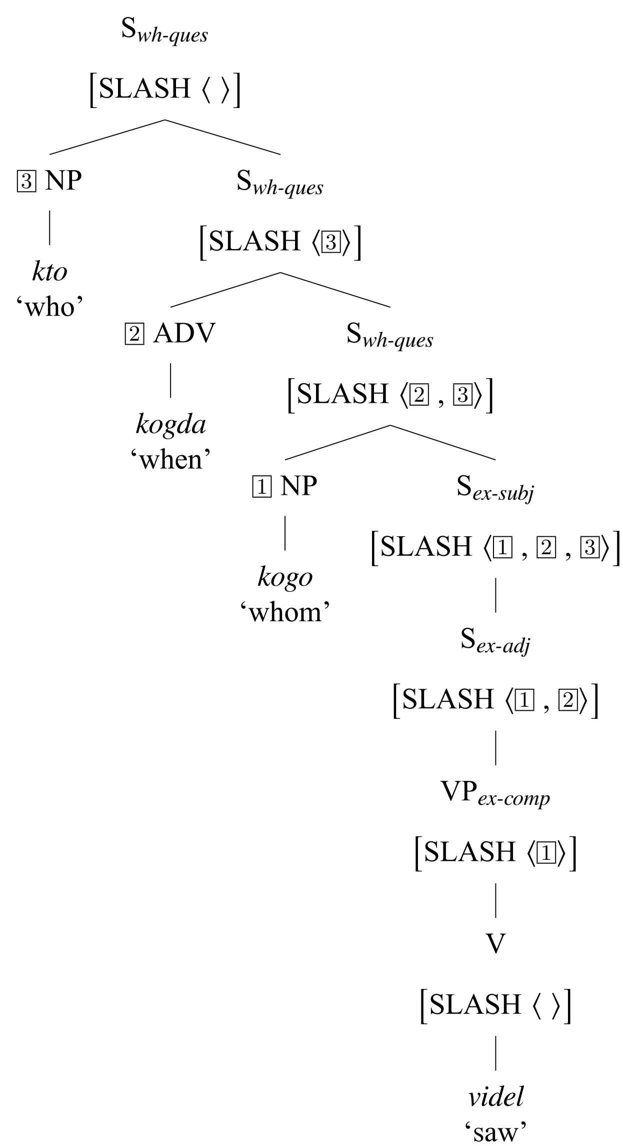
(238)
$$\begin{bmatrix} \textit{extracted-adj-first} \\ \text{SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC|SLASH|APP} & \left\langle \begin{bmatrix} \text{LIST} & \left\langle \begin{bmatrix} \text{CAT|HEAD|MOD} & \left\langle \begin{bmatrix} \text{LOC} & \begin{bmatrix} \textit{intersective-mod} \\ \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \end{bmatrix}, \boxed{3} \right\rangle \\ \text{MODIFIED} & \textit{hasmod} \end{bmatrix} \\ \text{HDR|SS} & \begin{bmatrix} \text{LOC} & \begin{bmatrix} \text{CAT|HEAD} & \boxed{1} \\ \text{CONT|HOOK} & \boxed{2} \end{bmatrix} \\ \text{NLOC|SLASH} & \boxed{3} \\ \text{MODIFIED} & \textit{notmod} \end{bmatrix} \end{bmatrix}$$

Without lexical threading however, the order of the elements on the SLASH list is not determined at the level of the lexical entry, and several adjunct extraction rules are not needed. Extraction rules now can apply in any order, not restricted by the verb's lexical entry. Any extraction rule, including the sole adjunct extraction rule, simply appends to the daughter's SLASH

[29] Abbreviations: SS: SYNSEM, LOC: LOCAL; NLOC: NON-LOCAL; APP: APPEND; HDR: HEAD-DTR

list. Even if the adjunct goes in between the arguments, without the lexical threading assumption, the verb's lexical entry does not constrain its SLASH list with respect to its arguments thus precluding the adjunct from going in between. Recall from example (233) how the combination of subject (234), complement (235), and adjunct (237) extraction yields an analysis for (231). Without the lexical threading assumption, the same set of rules, with only one *extracted-adj* as shown in (237), provides an analysis for (229) and (230) without further stipulation. I show the analysis for (230) below as (239).

(239)



The summary of the infrastructural changes associated with getting rid of lexical threading in the Grammar Matrix is given in §7.11.2.

Finally, note in the adjunct extraction rule (237) how, following Flickinger (2000), I block multiple adjunct extraction (225) by the MODIFIED feature and a hierarchy of mutually exclusive types (e.g. *hasmod* vs. *notmod*) appropriate for it. Removing the MODIFIED constraint would allow both (225) and (227) (which could perhaps be seen as desirable, given at least (227)), and then the limit on how many adjuncts can be extracted would have to be put either formally or through constraints on the parsing algorithm (the latter could in principle be seen as a way of modeling processing constraints).

6.5.2 Optional fronting

For the purposes of this project, I analyze (240)–(245) as optional fronting.

(240) Ты где работаешь?
Ty gde rabotaesh?
2SG where work.2SG.PRES
'Where do you work?' [rus]

(241) Где ты работаешь?
Gde ty rabotaesh?
where 2SG work.2SG.PRES
'Where do you work?' [rus]

(242) Книгу кто читает?

Knigu kto chitaet?

book.ACC who.NOM read.3SG.PRES

"Who is reading the book?' [rus]

(243) Кто книгу читает?

Kto knigu chitaet?

who.NOM book.ACC read.3SG.PRES

"Who is reading the book?' [rus]

(244) Ты что читаешь?

Ty chto chitaesh?

2SG.NOM what.ACC read.2SG.PRES

'What are you reading?' [rus]

(245) Что ты читаешь?

Chto ty chitaesh?

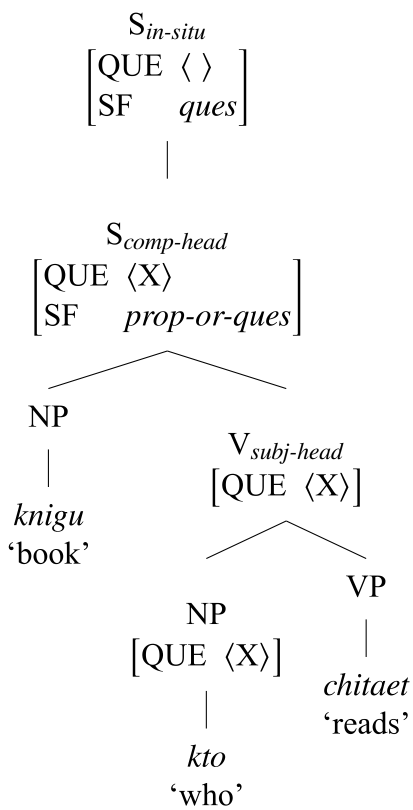
what.ACC 2SG.NOM read.2SG.PRES

'What are you reading?' [rus]

This is not how Russian fronting is seen in much of the literature; syntacticians argue that fronting in Russian is obligatory (Stepanov, 1998) and that whatever material precedes the question word at the left periphery was fronted as well (Bailyn, 2020). Futhermore, there is work about other Slavic languages, e.g. Serbo-Croatian [hbs], arguing against the concept of optional fronting as applied to these languages (Mišmaš, 2015). However, given that the notion of optional fronting does exist in typological literature (see §2.5.1), I decided to see how well it applies to Russian if looked at through the HPSG lens.[30] Given my analyses for single fronting (§6.3) and *in situ* (§6.4) languages, I hypothesize that optional fronting could be modeled as a hybrid, by allowing both the filler-gap *wh-ques* phrase and the *in situ* phrase in the grammar. The sentence (242) will then be analyzed using the *in situ* phrase (246).

[30]Recall once more that ultimately, the goal of this dissertation is not to so much to present individual grammars for individual languages and make strong claims about those languages as to to develop a system of interoperable analyses for a range of typological possibilities. So Russian here served for an analysis of an optionally fronting language, even though ultimately, Russian may have turned out to be not the best illustrative language for the purpose — which is interesting in the sense that it provides additional evidence to claims that Russian does not have optional fronting.

(246)



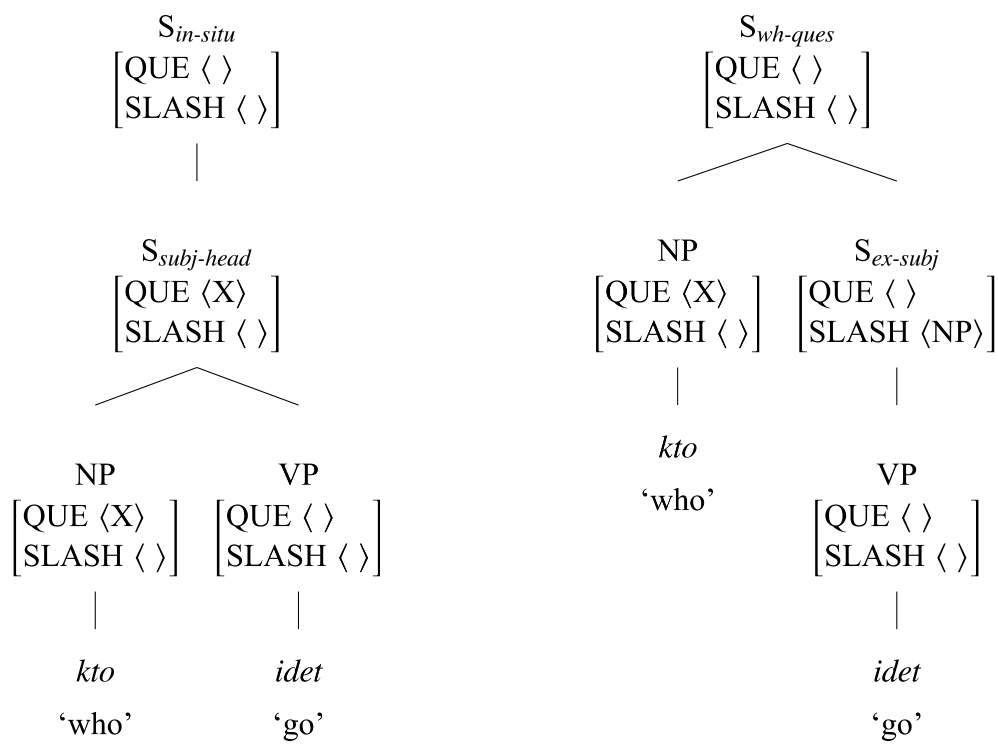
So far everything is simple; I use the same rules for optional fronting as for obligatory fronting (§6.3) and *in situ* (§6.4), combined. The problem, however, is the ambiguity which arises from having both the filler-gap construction for questions and other head-final rules, such as subject-head, which allow *wh* non-head daughters, in order for the *in situ* construction to apply at the top.

Recall from §6.1 and §6.3 that, under my analysis, all *wh*-words have nonempty QUE lists. In English, it was not a problem because it is an obligatory fronting language. The head final subject-head rule in English does not allow *wh* non-head daughters and therefore could never apply in the place of the filler-gap phrase (§6.3.4) thus causing unwanted structural ambiguity in the grammar. But if the grammar underspecifies the non-head-daughter's QUE value on e.g. the subject-head rule and includes both the filler-gap *wh-ques* phrase and the *in situ* phrase, undesirable structural ambiguity arises in sentences like (247), as illustrated in (248b)–(248b).

(247) Кто идет?
Kto idet?
who.NOM go.3SG.PRES
‘Who is there? (Lit.: ‘Who is coming?’)’ [rus]

(248)

a. b.



In other words, in a language which allows both fronted and *in situ wh*-elements, if e.g. a subject-head rule allows *wh-* non-head daughters, a sentence with a *wh*-phrase in the front (247) can be licensed by both extraction (248b) and a regular subject-head rule plus the *in situ* phrase (248a).

In the context of this work, I suggest using a peripheral or “edge” feature (Miller, 1992) to mitigate this problem. I call the feature L-QUE, for “question in the left periphery”. Previously in the Grammar Matrix, an edge feature was used in the context of the information structure library (Song, 2014). The point of the feature is to detect whether the element in the left periphery has certain properties or not; in the case of L-QUE, it is to detect whether such element is a *wh*-word or not. If it is, the whole structure is [L-QUE +], in the second [L-QUE −].

To implement L-QUE as an edge feature, for languages which allow both fronted and *in situ* constituent questions, I add L-QUE as a feature appropriate for the type *synsem* and then add its percolation to the *phrase-or-lexrule* type (249):[31]

(249) $\begin{bmatrix} \textit{phrase-or-lex-rule} & \\ \text{SYNSEM}|\text{L-QUE} & \boxed{1} \\ \text{ARGS} & \langle [\ \text{SYNSEM}|\text{L-QUE}\ \boxed{1}\ ], ... \rangle \end{bmatrix}$

This simple addition means that L-QUE value is passed up to the mother from the leftmost daughter, thus recording some information about what is at the left edge of the clause. Next, I introduce two lexical supertypes, one for all *wh*-words (250) and one for all other words (251).

(250) $\begin{bmatrix} \textit{basic-wh-word-lex} & \\ \text{SYNSEM}|\text{L-QUE} & + \end{bmatrix}$

(251) $\begin{bmatrix} \textit{basic-non-wh-word-lex} & \\ \text{SYNSEM}|\text{L-QUE} & - \end{bmatrix}$

All *wh*-words will inherit from *basic-wh-word-lex*; all other words from *basic-non-wh-word-lex*. Thus, all *wh*-words have L-QUE set to +, and therefore if there is a *wh*-word in the left periphery, the whole clause will end up [L-QUE +].[32]

The *in-situ* phrase (217) in Russian then includes a constraint on its head daughter's L-QUE so as to rule out spurious ambiguity of the kind described above. The idea is to prevent them from taking head daughters which have just attached another *wh*-word to the left periphery, or in other words to insist on head daughters which are [L-QUE −] as in (252).

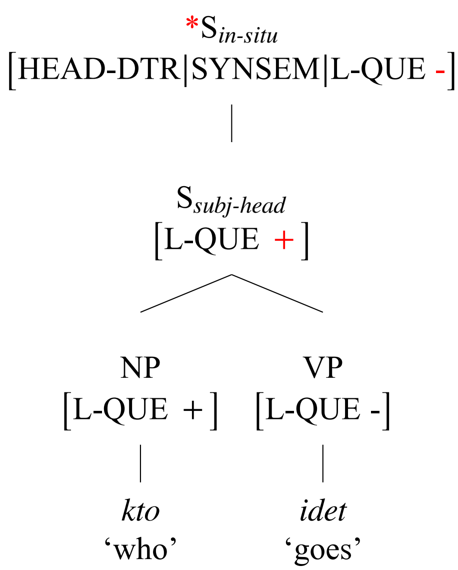
[31] Only the new constraint is shown on the *phrase-or-lex-rule* type.

[32] I will revisit these two supertypes again when I discuss customization of question particles (6.7.1). For now, for readers who are wondering why these types are not specifying the QUE value, I will just note that it is because of words like the English *whether*; it is a *wh*-word but it has nothing to do with constituent questions and its QUE list is empty.

(252)
$$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix} \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE|LIST} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0}\begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{L-QUE} & - \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE|LIST} & \langle \textit{ref-ind}, \ldots \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Derivation (248a) is then ruled out as follows (253), given a lexical entry for *kto* which is a subtype of *basic-wh-word* (250) and therefore [L-QUE +]:

(253)



The subject extraction rule also needs to be customized with respect to the L-QUE feature, as shown in (254).

(254)
$$\begin{bmatrix} \textit{extracted-subj-phrase} & \\ \text{SYNSEM} & \begin{bmatrix}\text{LOCAL|CAT|VAL|SUBJ} & \langle\ \rangle \\ \text{NON-LOCAL|SLASH|APPEND} & \left\langle \boxed{0}\, , \begin{bmatrix}\text{LIST } \langle \boxed{1} \rangle\end{bmatrix}\right\rangle \end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{L-QUE} & - \\ \text{LOCAL|CAT|VAL|SUBJ} & \left\langle \begin{bmatrix}\textit{gap} & \\ \text{LOCAL} & \boxed{1}\end{bmatrix}\right\rangle \\ \text{NON-LOCAL|SLASH} & \boxed{0}\end{bmatrix}\end{bmatrix}$$

This is to rule out derivations like (256a) and only admit (256b), for sentences like Russian (255).[33]

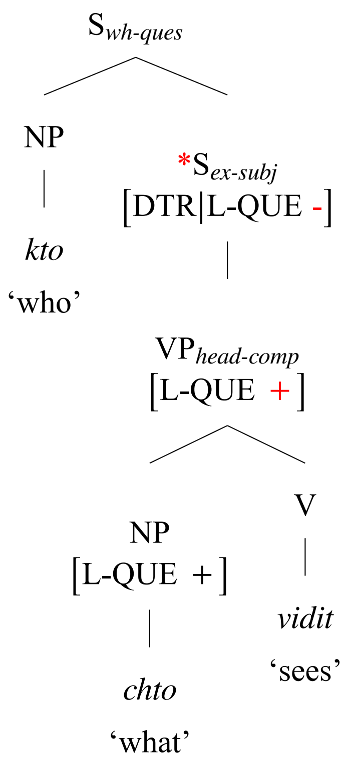
(255) Кто что видит?
Kto chto vidit?
who.NOM what.ACC see.3SG.PRES
'Who sees what?' [rus]

---

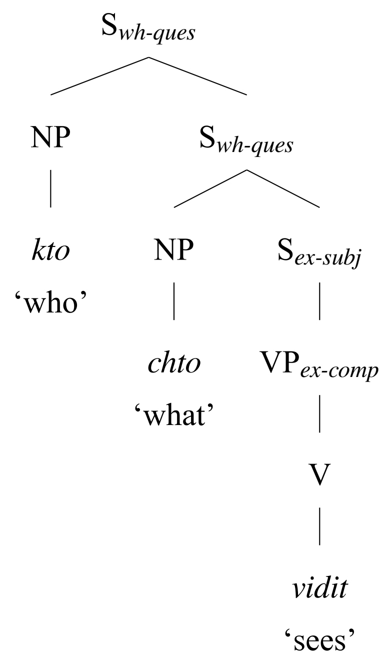
[33] Alternatives such as constraining the subject extraction rule with respect to its daughter's SLASH list or COMPS list will not work for languages with free word order, because the subject extraction rule needs to be able to apply both below and above complement and adjunct extraction, as illustrated in (239) and (233).

(256)

a.



b.



L-QUE alone however is not sufficient to deal with all the ambiguity arising from the optional fronting analysis.[34] Note that in my analysis of Russian, the adjunct-head phrase's head daughter cannot be constrained to be SLASH-empty. This is because otherwise, assuming also the adjunct extraction rule is stipulated as in (237), sentences like (257) would not be licensed.

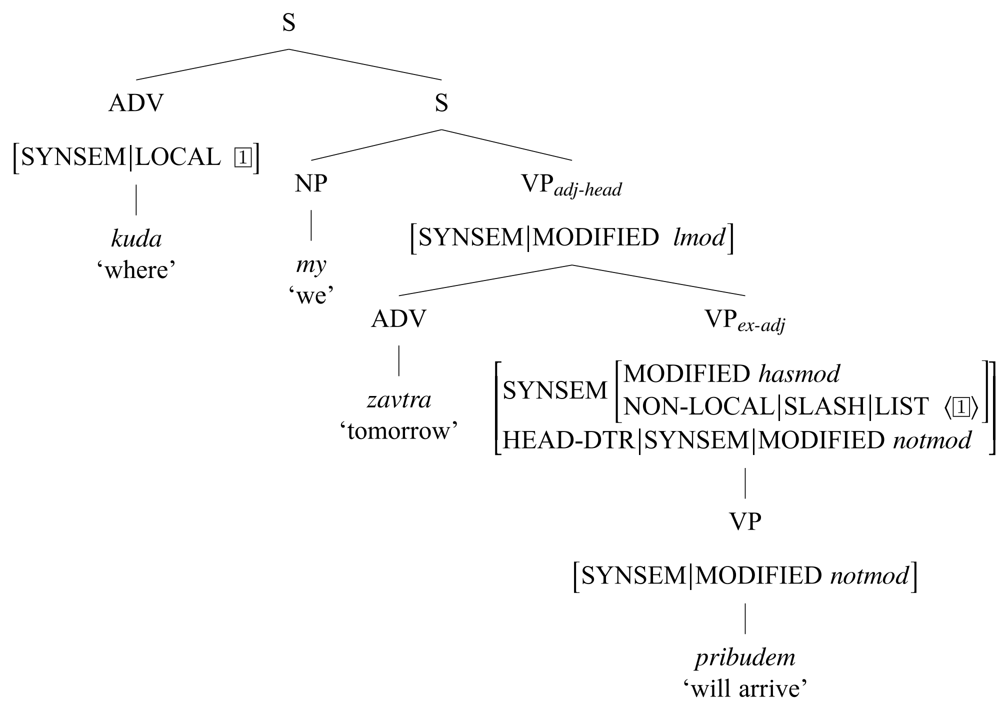
(257) Куда мы завтра прибудем?
Kuda my zavtra pribudem?
where 1PL.NOM tomorrow arrive.1PL.FUT
'Where will we arrive tomorrow?' [rus]

---

[34]Moreover, where this feature also will not help is in languages where *wh*-specifiers may attach to the noun on the right (*dog which*), if such languages exist. In such a case, the NP such as *dog which* will be [L-QUE −] and the hypothetical sentence *who [dog which] sees?*, meaning, in such a hypothetical language, *Who sees which dog?*, would result in two derivations, like in (256a)–(256b). This could perhaps be mitigated by nouns getting their L-QUE values from either the determiner of the bare NP rule, instead of starting out with the *minus* value in the lexicon. Testing this was not part of my work.

To see why, recall first that the adjunct extraction rule (237) is constrained to only apply to MODIFIED *notmod* head daughters,[35] in other words to structures which had not been modified. This is to preclude multiple adjunct extraction (since it is both rare and presents engineering problems for the parser). This means however the adjunct needs to be extracted low, before any other adjuncts, which will set the MODIFIED value to a subtype of *hasmod*, attach (259).

(259)

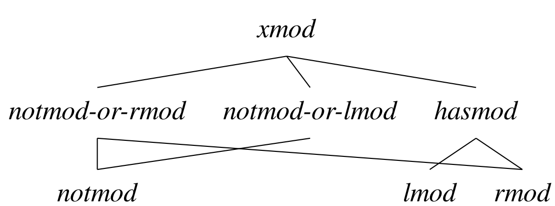


But this means, the adjunct-head rule must allow SLASHed head daughters. This results in spurious ambiguity where the same adjunct-head phrase attaches both below and above subject extraction. The situation is illustrated by (261a)–(261b) for the Russian sentence (260) below.

---

[35]The relevant portion of the type hierarchy is presented in (258). Note that *hasmod* and *notmod* do not unify as they do not have a unique greatest lower bound (see §3.2, p. 40), while e.g. *lmod* unifies with its parent, *hasmod*.

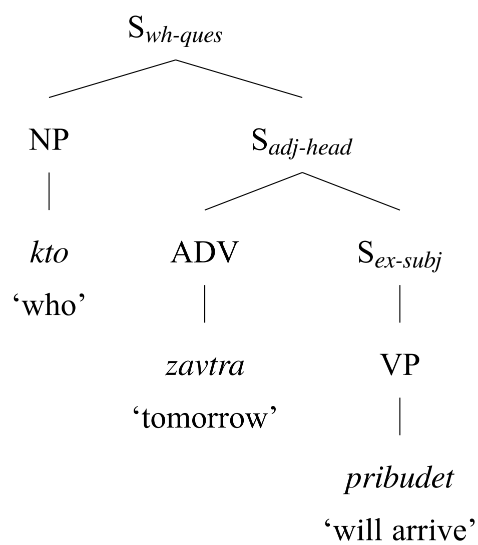
(258)



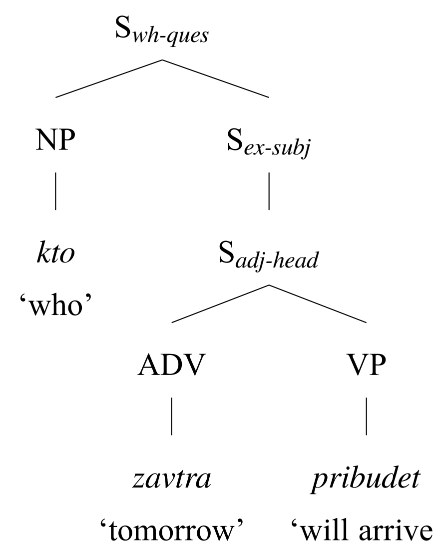
(260) Кто завтра прибудет?
Kto zavtra pribudet?
who.NOM tomorrow arrive.3SG.PRES
'Who will arrive tomorrow?' [rus]

(261)

a.



b.



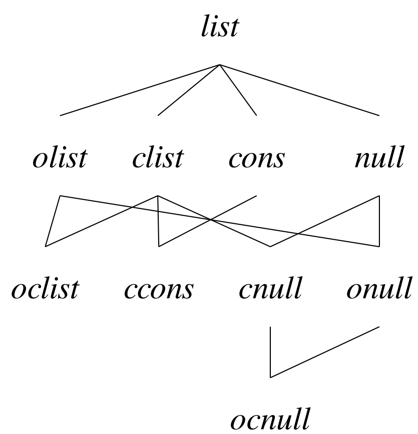
Perhaps this is an indication that multiple adjunct extraction should be allowed after all (given also acceptability of (227)); but in the context of my current analysis which does not allow multiple adjunct extraction, I propose a solution using a *parameterized list*.

parameterized lists are lists which place constraints on what kind of elements can be on them. For example, in the ERG and in the Grammar Matrix, *olist*, for *o*ptional element *list*, is a list of elements which can be dropped, such as dropped subjects or objects, for the argument optionality analysis in the Matrix (Saleem, 2010). For the purpose of ruling out spurious derivations like in (261), I use the *canonical list* type. *Canonical-list* is a list of elements which are not of type *gap* (the idea of a type hierarchy in which *gap* is not unifiable with *canonical-synsem* was suggested by Bouma et al. (2001a)). Lists of *canonical-synsem* have been used in HPSG in other contexts by e.g. Webelhuth and Bonami (2019) and Bolc (2005) *inter alia*. An instance of *canonical-list* can be empty or it can contain actual non-extracted elements.

(262) $\begin{bmatrix} \textit{ccons} & \\ \text{FIRST} & \textit{canonical-synsem} \\ \text{REST} & \textit{canonical-list} \end{bmatrix}$

The full hierarchy for this type of list is presented in (263) for readers interested in the details of formal implementation. This particular hierarchy is necessary in the context of other lists in the Matrix. For most readers, what is important is that a non-canonical *synsem* such as a *gap* could never be on this list; that would be a unification failure. The hierarchy for this new type follows other list hierarchies in the Matrix.[36]

(263)



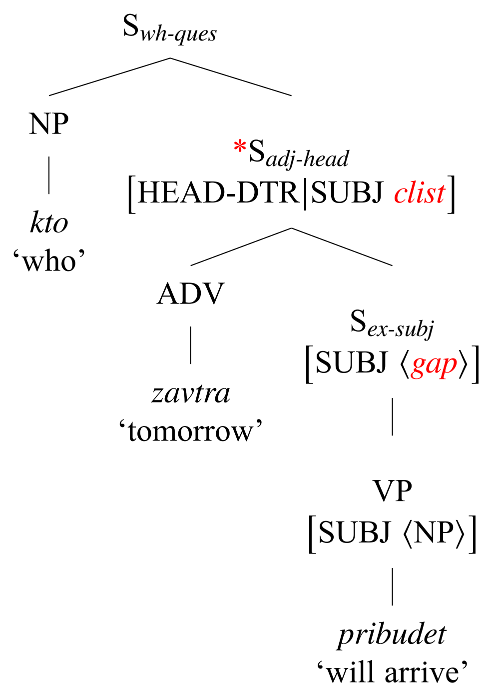
I use this part of the hierarchy to customize the adjunct-head phrase in Russian to only allow *clists* as SUBJ lists of their head daughters (264).

(264) $\begin{bmatrix} \textit{adj-head-int-phrase} & \\ \text{HEADD-DTR}|\text{SYNSEM}|\text{LOCAL}|\text{CAT}|\text{VAL}|\text{SUBJ} & \textit{clist} \end{bmatrix}$

This means they disallow “gappy” (131) subjects (while still allowing empty subject lists!), and so (261a) will be ruled out as shown below in (265).

[36]One type that is missing from this hierarchy that is present for other types of lists is a type which would inherit from both *ccons* (nonempty canonical list) and *ocons* (a list of optional elements). Introducing such a type causes issues in the system (`https://delphinqa.ling.washington.edu/t/in-situ-wh-words-in-languages-which-also-do-extraction/394/43`) while not adding it so far did not introduce any — none of the grammars required it — and, deciding what to do about this currently omitted type remains future work.

(265)



6.5.3 *Russian pied-piping*

In Russian, the question determiner can appear in the front of the sentence, separately from the noun (266)–(267a). At the same time, Russian requires pied-piping of adpositions (267b)–(268b).

(266) Какую Иван читает книгу?
Kakuju Ivan chitaet knigu?
which.ACC Ivan.NOM read.3SG.PRES book.ACC
'Which book is Ivan reading?' [rus]

(267) a. В какой Иван приехал город?
V kakoi Ivan priehal gorod?
In which.ACC Ivan.NOM arrive.3SG.PAST city.ACC?
'In which city did Ivan arrive?' [rus]

b. *Какой Иван приехал город в?
*Kakoi Ivan priehal gorod v?
Which.ACC Ivan.NOM arrive.3SG.PAST city.ACC in?
Intended: 'In which city did Ivan arrive?' [rus][37]

[37] It does not seem to be a phonological restriction (268b).

(268) a.

Из	какого	Иван	приехал	города?
Iz	kakogo	Ivan	priehal	goroda?
from	which.GEN	Ivan.NOM	arrive.PAST.SG	city.GEN

‘From which city did Ivan arrive?’ [rus]

b.

*Какого	Иван	приехал	из	города?
*Kakogo	Ivan	priehal	iz	goroda?
which.GEN	Ivan.NOM	arrive.PAST.SG	from	city.GEN

Intended: ‘From which city did Ivan arrive?’ [rus][38]

To model the determiner fronted separately from the noun, I suggest a determiner extraction rule (269), similar to subject and complement extraction (197)–(198) in that it takes an element off a list (specifically, the SPR list) and puts it on the SLASH list such that a LDD is created which can ultimately be realized by the filler-gap rule, as shown in (270). This rule also identifies the local features of the noun which the extracted determiner is the specifier for with the extracted element’s SPEC, in order for the correct semantics to be constructed, as illustrated in Figure 6.4. In particular, the identity ensures that the which_q_rel quantifier is correctly linked to the _book_n_rel relation via the HCONS (see §3.2.2).

(269)
$$\begin{bmatrix} \textit{extracted-det-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{5}\begin{bmatrix}\text{CAT}\mid\text{VAL} & \begin{bmatrix}\text{SUBJ} & \langle\,\rangle \\ \text{SPR} & \langle\,\rangle\\ \text{SPEC}&\langle\,\rangle\\ \text{COMPS}&\langle\,\rangle\end{bmatrix}\end{bmatrix}\\ \text{LIGHT} & \boxed{4} \\ \text{NON-LOCAL} & \boxed{1}\end{bmatrix} \\ \text{HEAD-DTR}\mid\text{SYNSEM} & \begin{bmatrix}\text{LOCAL}\mid\text{CAT} & \begin{bmatrix}\text{VAL}\mid\text{SPR} & \left\langle\begin{bmatrix}\textit{gap} & \\ \text{LOCAL} & \boxed{2}\begin{bmatrix}\textit{local} & \\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{det}\\ \text{VAL}\mid\text{SPEC} & \left\langle\begin{bmatrix}\text{LOCAL} & \boxed{5}\end{bmatrix}\right\rangle\end{bmatrix}\\ \text{CONT}\mid\text{HOOK} & \boxed{3}\end{bmatrix}\end{bmatrix}\right\rangle\end{bmatrix}\\ \text{NON-LOCAL} & \boxed{1}\begin{bmatrix}\text{SLASH}\mid\text{LIST} & \langle\boxed{2}\rangle\end{bmatrix}\\ \text{LIGHT} & \boxed{4}\end{bmatrix}\\ \text{C-CONT} & \begin{bmatrix}\text{RELS}\mid\text{LIST}&\langle\,\rangle\\ \text{HCONS}\mid\text{LIST}&\langle\,\rangle\\ \text{ICONS}\mid\text{LIST}&\langle\,\rangle\\ \text{HOOK}&\boxed{3}\end{bmatrix}\end{bmatrix}$$

[38]This sentence happens to be possible with the translation: “Why the hell did Ivan arrive from the city?’ (*Kakogo* being derived from ‘which devil’ and not modifying ‘city’), but that is not the structure which I intend to illustrate.

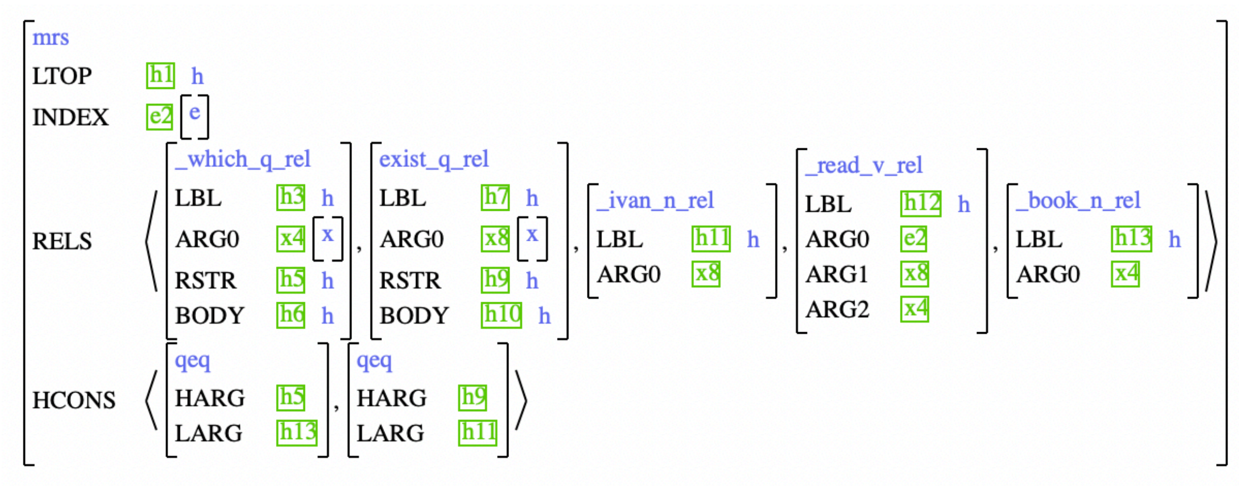


Figure 6.4: MRS for sentence (266).

(270)

- S*wh-ques*
  - D
    - *kakuju* 'which'
  - S*subj-head*
    - NP
      - *Ivan*
    - VP*head-comp*
      - V
        - *chitaet* 'reads'
      - NP*extr-det*
        - N
          - *knigu* 'book'

For adpositions, if pied-piping is obligatory, the complement extraction rule (235) can be easily constrained to not take adpositions as daughters (271).[39] Sentences like (267b) are then ruled out because there is no way the complement extraction rule would license a sentence with a "stranded" adposition, as is possible in English (214).

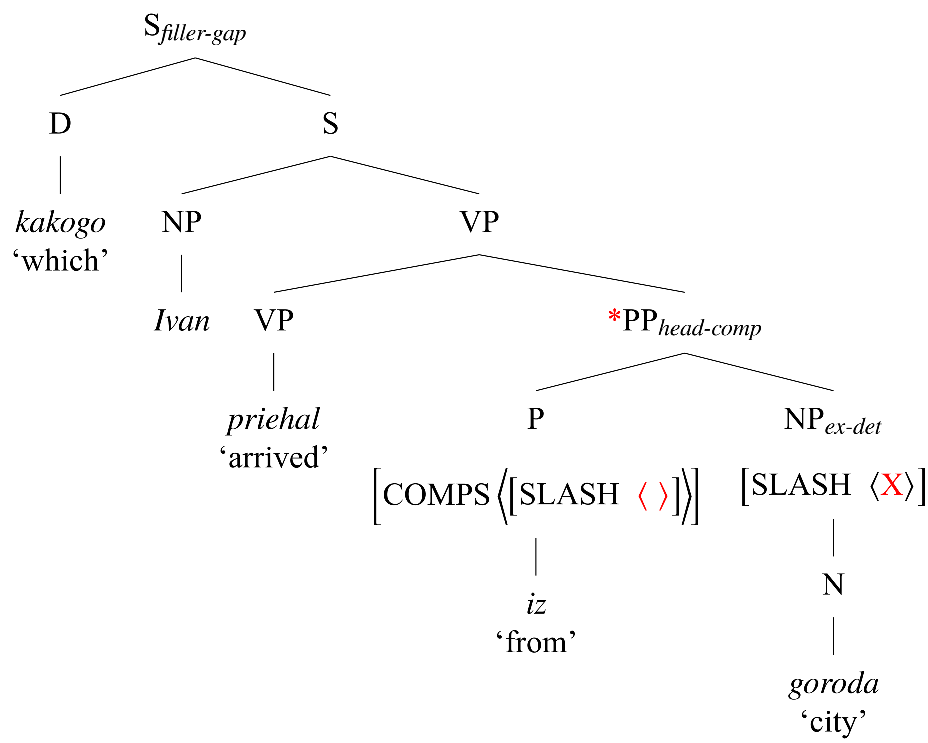
[39]The +*nvjrcdmo* is a disjunctive type that includes everything except adpositions. The full list of these types with a legend is included in every Matrix grammar.

(271)
$$\begin{bmatrix} \textit{extracted-comp-phrase} & \\ \text{SYNSEM} & \begin{bmatrix}\text{LOCAL|CAT|VAL|COMPS} & \boxed{0} \\ \text{NON-LOCAL|SLASH|APPEND} & \left\langle \boxed{1}\,, \left[\text{LIST } \langle\boxed{2}\rangle\right] \right\rangle\end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix}\text{VAL|COMPS} & \begin{bmatrix}\text{FIRST} & \begin{bmatrix}\textit{gap} & \\ \text{LOCAL} & \boxed{2}\end{bmatrix} \\ \text{REST} & \boxed{0}\end{bmatrix} \\ \textbf{HEAD} & \boldsymbol{+nvjrcdmo}\end{bmatrix} \\ \text{NON-LOCAL|SLASH} & \boxed{1}\end{bmatrix}\end{bmatrix}$$

In the presence of the determiner extraction rule however, it is also necessary to constrain adpositions themselves to not take gappy complements (272) in order to rule out sentences like (268b), as illustrated in (273).

(272)
$$\begin{bmatrix} \textit{norm-adposition-lex} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{adp} & \\ \text{MOD} & \left\langle \begin{bmatrix} \textit{intersective-mod} & \\ \text{LOCAL} & \begin{bmatrix} \text{CAT|VAL|SPR} & \textit{cons} \\ \text{CONT|HOOK|INDEX} & \boxed{5} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{SPEC} & \langle\ \rangle \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \left\langle \boxed{3} \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{VAL|SPR} & \langle\ \rangle \end{bmatrix} \\ \text{CONT|HOOK|INDEX} & \boxed{0} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK|INDEX} & \boxed{5} \\ \text{RELS|LIST} & \left\langle \begin{bmatrix} \text{PRED } \boxed{2} \\ \text{ARG0 } \textit{event} \\ \text{ARG1 } \textit{event-ot-ref-ind} \end{bmatrix} \right\rangle \\ \text{HCONS|LIST } \langle\ \rangle & \end{bmatrix} \\ \textbf{NON-LOCAL|SLASH|LIST } \langle\ \rangle & \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \textit{non-local-none} \end{bmatrix} \\ \text{LKEYS|KEYREL} & \begin{bmatrix} \textit{arg12-ev-rel} \\ \text{PRED } \boxed{2} \\ \text{ARG1 } \boxed{5} \\ \text{ARG2 } \boxed{0} \end{bmatrix} \\ \text{ARG-ST} & \langle\boxed{3}\rangle \end{bmatrix}$$

(273)



6.5.4 Interim summary

The analysis of multiple optional fronting presented above relies on the set of rules used in my analysis of single obligatory fronting and *in situ* languages, put together. The extraction and filler-gap rules, the constraint on the length of the SLASH list removed, take part in the analysis of fronted question phrases. The *in situ* phrase is used for nonfronted question phrases, for which it is also necessary that the subject-head rule allows *wh*-phrases as nonhead daughters. Put together, the combination yields optional fronting. This analysis is not perfect; a number of ambiguity issues arise, which can be handled with the addition of new features, but some issues will remain even then. Specifically, I present the analysis as working exactly to the degree presented in my description of the testing of the Russian grammar (§8.3.2). It is the biggest grammar that I test in the scope of this work, and I note that the combination of the *in situ* rule with the filler-gap rule appears awkward, given the ambiguity issues such as the ones presented above. The need for additional devices such as L-QUE feature and the *clist* type, which still do not succeed in ruling out all of the ambiguity completely, may point towards the view largely held in the Minimalist literature, namely that there is no optional fronting and that examples like (240) should probably be analyzed as involving multiple application of the filler-gap rule not only to *wh*-words but also to the subject of the clause.

6.6 Languages which do not allow multiple questions

Recall from Chapter 2 that some literature argues that there are languages such as Tamasheq (Berber) which do not permit multiple questions in one clause (274a)–(274b).

(274) a. May t-sghu terbatt
what.CM 3FS-bought girl
'What did the girl buy?' [taq] (Stoyanova, 2008, p. 174)

b. *Wiy yzrin may?
who.CM saw.PART what.CM
Intended: 'Who saw whom?' [taq] (Stoyanova, 2008, p. 174)

For this section of my analyses, I did not have a test suite from a real illustrative language;[40] instead, I constructed a specification and test suite for a pseudolanguage (§5.4). It is an optionally fronting VSO pseudolanguage (275).

(275)
```
tv the n1 the n2
who tv the n2?
tv who the n2?
tv the n1 what?
what tv the n1?
*tv who what?
*who tv what?
*what tv who?
```

Modeling this pseudolanguage requires a different version of the filler-gap *wh-ques-phrase*, since this language is fronting, while a language which does not allow multiple questions but that is *in situ*, requires a different version of the *in-situ-ques*. In the pseudolanguage presented above, the head daughter of the *wh-ques-phrase* is constrained to be QUE-empty (276). The length of its

[40]This is simply because of prioritizing in the context of various constraints, mainly time. I would have used Italian or Berber as an illustrative language, had I had more time.

SLASH list will be constrained to 1 because this type of language can only be specified as single fronting.[41]

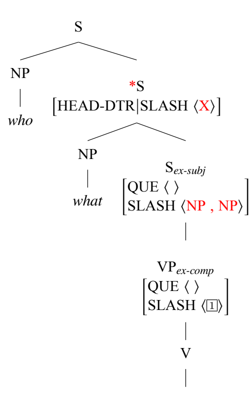
(276)
$$\begin{bmatrix} \textit{wh-ques-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \multicolumn{2}{l}{\text{CONT}\mid\text{HOOK}\mid\text{INDEX}\mid\text{SF}\ \textit{ques}} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}\mid\text{LIST} & \langle\ \rangle \\ \text{SLASH}\mid\text{LIST} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR}\mid\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\mid\text{CAT} & \begin{bmatrix} \text{VAL}\ \boxed{0} \begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH}\mid\text{LIST} & \langle\boxed{1}\rangle \\ \textbf{QUE}\mid\textbf{LIST} & \langle\ \rangle \end{bmatrix} \\ \text{NON-HEAD-DTR}\mid\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\ \boxed{1} \begin{bmatrix} \text{CONT}\mid\text{HOOK}\mid\text{ICONS-KEY} & \textit{focus} \end{bmatrix} \\ \text{NON-LOCAL}\mid\text{QUE}\mid\text{LIST}\ \langle\textit{ref-ind}\rangle \end{bmatrix} \end{bmatrix}$$

This means, there could be at most one application of the filler-gap *wh-ques-phrase*, as in other single fronting languages, and furthermore, if rules like subject-head or head-complement allow *wh*-phrases as non-head daughters, whichever phrase structure rules applied prior to the *wh-ques-phrase*, the clause so far cannot contain any *wh*-elements (277).[42]

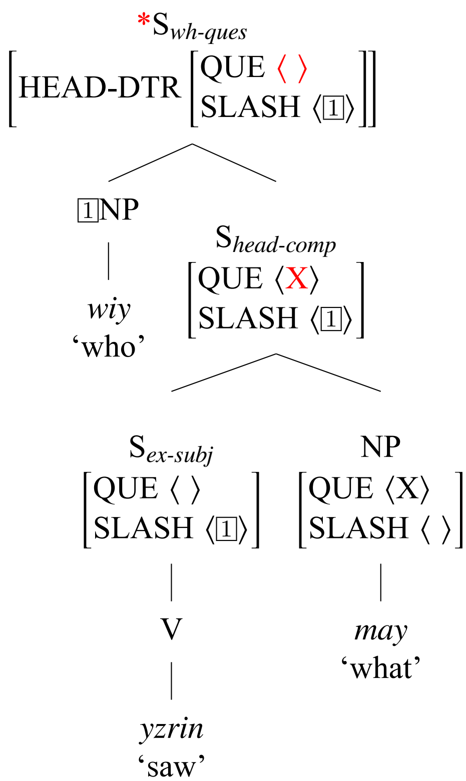
---

[41] Trying to specify a language which does not allow multiple questions as multiply fronting should lead to a Matrix questionnaire validation error. It is not a permitted choice because it does not make sense logically.

[42] In a hypothetical SOV language which would not allow multiple questions in one clause, the SLASH list length constraint would preclude also a multiple application of the filler-gap *wh-ques-phrase* which would otherwise be possible, as my *wh-ques-phrase* zeroes out the QUE list (i).

(i)


(277)

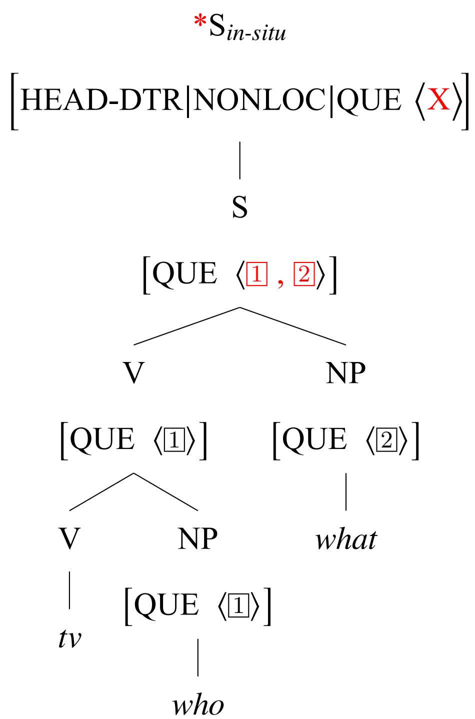


The *in situ* phrase in such languages will constrain its head daughter to have a QUE list of length exactly one (278).

(278)
$$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix}\text{MC} & \textit{bool}\\ \text{VAL} & \boxed{0}\end{bmatrix} \\ \text{NON-LOCAL} & [\text{QUE|LIST}\ \langle\ \rangle] \end{bmatrix} \\ \text{HEAD-DTR|SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0}\begin{bmatrix}\text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle\end{bmatrix}\end{bmatrix} \\ \text{NON-LOCAL} & [\mathbf{QUE|LIST}\ \langle \text{X}\rangle] \end{bmatrix}\end{bmatrix}$$

With this constraint in place, (279) is ruled out because phrasal types like head-subject and head-complement rule append their daughters' QUE values (§6.3.2).

(279)



If the pseudolanguage is extended to include also complex sentences, then the problem arises how to rule out sentences like (280).

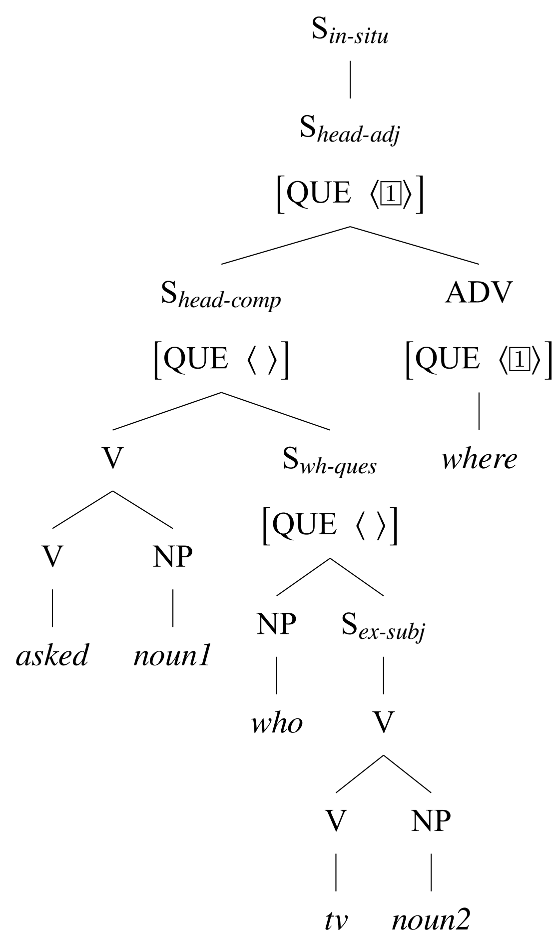
(280) *[Asked Noun1 who tv Noun2] where
'Where did Noun1 ask, who performed some action on Noun2?' [pseudo]

In an optionally fronting language (§6.5.2), there will be both the filler-gap phrase and the *in situ* phrase, resulting, problematically,[43] in (281). The QUE constraint is not going to help here because the filler-gap rule (and interrogative phrasal types generally) discharge the QUE dependencies. In other words, QUE is not a way to detect whether the structure is a constituent question; it is only a way to detect a long-distance dependency that has not yet been discharged. The point is, even if

[43] To reiterate, this is a constructed situation and artificially constructed ungrammaticality. Stoyanova (2008) argues that there are languages which do not allow multiple questions or multiple focus positions, all examples in her paper being simple clauses. It is not fully clear to me whether this 'ban' on multiple questions generalizes to complex clauses, given also that I am not working within the same syntactic theory tradition. I think it should generalize because she argues that it is the uniqueness of the focus position that is responsible for the 'ban', drawing comparisons with e.g. multiple fronting in Bulgarian. If multiple fronting is an example of a "cluster" focus position (Stoyanova, 2008), then the argument should probably apply to complex clauses and long-distance questions, because fronting is tightly connected to LDDs.

the *wh*-adverb constrains the element it modifies to have empty QUE, that is not going to violate any constraints on the structure which contains a full question, and constraining QUE lists in this language to be at most of length one is not going to help either if there is an full embedded question as in (281).

(281)



This situation can be ruled out if we keep track not only of whether there is a question-related dependency in the sentence but additionally whether there is a question word there. This can be done using a feature type (I will call it WH)[44] for which a boolean feature is appropriate:[45] [WH|BOOL *bool*]. Then suppose this BOOL is + in all *wh*- words and − in all other words. Now,

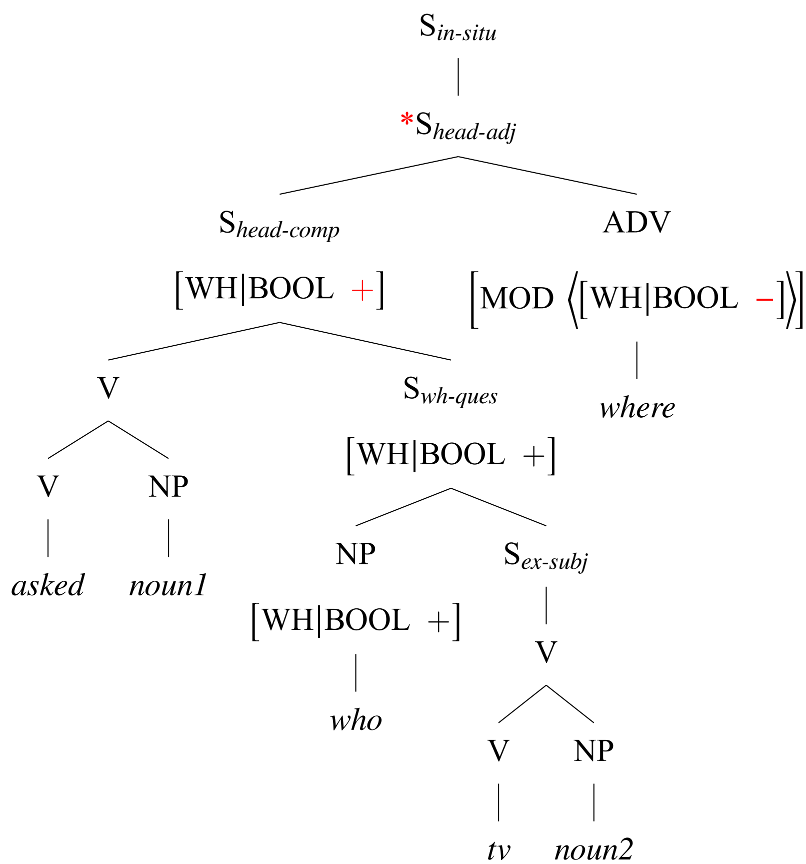
[44] Recall that in Ginzburg and Sag (2000), QUE is called WH. This is not how I use the feature name here; here I use QUE for Pollard and Sag's (1994) QUE and WH for the new feature.

[45] Generally, a boolean is a type which has exactly two possible values (usually *true* and *false*). In the Grammar Matrix *true* is called + and *false* is called −.

if the value of WH on mothers of phrases like head-subject, head-complement, and head-adjunct is a logical OR of the daughters,[46] it becomes possible to constrain the *wh*-adverb to not modify structures which already have a *wh*-word in them (282)–(283).

(282) $$\begin{bmatrix} \textit{wh-adverb} \\ \text{SYNSEM|HEAD|MOD } \left\langle \begin{bmatrix}\text{LOCAL|CAT|WH|BOOL } -\end{bmatrix} \right\rangle \end{bmatrix}$$

(283)



The first part of the solution exemplified by (283) involves revising the types (250) and (251) as (284) and (285), after adding WH as a feature appropriate for the CATegory substructures (286).

(284) $$\begin{bmatrix} \textit{basic-wh-word-lex} \\ \text{SYNSEM} \begin{bmatrix} \text{L-QUE} & + \\ \text{LOCAL|CAT|WH|BOOL} & + \end{bmatrix} \end{bmatrix}$$

[46] Logical OR is a function which takes two boolean values as input and outputs *true* if at least one of them is *true*, and *false* otherwise. In other words, OR returns *false* only if both inputs were *false*.

(285) $\begin{bmatrix} \textit{basic-non-wh-word-lex} & \\ \text{SYNSEM} & \begin{bmatrix} \text{L-QUE} & - \\ \text{LOCAL}|\text{CAT}|\text{WH}|\text{BOOL} & - \end{bmatrix} \end{bmatrix}$

(286) $\begin{bmatrix} \textit{cat} & \\ \text{HEAD} & \textit{head-min} \\ \text{VAL} & \textit{valence-min} \\ \text{MC} & \textit{luk} \\ \text{MKG} & \textit{mkg} \\ \text{HC-LIGHT} & \textit{luk} \\ \text{POSTHEAD} & \textit{bool} \\ \text{WH} & \textit{logical-or} \end{bmatrix}$

As for implementing the OR operation and the type *logical-or* in the DELPH-IN formalism, interested readers are invited to consult §7.11.3 for full details. What matters here is that WH takes the type *logical-or* as its value, which in turn has the feature BOOL. Ultimately, each specific structure has its value for BOOL either underspecified or $+$ or $-$. The value on the mother of e.g. the head-subject rule is the logical OR of the daughter's booleans, so that where there is any $+$ value, the result is $+$ regardless of what the second value is.

6.7 Question particles. Illustrative languages: Japanese (Japonic), Russian (Indo-European)

As discussed in §2.6, question particles are separate words in the clause which mark it as a question. I start here with an analysis of Japanese clause final particles (§6.7.1). As for second position, I did not include a real illustrative language specification and test suite, but second position particles are used in Russian for polar questions, and I include an illustrative analysis for those along with an analysis of a pseudolanguage with second position constituent question particles (§6.7.2).

6.7.1 Clause-final question particles

In Japanese, the particles are clause-final (287). Furthermore, I assume an analysis of Japanese where *no* and *ka* have different distribution, according to Miyagawa (1987). In particular, *no* is described as possible in both main and embedded clauses while *ka* is described as possible in constituent questions only in embedded clauses (287)-(290).[47]

(287) Dare ga kuru no?
who NOM come Q
'Who will come?' [jpn] (Miyagawa, 1987)

(288) *Dare ga kuru ka?
who NOM come Q
Intended: 'Who will come?' (Miyagawa, 1987)

(289) Boku wa [dare ga kuru no] sitteru
I TOP who NOM come Q know
'I know who will come.' [jpn] (constructed by me based on Miyagawa 1987)

(290) Boku wa [dare ga kuru ka] sitteru
I TOP who NOM come Q know
'I know who will come.' [jpn] (Miyagawa, 1987)

The lexical type for clause-initial and clause-final question particles was already in the Matrix for the polar questions analysis (Bender and Flickinger, 2005). Such particles were analyzed by Bender and Flickinger (2005) as complementizers and are therefore a subtype of the *complementizer-lex-item* and simply add an interrogative sentential force value to the clause; if a question particle attached, the clause's SF (sentential force; §4.2.1) value is no longer underspecified between *prop*osition and *ques*tion and becomes *ques* (291).

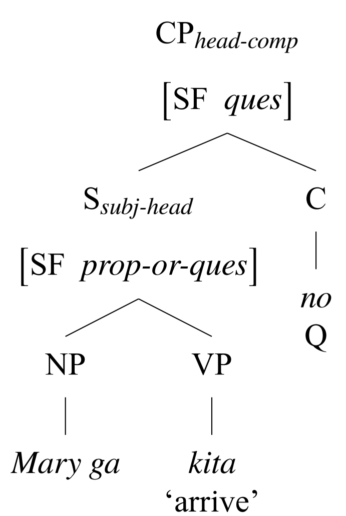
[47] Actually, it does not appear to be the case generally; see e.g. Wakabayashi and Okawara 2003 for examples of the use of *ka* in main clauses, with formally polite verb forms. Nevertheless, the ability to model a grammar fragment which does not include politeness and where *ka* is therefore not possible in main clauses is part of the goals of the grammar customization system.

(291)
$$\begin{bmatrix} \textit{qpart-comp-lex-item} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{comp} & \\ \text{MOD} & \langle\ \rangle \end{bmatrix} \\ \text{MC} & \textit{bool} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{SPEC} & \langle\ \rangle \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle \boxed{0} \rangle \end{bmatrix} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HCONS}|\text{LIST} & \langle\ \rangle \\ \text{RELS}|\text{LIST} & \langle\ \rangle \\ \text{HOOK} & \begin{bmatrix} \text{INDEX}|\text{SF} & \textit{ques} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \textit{non-local-none} \end{bmatrix} \\ \text{ARG-ST} & \left\langle \boxed{0} \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

The particle being a complementizer, the derivation for (292) looks like (293), with the particle and the clause joining under the head-complement rule:

(292) Mary ga kita no
Mary NOM arrive Q
'Did Mary arrive?' [jpn] (Sudo, 2013)

(293)



Under my analysis, the same particle lexical type is used in constituent questions like (287) as well. Note that the *in situ* rule and the particle perform duplicate semantic work; with or without the particle, the semantic structure will be the same (Figure 6.5).

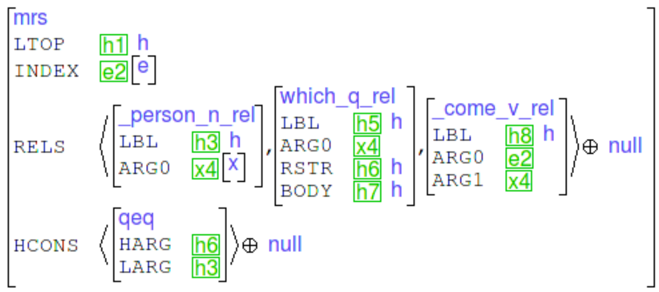


Figure 6.5: The semantic structure for the sentence (287)

(294)

CP*head-comp* [SF *ques*]
- S*in-situ* [SF *ques*]
  - S*subj-head* [SF *prop-or-ques*]
    - NP — *dare ga* 'who'
    - VP — *kuru* 'come'
- C — *no* Q

As for the optionality of the particle, the lexical type for the particle is not involved; rather, the question-forming phrasal type is. Note that, given the underspecified MC (main clause) feature value on the *in-situ-ques* type (217), the mother of the *in situ* phrase is unifiable with the *root* (75); it can (294) but does not have to (218) further go through the head-complement for a sentence to be well-formed. This is to account for the fact that particles in Japanese are optional (Miyagawa,

1987) (see §6.7.3 for the treatment of particles obligatory and impossible in constituent questions).

Finally, according to Miyagawa (1987), in constituent questions, the particle *ka* is only possible in embedded clauses (288)–(290). This is achieved with a subtype of the question particle (291) presented in (295).

(295)
$$\begin{bmatrix} \textit{ka-particle} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL|CAT} & \begin{bmatrix} \text{MC} & \boxed{1}- \\ \text{VAL|COMPS} & \left\langle \begin{bmatrix}\text{MC} & \boxed{1}\end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Such a type ensures that sentence (288) is blocked because the structure licensed by attaching *ka* to its complement will be [MC −] which is incompatible with the type *root* (75). Sentence (290), on the other hand, is licensed. The *no* particle, if specified as possible in both main and embedded clauses and in both polar and constituent questions, will not have these additional constraints and will license both (287) and (290).

6.7.2 Second position question clitics

Question particles also come in the form of second position elements, as is illustrated by Russian examples (296)–(297). In Russian, the clitic attaches to the first word in the sentence (rather than the first phrase), and the position is relative to the clause as shown in (297) where the position is second within the embedded clause.

(296)

Пишет	**ли**	студент	диссертацию?
Pishet	**li**	student	dissertatsiju?
write3SG.PRES	Q	student.NOM	dissertation.ACC

‘Is the student writing the dissertation?’ [rus]

(297)

Я	не	знаю,	пишет	**ли**	студент	диссертацию.
Ya	ne	znayu,	pishet	**li**	student	dissertatsiju.
1SG	NOT	know.1SG.PRES	write3SG.PRES	Q	student.NOM	dissertation.ACC

‘I don’t know whether the student is writing the dissertation.’ [rus]

(298)

***Кто**	**ли**	идет?
***Kto**	**li**	idet?
who.NOM	Q	arrive.3SG.PRES

Intended: ‘Who is arriving?’ [rus]

The Russian examples (296) and (297) show a second position clitic in polar questions. Indeed, in Russian this clitic is not possible in constituent questions (298). The analysis of second position clitics presented below works both for languages like Russian and those where the same particle can be used in polar and constituent questions, but the only natural language data I tested it with is from Russian (§8.3). So, during development, I tested the analysis applied to constituent questions only with artificial pseudolanguage data (§5.4). Because I worked mostly with Russian second position clitics, the discussion in this section needs to depart from constituent questions to a fair extent, in order to give sufficient detail on how the analysis of second position clitics works. However, these details are necessary to demonstrate the interaction between the two phenomena in the context of implementing an analysis for a range of question particles as a system.[48] The last thing to note here is that I do not implement support for second position clitics in embedded clauses (297). In this work, I implement the preliminary analysis sketched by Emily M. Bender for her grammar engineering class without any extensions. That analysis only covers cases like (296), where second position is taken strictly, to mean literally second position in any string of words, regardless of whether there are multiple clauses there.

The type for the second position clitic is presented in (299).

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[48]I have a section in the next chapter of this dissertation which is dedicated to interactions between libraries (§7.10). However, it did not make sense to postpone the discussion of second position clitics in polar questions until that section, because without such discussion, it is hard to explain how the analyses together cover a range of particle-related phenomena in the context of constituent questions.

(299)
$$\begin{bmatrix}\textit{ques-clitic-lex-item} & \\ \text{SYNSEM} & \begin{bmatrix}\text{LOCAL} & \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD} & \begin{bmatrix}\textit{adv} & \\ \text{MOD} & \left\langle\begin{bmatrix}\textit{intersective-mod} & \\ \text{CAT}|\text{HEAD} & +\textit{nvrpd} \\ \text{L-PERIPH} & + \\ \text{LIGHT} & +\end{bmatrix}\right\rangle\end{bmatrix} \\ \text{VAL} & \begin{bmatrix}\text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle\end{bmatrix}\end{bmatrix} \\ \text{CONT} & \begin{bmatrix}\text{RELS}|\text{LIST} & \langle\,\rangle \\ \text{NON-LOCAL} & \begin{bmatrix}\text{QUE}|\text{LIST} & \langle\,\rangle \\ \text{REL}|\text{LIST} & \langle\,\rangle \\ \text{SLASH}|\text{LIST} & \langle\,\rangle \\ \text{YNQ}|\text{LIST} & \langle\textit{*top*}\rangle\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

This type treats second position clitics as modifiers and differs from other modifiers in features YNQ[49].

That the particle only occurs in second position is achieved with the combination of L-PERIPH and LIGHT features. LIGHT is a boolean feature introduced to HPSG by Abeillé and Godard (2001).[50] This feature is used to indicate whether a constituent is more like a single word ([LIGHT +]) or more like a phrase ([LIGHT −]). I will demonstrate how it works soon below, after introducing the L-PERIPH feature, but in general, LIGHT is + in terminal nodes licensed by lexical entries and − on mothers of phrasal rules.[51]

L-PERIPH is an 'edge' feature (Miller, 1992), like L-QUE (§6.5.2), and it was first used in the Grammar Matrix by Song (2014), in the information structure library. The value of the feature is of type *luk*,[52] but for the present purposes, the reader can think of it simply as a boolean feature.

[49] Calling the feature YNQ may not be accurate because, as I explain below, the clitic can be used to form both polar and constituent questions. Perhaps the feature could be renamed in the future.

[50] In Abeillé and Godard 2001, LIGHT is called LITE.

[51] Such constraints were already in place on most of the types in the Grammar Matrix before my work.

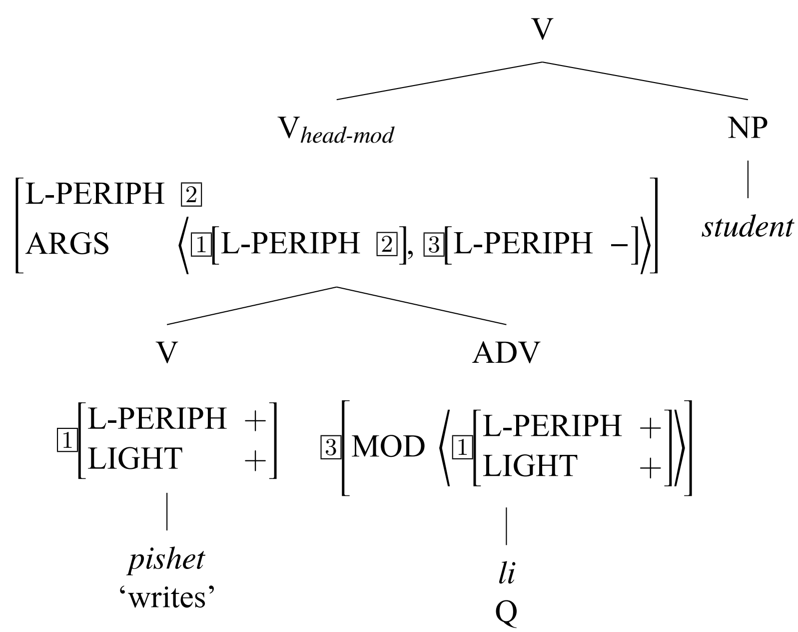
[52] *luk* includes subtypes + and − but additionally has a possible value of *n/a*; the need for this is not pertinent here but details can be found in Fokkens 2014, p.140 and in Song 2018, p.152.

Like the L-QUE value, the L-PERIPH value is propagated along the left edge of the clause (300). The specific value of the feature arises from the second position particle which states that the element it modifies is [L-PERIPH +] (299) in combination with any binary phrase constrained as (300), which states that its second daughter's L-PERIPH value is − and the mother's value is propagated from the first daughter.

(300)
$$\begin{bmatrix} \textit{basic-binary-phrase} & \\ \text{SYNSEM}|\text{L-PERIPH } \boxed{1} & \\ \text{ARGS} & \left\langle \left[\text{SYNSEM}|\text{L-PERIPH } \boxed{1}\right], \left[\text{SYNSEM}|\text{L-PERIPH } -\right] \right\rangle \end{bmatrix}$$

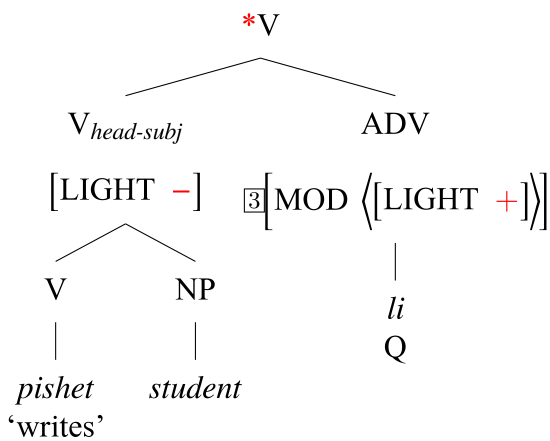
Such a constraint needs to be added to all binary phrases as well as to the bare NP rule (which simply propagates the value to mother from the sole daughter). This, together with the LIGHT constraint on the element the question clitic modifies (299), ensures the particle which modifies [L-PERIPH +] elements will only appear in second position, as illustrated by (301) and (302)–(303) for a fragment of the sentence (296).[53]

(301)

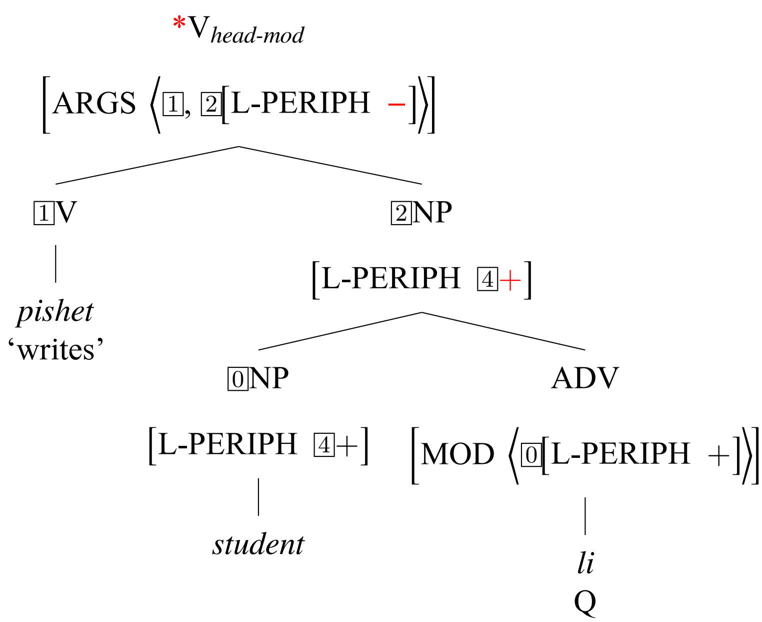


[53] Examples of full sentences to follow once the YNQ feature and the associated phrase structure rule are introduced.

(302)



(303)



A fragment where the clitic is in the third position is impossible because, first of all, as illustrated by (302), the clitic cannot attach to a phrase, because of the LIGHT constraint. The only way for the clitic to attach to a word would be low; but then, unless it is actually in the second position, the resulting structure becomes [L-PERIPH +] and cannot serve as the second daughter to any other binary rule, precluding any derivation, as illustrated by (303).

To license full question sentences with second position clitics, I need yet another feature, and an additional phrase structure rule.[54] The feature YNQ is similar to QUE in that it is a nonlocal

[54]Once again, I owe this analysis to Emily M. Bender and her grammar engineering class.

feature that signals that a clause is a question, but is different from it in that it is not tied to a *wh*-word. So, in Russian, the type which introduces nonlocal features into the type hierarchy will look like (304).

(304) $\begin{bmatrix} \textit{non-local} & \\ \text{SLASH} & \textit{append-list} \\ \text{QUE} & \textit{append-list} \\ \text{REL} & \textit{append-list} \\ \text{YNQ} & \textit{append-list} \end{bmatrix}$

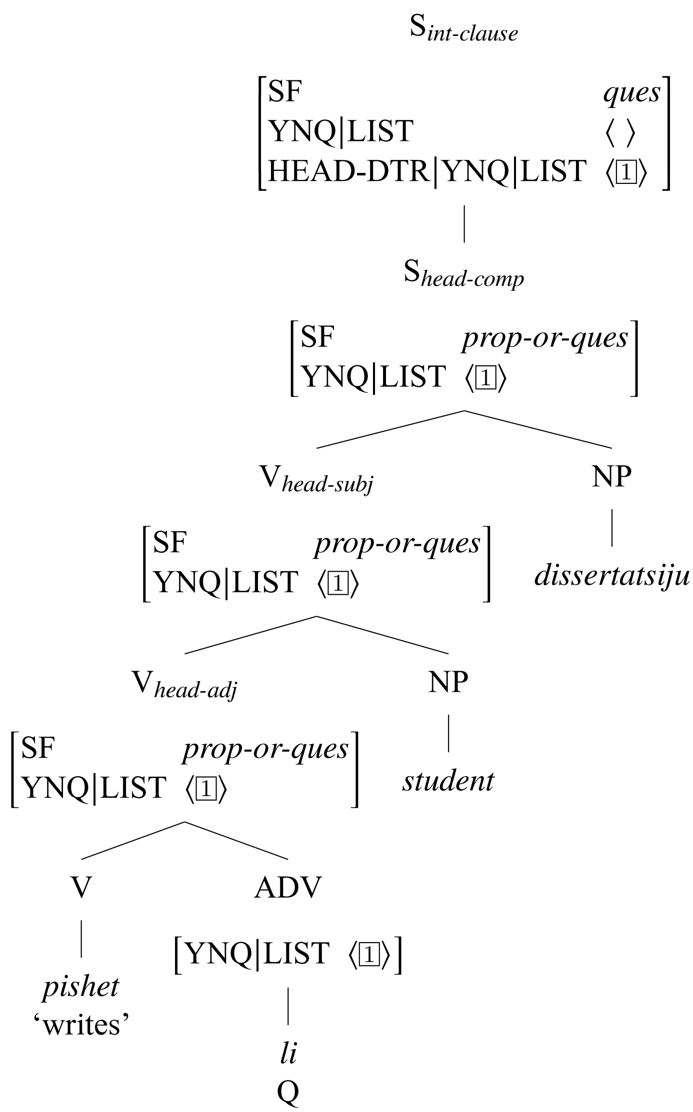
The unary phrase structure rule is presented below as (305)[55] and the derivation for (296) which leads to the semantic representation in Figure 6.6 is shown in (306).

(305) $$\begin{bmatrix} \textit{int-cl-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & +\textit{vc} \\ \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \textit{non-local-none} \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT}|\text{VAL} & \boxed{0} \begin{bmatrix} \text{SUBJ} & \langle\, \rangle \\ \text{SPR} & \langle\, \rangle \\ \text{SPEC} & \langle\, \rangle \\ \text{COMPS} & \langle\, \rangle \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH}|\text{LIST} & \langle\, \rangle \\ \text{REL}|\text{LIST} & \langle\, \rangle \\ \text{QUE}|\text{LIST} & \langle\, \rangle \\ \text{YNQ}|\text{LIST} & \langle \textit{*top*} \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

---

[55]Recall from §3.1 that **top** is the “top” type in the Matrix hierarchy. What is important here is that the YNQ list is nonempty.

(306)



Consider (306) in more detail. Under the present analysis, second position question particles are modifiers (299), and as such they attach to heads as non-head daughters of the head-adjunct rule. The resulting mother structure can unify with the head daughter of a rule such as the head-subject rule. The YNQ nonlocal feature is percolated up the derivation tree just like other nonlocal features are (§6.3.2). Once a feature structure which could be a stand-alone sentence — except it has got a nonempty YNQ list — is formed, the special YNQ phrase structure rule (305) can apply, yielding a structure with appropriately interrogative content (Figure 6.6), and with all nonlocal features empty, the latter being a constraint placed explicitly on the *root* node (75).

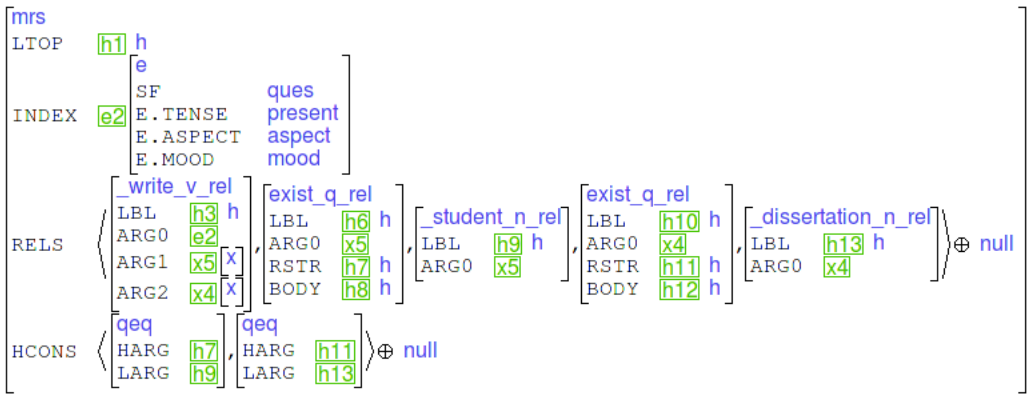


Figure 6.6: The semantic structure for the sentence (296)

Note that the phrase structure rule shown in (305) is a subtype of *interrogative-clause* (137) but unlike other subtypes of *interrogative-clause*, such as the *in situ* rule and the *wh-ques-phrase*, it is used in Russian only for polar questions. To achieve this effect (i.e. to rule out (298)), the question clitic itself needs to be constrained to not modify question phrases. Because this issue pertains not only to second position clitics but to question particles in general (some particles may be possible only in polar questions, some only in constituent questions, and some in both), this aspect of the analysis is discussed separately in §6.7.3.

As a final note on second position clitics in Russian polar questions, consider that in this grammar, both the *in situ* constituent question rule (217) and the polar question second position rule (305) are present, and it is not a problem so long as the *in-situ-ques* (217) is constrained to propagate the YNQ feature value from daughter to mother, as shown in (307).[56]

[56]The *in situ* phrase is not a subtype of *unary-nonloc-phrase* (418) of course, because it needs to discharge the QUE dependencies. The YNQ constraint needs to be added specially.

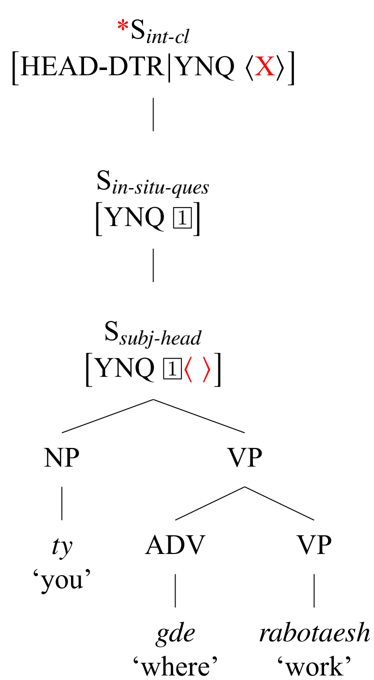
(307)
$$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}|\text{LIST} & \langle\ \rangle \\ \textbf{YNQ} & \boxed{1} \end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0} \begin{bmatrix} \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \textbf{QUE}|\textbf{LIST} & \langle \text{X} \rangle \\ \textbf{YNQ} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

This prevents the two different unary question rules, (305) and (217), from applying to each other like in (309), which is an unwanted tree for the Russian sentence (240) repeated here as (308).

(308) Ты где работаешь?
Ty gde rabotaesh?
2SG where work.2SG.PRES
'Where do you work?' [rus]

(308) should be analyzed using only one of the rules, as applying the second one would not result in any meaningful semantic difference in the MRS representations.

(309)



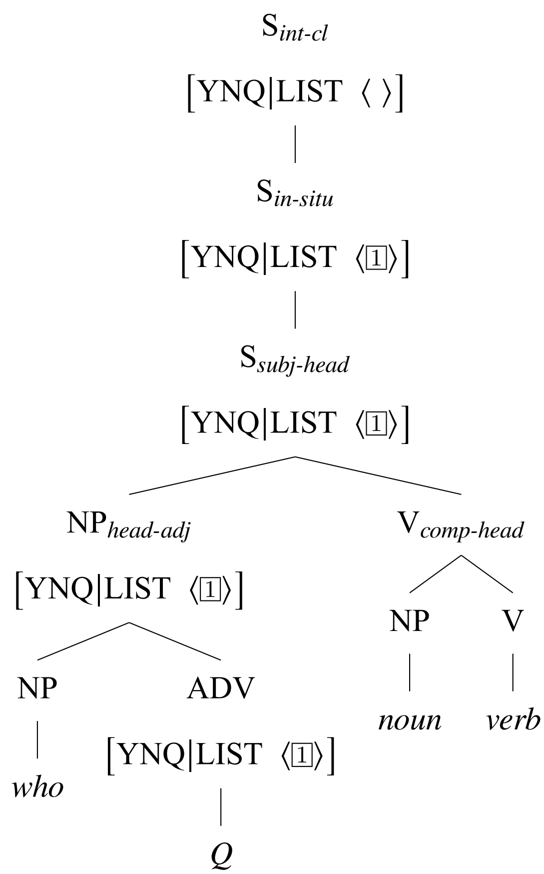
Now that I explained how the additional unary rule (305) works using Russian as an illustrative language, consider a pseudolanguage illustrating second position clitics in constituent questions (310). This artificial V-final language uses the same (obligatory) second position particle for polar and for constituent questions.

(310)
```
n1 iv
*iv n1
n1 Q iv
*n1 iv Q
*Q n1 iv
n1 n2 tv
*n1 tv n2
*tv n1 n2
n1 Q n2 tv
*Q n1 n2 tv
*n1 n2 Q tv
*n1 n2 tv Q
who Q iv
*who iv
who Q what tv
*who what Q tv
*Q who iv
*Q who what tv
*who what tv Q
where Q n1 iv
```

I suggest that in such languages, the derivation for a constituent question simply involves both the *in-situ-ques* and the *int-cl*, as illustrated by (311). As in the Russian example above, the *in-situ-ques* alone will not be sufficient because the YNQ list will not be empty and so will violate the *root* constraint (75), so there will be no spurious ambiguity. If the particle is present in the sentence string, the *int-cl* (311) will be required on top of the *in situ* phrase; if there is no particle, then *int-cl* cannot apply.[57]

[57]Emily M. Bender suggests an alternative analysis where the *in situ* phrase discharges both QUE and YNQ. For the particle to be obligatory, the *in situ* phrase will require nonempty YNQ on the daughter. In the present work, I did not explore this alternative.

(311)



No changes are required to either rule compared to the Russian grammar. The main difference of this pseudolanguage and Russian is in how the clitic itself is defined. In the artificial language where the same particle is possible in both polar and constituent questions, no additional constraints are needed on the particle. In languages like Russian, additional constraints need to be placed. This aspect of the analysis is presented in the next section.

6.7.3 Particles which are impossible, optional, or obligatory in constituent questions. Illustrative languages: Russian (Indo-European), Japanese (Japonic).

In constituent questions, question particles (regardless of the particle position) may be impossible (312a)–(312b), like the second-position *li* in Russian; required (313), like *pa* in Ladin ([lld];

[58]The particle *pa* in Ladin appears neither clause-initial nor second position, and my analysis does not cover such particles. I use a pseudolanguage to test the obligatoriness of particles in my analysis.

Indo-European);[58] or optional (314), like in Japanese.

(312) a. Иван ли идет?
Ivan li idet?
Ivan.NOM Q arrive.3SG.PRES
'Is it Ivan who is arriving?' [rus]

b. *Кто ли идет?
*Kto li idet?
who.NOM Q arrive.3SG.PRES
Intended: 'Who is arriving?' [rus]

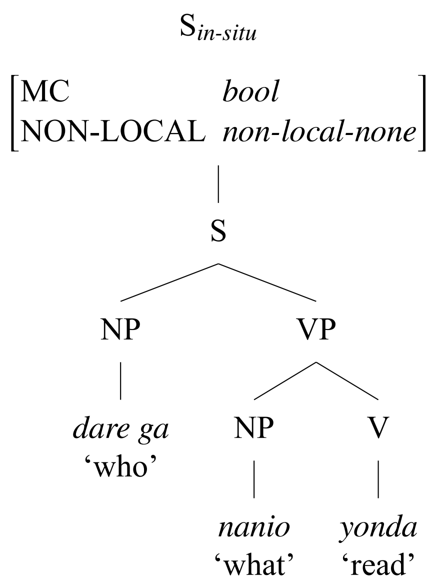
(313) a. Can compr = i pa n liber?
when buy.3PL = SCL PA a book
'When are they going to buy a book?' [lld] (Hack, 2014)

b. *Can compr = i n liber?
when buy.3PL = SCL a book
Intended: 'When are they going to buy a book?' [lld] (Hack, 2014)

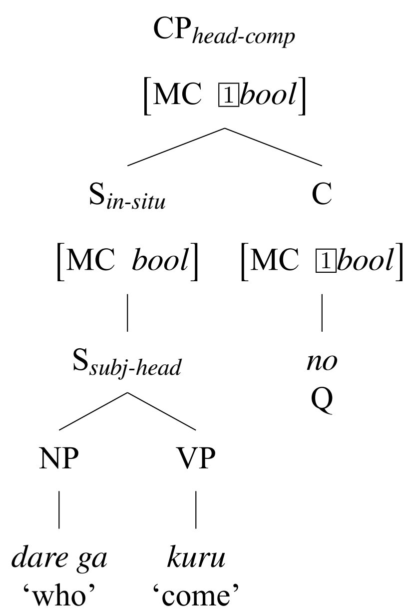
(314) Dare ga kuru (no)?
who NOM come Q
'Who will come?' [jpn] (Miyagawa, 1987)

As already mentioned in §6.7.1, for languages like Japanese where the particle is optional (314), no additional constraints are required on either the phrase structure rules or on the particle lexical type. Given (217) and (291), (314) is possible with and without the particle, simply because the *in situ* rule unifies with the *root* (75) (in particular, its nonlocal lists are empty and its MC (main clause) feature value is underspecified and therefore unifies with +), which yields (219) repeated here as (315), and can at the same time also serve as a complement for the particle, as in (294), repeated here as (316).

(315)



(316)



To make a particle obligatory in constituent questions (313),[59] the *in situ* phrase can be constrained to be [MC −] (317); this will preclude it from unifying with the *root* and it will not yield a derivation like (315) unless combined with the particle, like in (316).[60] If it does combine with

[59]I did not compile a test suite for Ladin [lld] (313) and tested this analysis with a pseudolanguage.

[60]In that case, there would be an [MC -] on the mother of the *in situ* phrase, which would not unify with *root* (75).

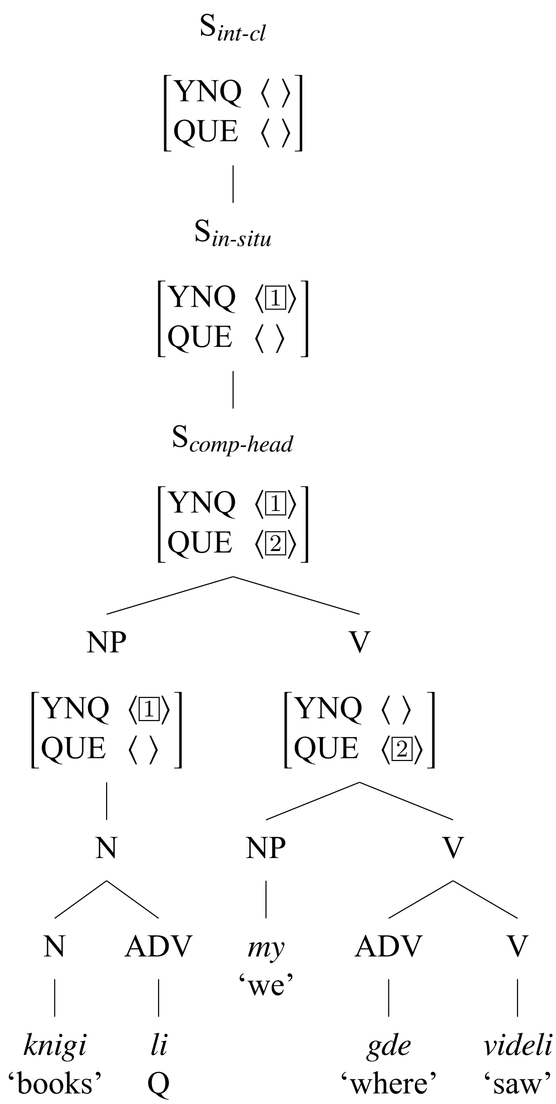
a particle, the mother of the head-complement rule will have the MC value of the head daughter (the particle), which is *bool* (291).

(317)
$$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\mid\text{CAT} & \begin{bmatrix} \text{MC} & - \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix}\text{QUE}\mid\text{LIST} & \langle\ \rangle\end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR}\mid\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}\mid\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0}\begin{bmatrix}\text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle\end{bmatrix}\end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix}\text{QUE}\mid\text{LIST} & \langle \textit{ref-ind}, \ldots\rangle\end{bmatrix} \end{bmatrix}\end{bmatrix}$$

But how to constrain a particle so it only appears in polar questions but not in constituent questions, like the Russian *li* (312a)–(312b)? Perhaps the first thing that comes to mind is to use the QUE constraint to prevent particles from attaching to question phrases; indeed that is what Fan (2018, p.119) says she did for her analysis of Mandarin where the clause-final particle *ma* appears only in polar questions. After all, nonempty QUE lists arise from *wh*-words. But recall from §6.6 that the QUE feature is not for detecting whether a structure is a question; it is only to track long-distance dependencies. So, constraining the particle to only modify QUE-empty things would only prevent the particle from attaching directly to a *wh*-word, not from it appearing in a constituent question where the question is about some other constituent (318), resulting in the unwanted derivation (319).

(318) *Книги ли мы где видели?
*Knigi li my gde videli?
book.ACC.PL Q 1PL.NOM where see.1PL.PAST
Intended: 'Where did we see the books?' [rus]

(319)



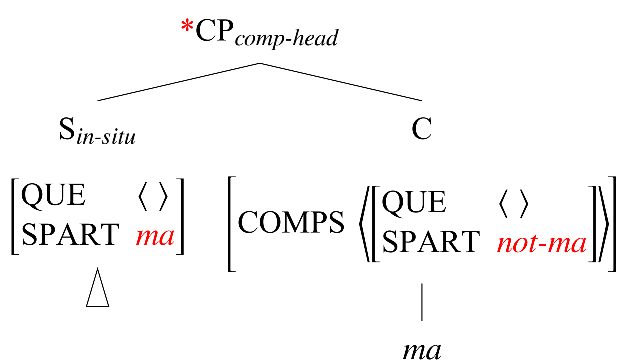
Furthermore, using QUE would not work for the analysis of clause-initial and clause-final particles. Recall from the Japanese section (§6.7.1) that such particles attach to structures which

[61] In the text of her dissertation, Fan (2018) actually states that she used the feature QUE to achieve this effect (p. 119). However, this appears to be a mistake. Upon downloading and inspecting her grammar, I conclude that QUE has no effect there (as it could not possibly have any effect there, QUE being empty on the mother of the *in situ* phrase), and what leads to the correct behavior in the Zhong grammar is the feature SPART. A related discussion can be found on the DELPH-IN Q&A site: `https://delphinqa.ling.washington.edu/t/request-for-sample-input-for-jacy-and-zhong/440/14`. Pointing this out is not a criticism of Fan's (2018) work (I have no doubt that lots of mistakes of this sort can be found in any dissertation) but an illustration of how important it is to have an engineered artifact that can be inspected in every detail to verify how exactly the analysis works. I include this remark here mostly for the sake of precision.

already went through a phrase structure rule that discharged the QUE dependency, such as the *in situ* rule in (294). If the QUE dependency has been discharged, the QUE list is empty and at that point, there is no distinction between a constituent question and a polar question that could be detected using this feature.

Fan (2018) models Mandarin *ma* using a special feature called SPART.[61] The feature can take a number of values, of which the two pertinent here are *ma* and *not-ma*. *Ma* and *not-ma* cannot unify with each other, given the type hierarchy in Zhong (Fan, 2018). The particle which is impossible in constituent questions will require its complement's SPART to have a value of *not-ma*. At the same time, the *in situ* phrase is SPART *ma* and as such is not a possible complement for the particle. The situation (including why QUE would not work here) is illustrated in (320).

(320)



To model question particles which are impossible in constituent questions, whether or not they are second position or clause initial/final, I propose a solution similar to Fan's (2018) SPART, though not in every respect. I use the same feature WH that I mentioned briefly in the section about languages which disallow multiple questions (§6.6). In §6.6, I posit the feature as type *logical-or*, containing a boolean feature inside it. The details about the *logical-or* type can be found in §7.11.3; here, it is mostly enough to focus on the boolean part of it.

For languages like Mandarin, the analysis is similar to Fan's (2018). The particle insists on a [WH|BOOL −] complement (321); it will then be impossible in constituent questions so long as the *in situ* phrase is [WH|BOOL +]. The main difference is that the feature WH is not specific to Chinese particles and instead of *ma* and *not-ma*, it is just + and −.

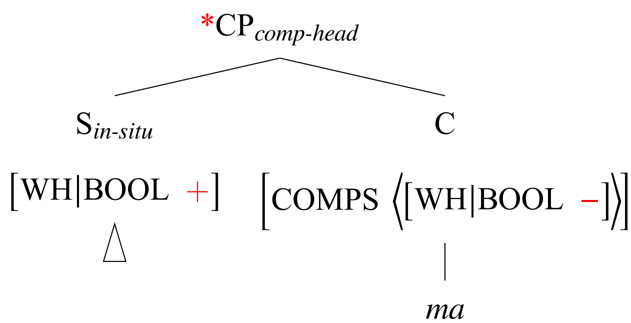
(321) $$\begin{bmatrix} \textit{qpart-comp-lex-item} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{comp} & \\ \text{MOD} & \langle\,\rangle \end{bmatrix} \\ \text{MC} & \textit{bool} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\boxed{0}\rangle \end{bmatrix} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HCONS}|\text{LIST} & \langle\,\rangle \\ \text{RELS}|\text{LIST} & \langle\,\rangle \\ \text{HOOK} & \begin{bmatrix} \text{INDEX}|\text{SF} & \textit{ques} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \textit{non-local-none} \end{bmatrix} \\ \text{ARG-ST} & \left\langle \boxed{0} \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{WH}|\text{BOOL} & - \\ \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

The *in situ* phrase in such languages is [WH|BOOL +] (322).[62] The unwanted derivation is ruled out as shown in (323).

(322) $$\begin{bmatrix} \textit{in-situ-ques} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{WH}|\text{BOOL} & + \\ \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}|\text{LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \boxed{0}\begin{bmatrix} \text{SUBJ} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{QUE}|\text{LIST} & \langle \textit{ref-ind}, ...\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

[62]Note that, if WH is a *logical-or* feature, as suggested in §6.6, then the *in situ* phrase could also be stated to propagate the WH value from daughter to mother. Assuming a binary phrase attached the *wh*-word somewhere below the *in situ* phrase, it would have the same effect as to say that the *in situ* phrase is [WH +], because binary phrases compute the logical OR of the daughters' WH, while unary phrases such as the bare-NP rule and lexical rules propagate the WH value from daughter to mother. The *in situ* phrase requires that the daughter structure's QUE is not empty, therefore a *wh*-word must have been attached at some point below, resulting in the OR value set to + in the very first binary phrase that attached the *wh*-word and remaining + after that. In my implemented version of the Matrix, it is explicitly +, because this is a simpler analysis which would work in the absence of the logical OR mechanism in the grammar. To remind the reader, the use of the logical OR in my system is motivated

(323)



As for Russian, consider once more the unwanted derivation for (318) which would arise had the particle *li* only been prevented from modifying *wh*-words, not from generally occurring in constituent questions (319). Because in Russian the clitic is second position and attaches not to the entire *in situ* construction but to the word, to rule (319) out, it is necessary that the *in situ* phrase is ineligible to serve as the daughter to the *int-cl* phrase. This can be done straighforwardly using the same WH boolean feature, as illustrated in (324). The only other thing this requires is that the *int-cl* rule is stated explicitly as (325), with [WH|BOOL −] on the daughter.

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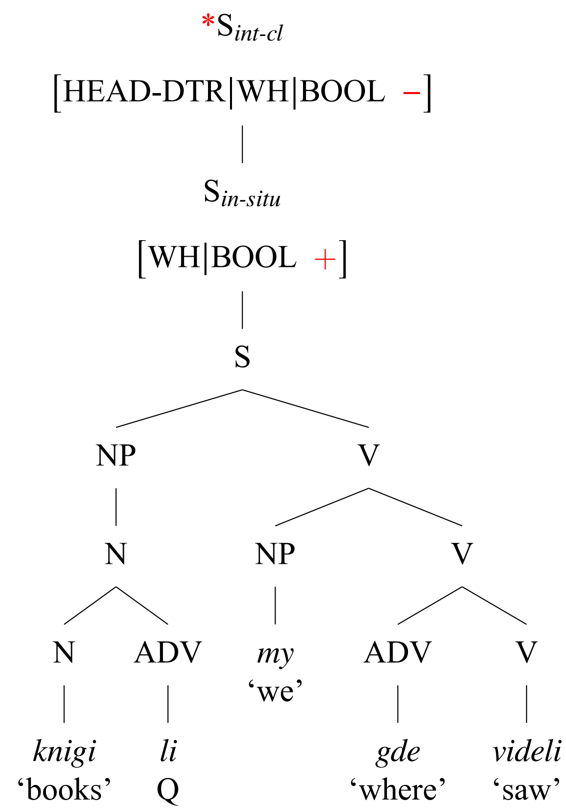
by optional fronting in combination with a ban on multiple questions. Both these concepts (optional fronting and impossibility of multiple questions) do not seem to be mainstream in the literature, and while I include analyses for both, these analyses add complexity to the overall system. In other words, if the data could indeed be reanalyzed without the use of the concepts, it would lead to an overall simpler system.

(324)



(325)

$$\begin{bmatrix} \textit{int-cl-phrase} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{HEAD} & +\textit{vc} \\ \text{MC} & \textit{bool} \\ \text{VAL} & \boxed{0} \end{bmatrix} \\ \text{NON-LOCAL} & \textit{non-local-none} \end{bmatrix} \\ \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL}|\text{CAT} & \begin{bmatrix} \text{WH}|\text{BOOL} & - \\ \text{VAL} & \boxed{0}\begin{bmatrix} \text{SUBJ} & \langle\,\rangle \\ \text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{COMPS} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH}|\text{LIST} & \langle\,\rangle \\ \text{REL}|\text{LIST} & \langle\,\rangle \\ \text{QUE}|\text{LIST} & \langle\,\rangle \\ \text{YNQ}|\text{LIST} & \langle \textit{*top*} \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

6.8 Morphological marking of questions. Illustrative language: Yukaghir (Isolate)

The goal of my analysis of morphological marking of constituent questions is to cover languages like Yukaghir [yux] (326)–(327). Such languages are often polysynthetic and usually do not employ fronting, which is why I focus on morphological marking in combination with the *in situ* strategy (fronting impossible).[63]

(326) kin ejre?
who.NOM walk.ITRG.3SG
'Who is coming?' [yux] (Constructed by me based on Maslova (2003))

(327) touke-lek ejre?
dog-PRED walk.ITRG.3SG
'Is the dog coming?' [yux] (Constructed by me based on Maslova (2003))

The interrogative marking in (326)–(327) is represented by the ITRG gloss. Examples like (327) are already covered in the Grammar Matrix by the polar questions library (Bender and Flickinger, 2005). In this section, I present an analysis for (326) which is integrated with the analysis for (327). Both analyses rely on HPSG lexical rules. In the context of question marking, a lexical rule can be (i) indicative or (ii) interrogative; and if it is interrogative, it can serve (a) polar, (b) constituent questions, or (c) both (328).[64] In my illustrative language Yukaghir it is both (327)–(326).

(328) lexical rule
- (i) indicative
- (ii) interrogative
  - (a) polar
  - (b) constituent
  - (c) both

The discussion of morphological marking motivates another discussion of lexical threading, Bouma et al.'s (2001a) idea that a lexical head's nonlocal feature value is the union of the values

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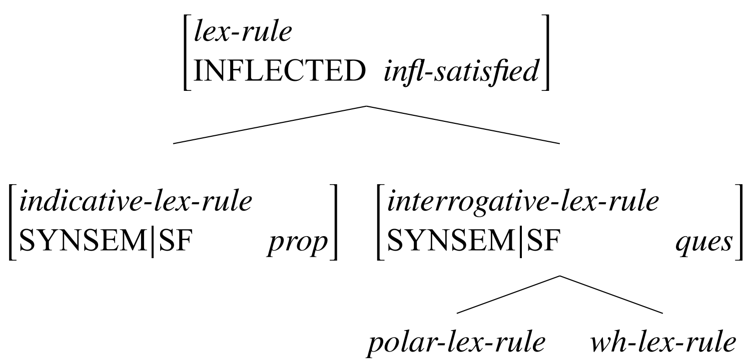
[63] I do not claim any typological correlations here.

[64] Example (328) is not an HPSG hierarchy; it is merely a reference point for what I will call (i), (ii), (a), (b), and (c).

of its arguments (§4.1.2). Recall from §6.5.1 that I do not use lexical threading in the system of analyses presented here. The reasons for this include a more straightforward analysis of fronting in languages with flexible word order and the overall better ease of understanding of Matrix analyses and code (to put it differently, lexical threading makes reasoning about analyses and grammars more difficult). Morphological marking of constituent questions, however, is an example of where lexical threading allows for a particularly elegant analysis, especially when it comes to modeling the distinction between options (a), (b), and (c) above. While I do not use the lexical threading analysis below in the Grammar Matrix, I present it anyway as an illustrative case for lexical threading, at least at the level of an individual language.

Modeling the difference between (i) and (ii) is straightforward either way (with or without lexical threading). Consider an HPSG hierarchy of lexical rules (329).

(329)



An *indicative-lex-rule* simply says its SF value is *prop*. This ensures the correct semantics. As for blocking an application any subtype of the *interrogative clause*, it will be ruled out even without saying anything about the nonlocal features of the verb or of its argument, due to the identity between the mother and the daughter's semantic HOOK values which comes from the definition of all head-compositional phrases in the Matrix, including *interrogative-clause* (137). This is illustrated in (330).

(330)

*S*in-situ*

[LOCAL|CONT|HOOK|INDEX|SF $\boxed{1}$*ques*
HEAD-DTR $\boxed{2}$[SYNSEM|LOCAL|CONT|HOOK $\boxed{1}$]]

$\boxed{2}$S*subj-head*
[LOCAL|CONT|HOOK|INDEX|SF *prop*]

NP

wh-noun

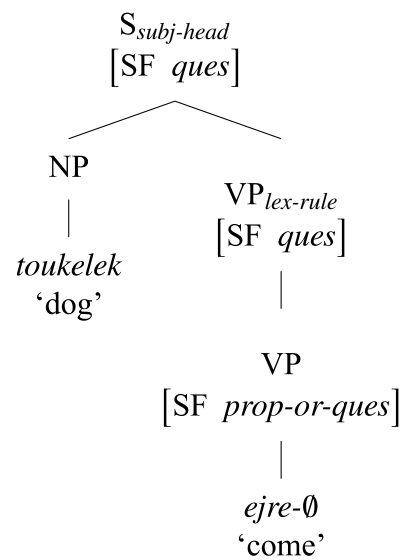
VP*lex-rule*
[LOCAL|CONT|HOOK|INDEX|SF *prop*]

VP
[LOCAL|CONT|HOOK|INDEX|SF *prop-or-ques*]

verb-IND

An *interrogative-lex-rule*, on the other hand, will say that its SF value is *ques*, allowing verbs marked with such rule to go through a question-forming phrase structure rule, or, if it is a polar question, to make the semantics of the clause interrogative without an additional phrase structure rule, like in (331) for the Yukaghir sentence (327).

(331)



While the distinction between (i) and (ii), and by extension (c),[65] is straightforwardly modeled with just the SF feature with or without lexical threading (assuming semantic compositionality which ensures the semantic HOOK identities in the phrasal rules), modeling the distinction between (a) and (b) is much easier with lexical threading than without it. I discuss this option below before describing the actual analysis without lexical threading which I included in the Matrix in order to be able to use simpler analyses in other parts of the system.

6.8.1 Morphological marking of constituent questions under the lexical threading assumption

Recall from §4.1.2 that lexical threading means lexical items amalgamate their arguments' non-local values. Therefore a verb's QUE value will be the append of its subject's and object's (332).

(332)
$$\begin{bmatrix} \textit{sample intransitive verb} \\ \text{SYNSEM} \begin{bmatrix} \text{NON-LOCAL}|\text{QUE}|\text{APPEND} \ \langle \boxed{1}, \boxed{2} \rangle \\ \text{LOCAL}|\text{CAT}|\text{VAL} \begin{bmatrix} \text{SUBJ} \ \left\langle \left[\text{NON-LOCAL}|\text{QUE} \ \boxed{1} \right] \right\rangle \\ \text{COMPS} \ \left\langle \left[\text{NON-LOCAL}|\text{QUE} \ \boxed{2} \right] \right\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

In other words, if one or more of the verb's arguments are *wh*-words (326), the verb's own QUE

[65] Option (c) is essentially a statement that only the distinction between (i) and (ii) is relevant.

list will be nonempty (333).[66]

(333)
$$\begin{bmatrix} \textit{ejre} & \\ \text{SYNSEM} & \begin{bmatrix} \text{NON-LOCAL}|\text{QUE}|\text{LIST} & \langle \boxed{1} \rangle \\ \text{LOCAL}|\text{CAT}|\text{VAL} & \begin{bmatrix} \text{SUBJ} & \left\langle \begin{bmatrix} \text{NON-LOCAL}|\text{QUE}|\text{LIST} \ \left\langle \boxed{1}\textit{ref} \right\rangle \end{bmatrix} \right\rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Otherwise it will be empty (334), like another instance of the same verb *ejre* in (327), assuming a different sentence, with no *wh*-argument.

(334)
$$\begin{bmatrix} \textit{ejre} & \\ \text{SYNSEM} & \begin{bmatrix} \text{NON-LOCAL}|\text{QUE}|\text{LIST} & \langle\ \rangle \\ \text{LOCAL}|\text{CAT}|\text{VAL} & \begin{bmatrix} \text{SUBJ} & \left\langle \begin{bmatrix} \text{NON-LOCAL}|\text{QUE}|\text{LIST} \ \langle\ \rangle \end{bmatrix} \right\rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Given this, customizing lexical rules to model the distinction between (i) and (ii) and furthermore between (a) and (b) is straightforward. Markers which are to be used exclusively in polar questions (a) simply need to constrain the daughter of the rule (the verb) to be QUE-empty (335). Under the lexical threading assumption, this is the same as to say that neither of the arguments is a *wh*-word. There is no need to worry about how many arguments the verb has and how many of them are *wh*-arguments, and which positions they occupy on the argument list. Conversely, the ones which are to be used exclusively for *wh*-questions[67] are customized to take QUE-nonempty daughters (336).[68] This means one or more of the arguments is a *wh*-word, and with lexical threading, the analysis need not worry about which one or how many.

(335)
$$\begin{bmatrix} \textit{polar-lex-rule} & \\ \text{SYNSEM}|\text{SF} & \textit{ques} \\ \text{DTR}|\text{SYNSEM}|\text{NON-LOCAL}|\text{QUE}|\text{LIST} & \langle\ \rangle \end{bmatrix}$$

(336)
$$\begin{bmatrix} \textit{wh-lex-rule} & \\ \text{SYNSEM}|\text{SF} & \textit{ques} \\ \text{DTR}|\text{SYNSEM}|\text{NON-LOCAL}|\text{QUE}|\text{LIST} & \textit{cons} \end{bmatrix}$$

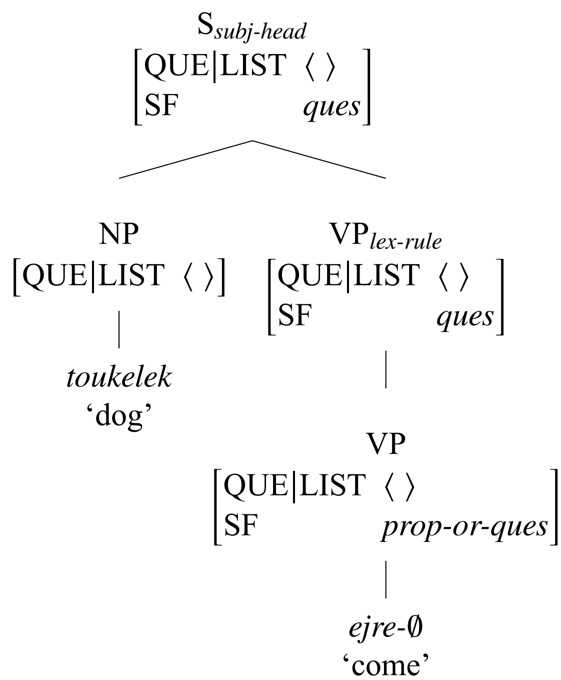
[66] Example (333) is not a lexical entry but rather a specific instance of a feature structure in an actual derivation.

[67] This distinction is not represented in my illustrative languages.

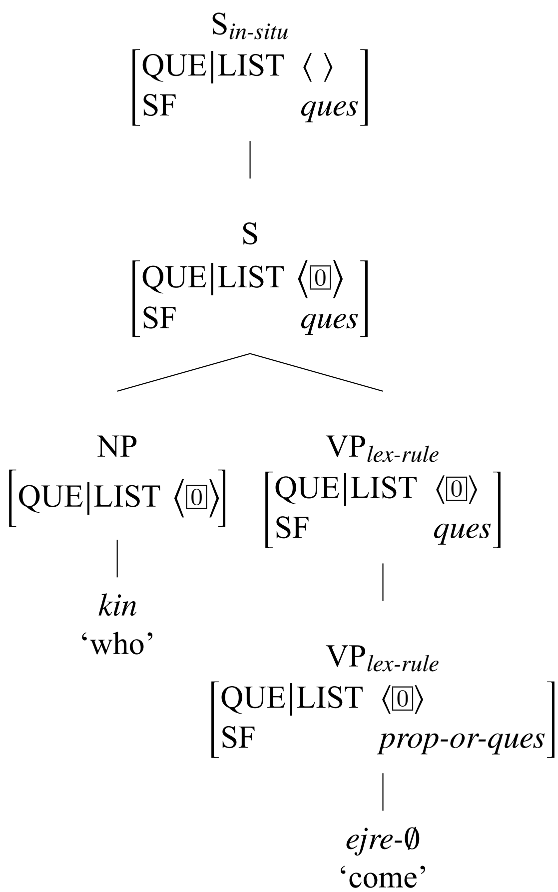
[68] Recall from (77) in §3.2 that *cons* is a type for nonempty list in the DELPH-IN formalism.

If the same marker is used for both polar and constituent questions (c), the QUE value on the daughter is left underspecified. This way, for the Yukaghir sentence (327), the grammar outputs the tree (337); for the sentence (326), it outputs (338). This grammar uses one and the same lexical rule for both sentences.

(337)



(338)



6.8.2 Morphological marking of questions without lexical threading

Without lexical threading, option (c) (languages which just use one marker for all types of questions) still does not pose complications; the analysis is the same as with lexical threading as the QUE value of the rule's daughter is underspecified on the rule. However, neither (335) nor (336) will lead to the desired analysis of (a) and (b). Recall from §6.1 that lexical entries which are not *wh*-words have empty QUE-lists, and the way the QUE values are propagated up the tree is an explicit inheritance in unary and an explicit append in binary rules. Verbs do not take their arguments' QUE values and their own QUE lists are empty. This means that most verbs will unify with the daughter of (335) regardless of what their arguments are. An explicit constraint must be put on the verb's arguments instead, but this means an explicit constraint is required for the subject and yet another for the complement.

For the analysis of options (a) and (b), I use a pseudolanguage for an exposition. Consider a pseudolanguage which uses the *in situ* strategy and two completely separate paradigms for polar and constituent questions (339)–(347).[69]

(339) noun tverb-PQ noun?

(340) *noun tverb-WHQ noun?

(341) who iverb-WHQ?

(342) who tverb-WHQ what?

(343) who tverb-WHQ noun?

(344) noun tverb-WHQ what?

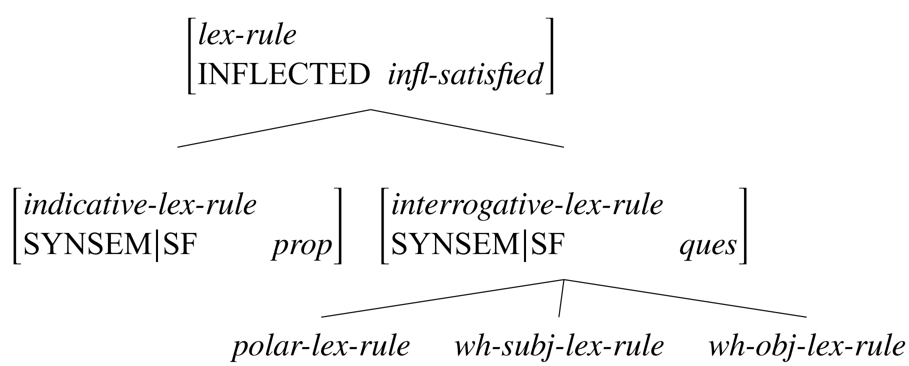
(345) *who tverb-PQ what?

(346) *who tverb-PQ noun?

(347) *noun tverb-PQ what?

For a grammar to behave correctly with respect to (339)–(347), the *interrogative-lex-rule* type should in fact be expanded not into just two but into three further subtypes (348).

(348)



The complication here compared to the analysis with lexical threading has to do with the number of the arguments of different verbs. Now that the QUE constraints have to be placed

[69]This typological combination is not known to be widely attested (Haspelmath, p.c.).

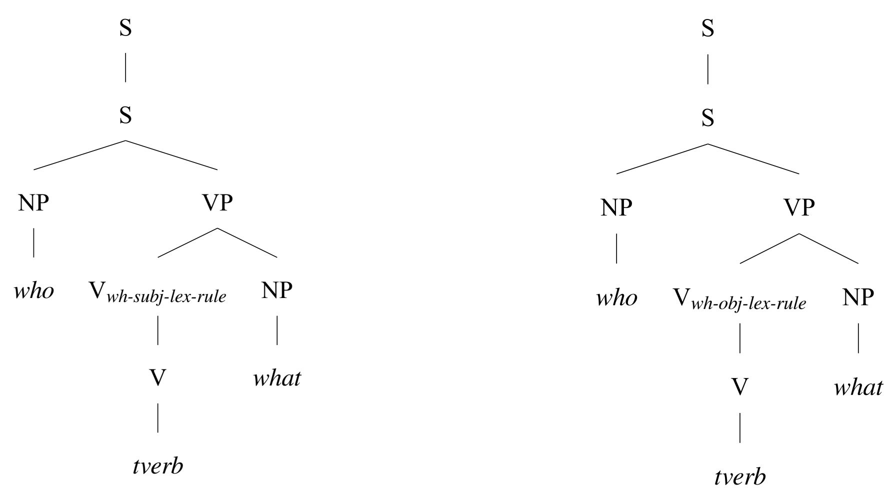
directly on the arguments, a need arises to somehow disallow *wh*-subjects and objects for both transitive and intransitive verbs, for example, in the *polar-lex-rule*. Similarly, a need arises to cover both (341) and (342) as well as (344). This can be done by having two rules, as suggested in (348), but note that the rules as presented in (349) and (350), without additional constraints, will both apply in e.g. (342), leading to spurious ambiguity(351a)–(351b).

(349) $\begin{bmatrix} \textit{wh-subj-lex-rule} \\ \text{SYNSEM|LOCAL|CAT|VAL|SUBJ } \left\langle \begin{bmatrix} \text{NON-LOCAL|QUE|LIST } \text{cons} \end{bmatrix} \right\rangle \end{bmatrix}$

(350) $\begin{bmatrix} \textit{wh-obj-lex-rule} \\ \text{SYNSEM|LOCAL|CAT|VAL } \begin{bmatrix} \text{COMPS } \left\langle \begin{bmatrix} \text{NON-LOCAL|QUE|LIST } \text{cons} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$

(351)

a. b.



I would like the *wh-subj-lex-rule* to only apply where *wh-obj-lex-rule* cannot. I cannot however constrain the SUBJ list of the *wh-obj-lex-rule* to be empty, because I still need to license sentences with non-*wh* subjects (344).[70]

This can be addressed by using another parameterized list (previously, I used a parameterized

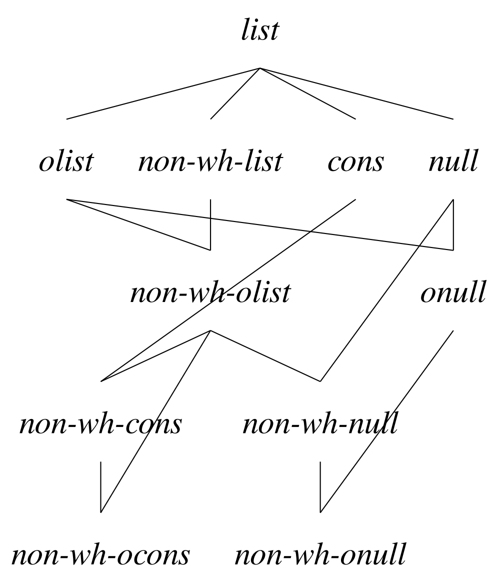
[70]In fact, constraining the SUBJ list of the *wh-obj-lex-rule* to be empty would violate a constraint on the lexical rule supertype. By the lexicalist assumption, lexical rules apply before phrase structure rules, and so the subject

list to deal with some of the ambiguity which arises in the context of my analysis of optional fronting (§6.5.2; see example (263)). I posit a new parameterized list called *non-wh-list* (352). Simply put, it is a list which stipulates that all elements on it, which are zero or more, are not *wh*-words.

(352) $$\begin{bmatrix} \textit{non-wh-cons} & \\ \text{FIRST} & \begin{bmatrix} \textit{synsem} \\ \text{NON-LOCAL.QUE.LIST} \ \langle\, \rangle \end{bmatrix} \\ \text{REST} & \textit{non-wh-list} \end{bmatrix}$$

The full hierarchy for this set of types is presented in (353). Just like with the hierarchy for *clist* (263), I include it mostly for the readers interested in the details of the formal implementation. For most readers, what matters is that a *wh-word* could never be on this list; it would lead to a unification failure.

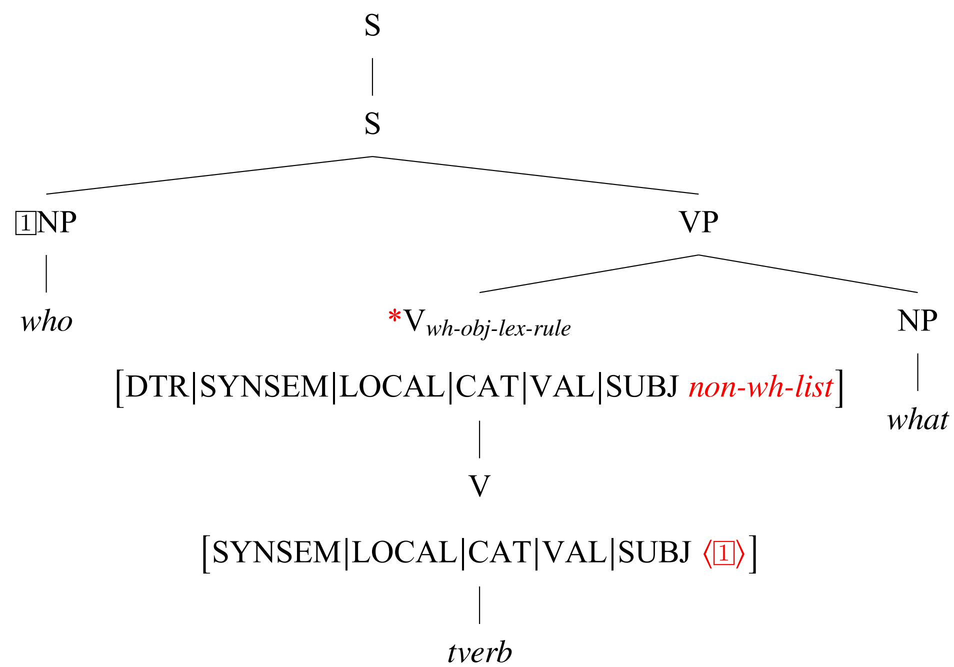
(353)



I can use *non-wh-list* to constrain lexical rules such that they underspecify between (allow both) empty lists and lists which do not contain *wh*-words. This way, *wh-obj-lex-rule* can insist that the subject is not a *wh*-word — that case would be for the *wh-subj-lex-rule* to take care of — but does not have to be empty. The unwanted second tree is then ruled out (354).

list of a verbs is necessarily nonempty, since the head-subject rule has not applied yet.

(354)



The complete set of interrogative lexical rules for a grammar for the pseudolanguage covering options (a) and (b) and presented as data in (339)–(347) then looks like this (355)–(356).[71]

(355) $$\begin{bmatrix} \textit{polar-lex-rule} \\ \text{SYNSEM}\mid\text{LOCAL}\mid\text{CAT}\mid\text{VAL} \begin{bmatrix} \text{SUBJ} & \left\langle \begin{bmatrix} \text{NON-LOCAL}\mid\text{QUE}\mid\text{LIST} \ \langle\ \rangle \end{bmatrix} \right\rangle \\ \text{COMPS} & \textit{non-wh-list} \end{bmatrix} \end{bmatrix}$$

(356) $$\begin{bmatrix} \textit{wh-subj-lex-rule} \\ \text{SYNSEM}\mid\text{LOCAL}\mid\text{CAT}\mid\text{VAL}\mid\text{SUBJ} \left\langle \begin{bmatrix} \text{NON-LOCAL}\mid\text{QUE}\mid\text{LIST} \ \ \text{cons} \end{bmatrix} \right\rangle \end{bmatrix}$$

(357) $$\begin{bmatrix} \textit{wh-obj-lex-rule} \\ \text{SYNSEM}\mid\text{LOCAL}\mid\text{CAT}\mid\text{VAL} \begin{bmatrix} \text{SUBJ} & \textit{non-wh-list} \\ \text{COMPS} & \left\langle \begin{bmatrix} \text{NON-LOCAL}\mid\text{QUE}\mid\text{LIST} \ \ \text{cons} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

This section presented an analysis of morphological marking of questions. The analysis relies on lexical rules. In the presented analysis of Yukaghir, the only relevant distinction is that of indicative and interrogative lexical rules which can be easily modeled using the semantic SF

[71] Recall that all these rules are subtypes of the interrogative rule (348) and so their sentential force value is *ques*

(sentential force) feature, in the context of how semantic compositionality is implemented in the Grammar Matrix system (a proposition cannot be a head daughter or an interrogative phrasal type; only a structure underspecified between a proposition and a question can). In the presented analysis of an artificial language where two separate paradigms exist for constituent and polar questions, additional machinery in the form of a parameterized list is required to rule out spurious ambiguity, unless lexical threading used.

6.9 Interrogative verbs. Illustrative language: Chukchi (Chukotko-Kamchatkan)

As discussed in §2.10, interrogative verbs (358)–(361) are words which function as the main or secondary predicate in the sentence and at the same time question the state of affairs denoted by the predicate (Hagège, 2008).

(358) req-ərkən-əm igirkej gə-nin ekək?
do.what-PROG-EMPH right.now 2SG-POS son-ABS
'What is your son doing right now?' Chukchee [ckt] (Mackenzie, 2009, p. 1147)

(359) ke trò?
2SG be.what
'What is the matter with you?' [cir] (Hagège, 2008, p. 5)

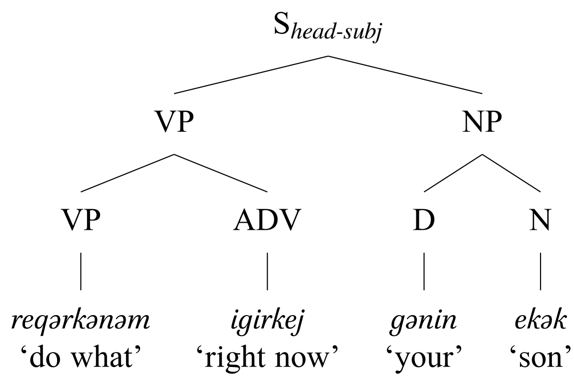
(360) ine- n- req -ēk -wʔi?
INE- N- do.what? -TH -TH
'What are you doing to me?' [ckt] (Dunn, 1999, p.89)

(361) čem-šen-∅
go.where.PST-foot-3SG.S
'Where did he walk to?' [coo] (Hagège, 2008, p. 5)

At the semantic representation (MRS) level, the property of the interrogative verb then is that it has an extra semantic relation: a predication (noun- or adverb-like) which is not realized as overt argument or adjunct on the surface. All of the examples I have seen involve an overt subject (358)–(361), so I model only interrogative verbs whose additional predication is either the ARG2 (the theme/patient-like semantic argument) or an adverbial relation. The other property of interrogative verbs is that the verb itself sets the clause's semantics to be SF *ques*.

If the information about an argument is supplied by the verb itself, then the derivation for sentences like (358) will not include a head-complement rule, as illustrated by (362).

(362)



Essentially, the verb acts syntactically as intransitive, in that it only is looking for a subject in the tree.

For a semantic representation like in Figure 6.7 to be built in a derivation like (362), I first posit a basic question verb type (363). This supertype only constrains the sentential force and is underspecified with respect to the number and type of semantic relations.

(363)
$$\begin{bmatrix} \textit{wh-verb-lex} & \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{MOD} & \langle\ \rangle \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{SPEC} & \langle\ \rangle \\ \text{SUBJ} & \langle \boxed{1} \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \\ \text{WH}|\text{BOOL} & + \end{bmatrix} \\ \text{CONT}|\text{HOOK} & \begin{bmatrix} \text{INDEX}|\text{SF} & \textit{ques} \\ \text{XARG} & \boxed{0} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{L-QUE} & + \\ \text{ARG-ST} & \left\langle \boxed{1} \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT}|\text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{SPEC} & \langle\ \rangle \\ \text{SUBJ} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \\ \text{CONT}|\text{HOOK}|\text{INDEX} & \boxed{0} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

The subject list specifies an overt subject; the complement list is empty, so, an overt complement

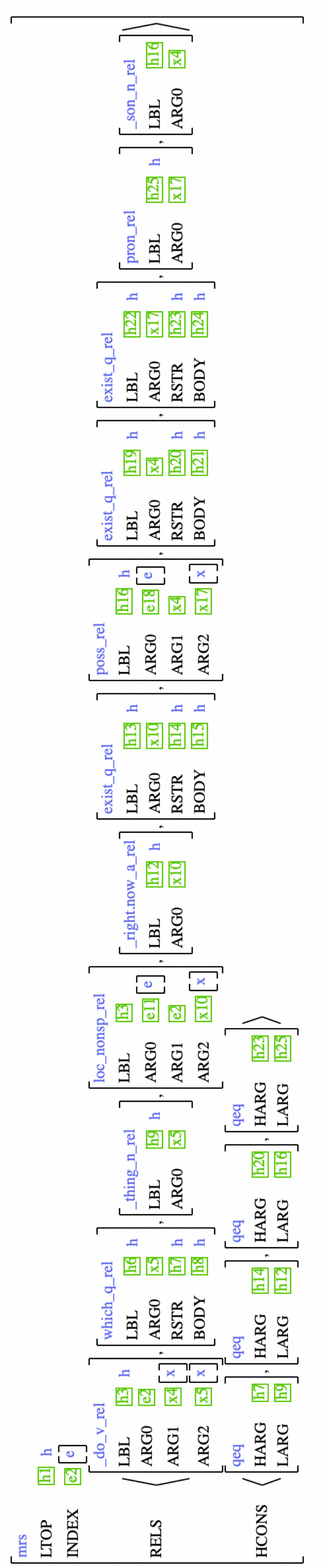


Figure 6.7: The semantic structure for sentence (358)

is not possible. This does not yet supply the necessary information about the object-like semantic argument, nor an adverbial relation.

To model verbs like the Chukchi *req* (358) which have the 'do.what' type of semantics in that they supply information about the object-like semantic argument (ARG2), I add a subtype of interrogative verb which has three semantic relations: one that refers to its own event (called the *key* relation in the Grammar Matrix as well as in the ERG), and the other two forming a referent-type relation, a quantifier and a thing being quantified. The second and the third relations are modeled as the second semantic argument of the event, just like an ordinary object of the transitive verb would be (364).

(364)

$$
\begin{bmatrix}
\textit{three-rel-wh-verb-lex} \\
\text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{verb}\\ \text{MOD} & \langle\rangle\end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\rangle \\ \text{SPEC} & \langle\rangle \\ \text{SUBJ} & \langle \boxed{6} \rangle \\ \text{COMPS} & \langle\rangle \end{bmatrix} \\ \text{WH}\vert\text{BOOL} & + \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX}\vert\text{SF} & \textit{ques} \\ \text{XARG} & \boxed{0} \\ \text{CLAUSE-KEY} & \boxed{1}\end{bmatrix} \\ \text{RELS}\vert\text{LIST} & \left\langle \boxed{5}\begin{bmatrix}\text{ARG2} & \boxed{2}\end{bmatrix}, \begin{bmatrix}\textit{quant-relation} \\ \text{PRED} & \text{which\_q\_rel} \\ \text{ARG0} & \boxed{2} \\ \text{RSTR} & \boxed{3}\end{bmatrix}, \begin{bmatrix}\textit{noun-relation}\\ \text{LBL} & \boxed{4} \\ \text{ARG0} & \boxed{2}\end{bmatrix}\right\rangle \\ \text{HCONS}\vert\text{LIST} & \left\langle \begin{bmatrix}\text{HARG} & \boxed{3} \\ \text{LARG} & \boxed{4}\end{bmatrix}\right\rangle \\ \text{ICONS}\vert\text{LIST} & \langle\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\
\text{LKEYS}\vert\text{KEYREL} & \boxed{6}\begin{bmatrix}\textit{event-relation} \\ \text{LBL} & \boxed{5} \\ \text{ARG0} & \boxed{0} \\ \text{ARG1} & \boxed{1} \\ \text{ARG2} & \boxed{2}\ \textit{ref-ind}\end{bmatrix} \\
\text{L-QUE} & + \\
\text{ARG-ST} & \left\langle \boxed{6}\begin{bmatrix}\text{LOCAL} & \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{noun} \\ \text{VAL} & \begin{bmatrix}\text{SPR}&\langle\rangle\\ \text{SPEC}&\langle\rangle\\ \text{SUBJ}&\langle\rangle\\ \text{COMPS}&\langle\rangle\end{bmatrix}\end{bmatrix} \\ \text{CONT}\vert\text{HOOK} & \begin{bmatrix}\text{LTOP} & \boxed{5} \\ \text{INDEX} & \boxed{0}\begin{bmatrix}\textit{ref-ind} \\ \text{ICONS-KEY}\vert\text{IARG1} & \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle
\end{bmatrix}
$$

Note that the same type works for verbs glossed with 'be.what' (359). I do not need any additional types such as a copula or a verb type with different transitivity because the subject here is overt, just like in (360), and the additional relation can be analyzed as an implicit second argument even if it is not a patient or a theme.[72]

For verbs which have semantics of type ‘go.where’, like in the Comox [coo] sentence (361), I add a type with three extra semantic relations in addition to the key verb relation. This is because adverbs for location in time/space in the Grammar Matrix in general contribute three semantic relations (§6.1).

(365)

$$\begin{bmatrix} \textit{four-rel-wh-verb-lex} \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{verb}\\ \text{MOD} & \langle\,\rangle\end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\,\rangle \\ \text{SPEC} & \langle\,\rangle \\ \text{SUBJ} & \langle \boxed{6} \rangle \\ \text{COMPS} & \langle\,\rangle\end{bmatrix} \\ \text{WH|BOOL} & + \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{HOOK} & \begin{bmatrix} \text{INDEX|SF} & \textit{ques} \\ \text{XARG} & \boxed{0} \\ \text{CLAUSE-KEY} & \boxed{1}\end{bmatrix} \\ \text{RELS|LIST} & \left\langle \boxed{5}\begin{bmatrix}\text{LBL} & \boxed{7}\\ \text{ARG0} & \boxed{1}\end{bmatrix}, \begin{bmatrix}\textit{quant-relation} \\ \text{PRED} & \text{which\_q\_rel}\\ \text{ARG0} & \boxed{2} \\ \text{RSTR} & \boxed{3}\end{bmatrix}, \begin{bmatrix}\textit{noun-relation}\\ \text{LBL} & \boxed{4}\\ \text{ARG0} & \boxed{2}\end{bmatrix}, \begin{bmatrix}\text{LBL} & \boxed{7}\\ \text{ARG0} & \textit{event}\\ \text{ARG1} & \boxed{1}\\ \text{ARG2} & \boxed{2}\end{bmatrix}\right\rangle \\ \text{HCONS|LIST} & \left\langle\begin{bmatrix}\text{HARG} & \boxed{3}\\ \text{LARG} & \boxed{4}\end{bmatrix}\right\rangle \\ \text{ICONS|LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{LKEYS|KEYREL} & \boxed{6}\begin{bmatrix}\textit{event-relation}\\ \text{LBL} & \boxed{5}\\ \text{ARG0} & \boxed{0} \\ \text{ARG1} & \boxed{1}\end{bmatrix} \\ \text{L-QUE} & + \\ \text{ARG-ST} & \left\langle \boxed{6}\begin{bmatrix}\text{LOCAL} & \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{noun}\\ \text{VAL} & \begin{bmatrix}\text{SPR}&\langle\,\rangle\\ \text{SPEC}&\langle\,\rangle\\ \text{SUBJ}&\langle\,\rangle\\ \text{COMPS}&\langle\,\rangle\end{bmatrix}\end{bmatrix}\\ \text{CONT|HOOK} & \begin{bmatrix}\text{LTOP} & \boxed{5}\\ \text{INDEX} & \boxed{0}\begin{bmatrix}\textit{ref-ind}\\ \text{ICONS-KEY|IARG1} & \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle \end{bmatrix}$$

A sample semantic structure, for sentence (361), is shown in Figure 6.8.

In summary, I model interrogative verbs by a set of lexical types which have extra semantic predications (compared to other verbs) and link a which_q_rel quantifier to an appropriate referent while supplying question semantics to the clause, without an overt *wh*-word. I need separate types

[72]This is also how the English Resource Grammar (Flickinger, 2000) analyzes the English *be* copula in sentences like *Who are you?*.

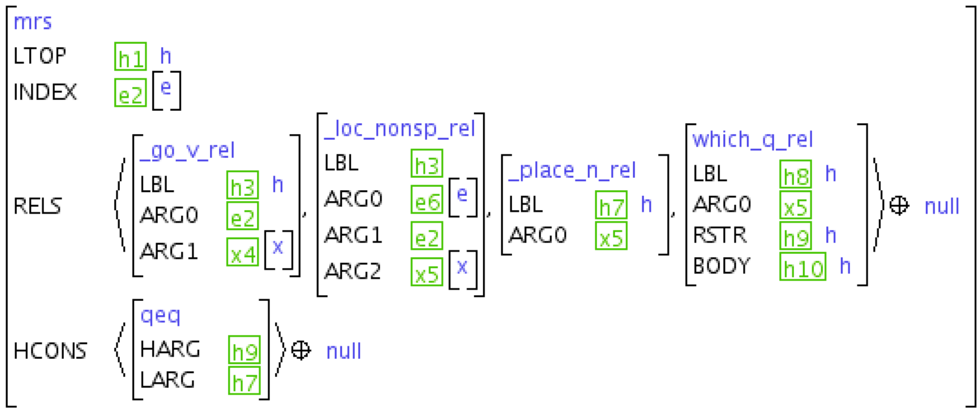


Figure 6.8: The semantic structure for sentence (361)

for verbs which question the state of affairs with respect to a patient/theme-like argument and for verbs which question the state of affairs with respect to time, location, or manner of the event.

6.10 Summary

This chapter described illustrative analyses of constituent questions. In particular, it presented an analysis of single obligatory fronting, like in English; multiple optional fronting, like in Russian; *in situ* questions like in Japanese; morphologically marked questions, like in Yukaghir; and questions formed with interrogative verbs, like in Chukchi. All of the analyses apart from interrogative verbs rely on lexical types for *wh*-pronouns and adverbs; fronting languages rely on a combination of extraction rules and a filler-gap rule; in situ languages rely on a unary *in situ* phrase structure rule. Optionally fronting languages include both the *in situ* phrase and the extraction + filler-gap phrases, which gives rise to ambiguity which requires some additional machinery to be ruled out. The most complicated analysis seems to be the one for a hypothetical language which has optional fronting and at the same time bans multiple questions; it is just as well then that such a language may not exist. Morphological marking of questions provides a case for lexical threading, although it is possible to implement it without, with some additional machinery. An analysis of interrogative verbs relies fully on appropriate lexical entries which contain not only a predication for the main event but also additional predications for the implied semantic argument. The next chapter discusses how these and similar analyses can be automatically obtained via the Grammar Matrix *customization* system.

Chapter 7

CUSTOMIZING ANALYSES AUTOMATICALLY. THE CONSTITUENT QUESTIONS LIBRARY

This chapter describes the new constituent questions library. Like any library (see §3.4), this one is built of the web questionnaire, the HPSG type hierarchy, and the customization component which is responsible for outputting a specific set of further constrained types given an input of questionnaire choices. While each of the parts (the questionnaire, the core, and the customization) is designed and programmed separately, all parts of the system together serve to provide support for modeling data which lies in the typological space outlined in Chapter 2. For this reason, I organize the material in this chapter around the illustrative languages, in parallel with the organization of Chapter 6 which presents illustrative analyses.

In the context of this chapter, each illustrative analysis from Chapter 6 is an example of the customization system's **output**. The **input** is provided in the form of a language specification, which in turn is elicited via the web questionnaire. The goal of this chapter is to explain both what the expected input is for each illustrative analysis and how the corresponding output result is achieved. Furthermore, this chapter summarizes what the library does generally, beyond what just the specific illustrative analyses contain.

The summaries are presented in tables which have the form as in sample Table 7.1. Each row

Specification	Types	Core?	New?	Custom Features
foc. mkg on ques. words	*infostr-marking-mod-lex*	no	no	none
no foc. mkg on ques. words	*infostr-marking-mod-lex*	no	no	WH|BOOL –

Table 7.1: Sample customization summary table

represents a type of language, as characterized by the Grammar Matrix specification. The leftmost column refers to the main aspects of the specification. For example, Table 7.1 is about languages which either allow or disallow overt focus marking on question words. The second column lists the main HPSG types relevant for the analysis; details about these types and the analyses they participate in are found in Chapter 6. The next column informs the reader about whether the types listed in the Types column are considered "core" (in the Grammar Matrix terms). "Core" in the Grammar Matrix means the type will be included in all grammars (though some will only be used in the grammars which cover constituent questions).[1] Note here that customization can happen at different levels. For example, a grammar can be customized with respect to which types it contains (all grammars will contain the core types but grammars will generally differ with respect to other types). At the same time, customization can happen at the feature level (within the same type). One language's head-subject rule may be customized to be head-final and another's head-initial; one language's filler-gap rule may limit its SLASH list length to 1 and another's may not include that constraint. The first level of customization is reflected in the Types column in tables like Table 7.1; the second in the Custom Features column. Finally, the New? column simply informs the reader whether the type in question existed in the Matrix prior to my work.

Many of the below sections have corresponding sections in Chapter 6. In such cases, each section outlines the typological space that it covers along with motivational data and restates which languages served as illustrative. This means in particular that I tested the customization system using test suites from these languages (this will be further discussed in Chapter 8). Each such section then shows the appropriate portion of the web questionnaire and how it is filled out to obtain the illustrative specification (in some cases, pseudolanguage specification will be used, as in Chapter 6). This part explains how the input to the system is conceptualized. Next, each section explains how the input specification is mapped to the output grammars. These subsections rely on the notions of *core* and *customized* HPSG types. They refer a lot to the analyses in Chapter

[1]As explained in Chapter 5 (§5.8.2), core types will be included in all grammars so long as they are properly stored in the file `matrix.tdl`. It does happen in practice that a type that should be stored there is instead stored in `lexbase.tdl` or even in a library file such as `wh-ques.tdl`. Such cases do not lead to any unexpected behavior but conceptually they represent mistakes which should be corrected. Types which are used in all grammars covering a particular phenomenon should be stored in `matrix.tdl` and included in all grammars.

6 but the focus is which parts are core, which are customized to the particular kind of language, and what logic is behind the customization.[2]

Below, after introducing the questionnaire for constituent questions as a whole (§7.1), I start with the questionnaire and the customization for question words (§7.2), which is fairly simple given the existing system for the lexicon (Drellishak, 2009b; Bender et al., 2010b). The reader is invited to refer back to §6.1 for relevant examples. The next section (§7.3) does not have a corresponding section in Chapter 6, because the analysis for focus marking on question words is provided mainly by the information structure library and is not part of my constituent questions library per se. The next section (§7.4) covers the distinction between different clause-embedding verbs, as some of them embed questions and some do not. The corresponding Chapter 6 section is §6.2. Then in §7.5 I present the typological space and the customization system with respect to the position of question phrases (fronting or *in situ*, and the related dimensions of how many phrases can be fronted and whether the fronting is obligatory or optional). The illustrative analyses and examples for the range of phenomena associated with positioning of question phrases were presented in §6.3–§6.5. The next section (§7.6) is dedicated to the questionnaire and customization for languages which use question particles, which is followed by the section on morphological marking (§7.7). The chapter concludes after a section on languages which use interrogative verbs (§7.8).[3]

7.1 General properties of the questionnaire

The web page for the constituent questions questionnaire (shown in full in Figure 7.1) consists of two main regions: one for choices regarding the positioning of question phrases, and one for all other choices. This is commensurate with the complexity of the analysis for fronting (§6.3.1–§6.5) and also with the amount of attention which fronting receives in the literature. Lexical items, such

[2] I also state which types are new (introduced by me) and which are not, meaning they were introduced by other Matrix developers at different times.

[3] I do not include a summary for languages which do not allow multiple question phrases (§6.6). As stated in §6.6, the customization there consists mainly of constraining the QUE list on the head daughter of the question-forming phrase structure rule to be of length 1.

as the ones for question words, are added in the Lexicon portion of the questionnaire, and some of the particle-related choices are located in the Yes/No Questions portion. All of these parts of the questionnaire are reviewed separately below (§7.2–§7.8), with illustrative screenshots.

Choices regarding the position of question phrases

Question phrases can appear at the left edge of the sentence regardless of the position the questioned constituent would appear in (*Who did you see? I know who you saw* etc.):
○ Only one question phrase can be fronted
○ All question phrases can be fronted
○ Question phrases cannot be fronted (stay *in situ*)

There is **obligatory** fronting:
○ of at least one question phrase
○ of all question phrases
○ fronting is optional

There is pied piping of:
☐ noun phrases (*Which book did you read?* is possible), ☐ and it is obligatory (**Which did you read book?* is impossible in your language);
☐ adpositional phrases (*To whom did you speak?* is possible), ☐ and it is obligatory (**Who did you speak to?* is impossible in your language).

Other choices

☐ Only one question phrase is allowed per sentence.

☐ Constituent questions are marked morphologically (specify lexical rules on the Morphology page).

☐ Question words may bear overt focus marking (specify on Information Structure page).

☐ Interrogative verbs (add appropriate entries on the Lexicon page).

If you specified Auxiliary-Subject inversion for polar questions, does it also happen in constituent questions?
☐ yes, in matrix clauses
☐ also in embedded clauses with constituent questions
☐ but not in questions about subjects.

Figure 7.1: The Constituent Questions questionnaire subpage

7.1.1 Questionnaire-back-end interface

The choices which the user makes via questionnaire are serialized by the interface written in a combination of python and javascipt programming languages (the interface was originally developed by Drellishak (2009b)). Any checkbox or radio button or text field that is interacted with in the questionnaire is mapped via this interface to some plain text serialization. For example, checking the "single fronting" box results in `front=single` serialization, etc. For example, a *wh*-questions questionnaire filled out for a language like English (as in Figures 7.3–7.9 and 7.12 below), will translate to the following machine-readable text specification (366).

(366)
```
section=wh-q
  front-matrix=single
  matrix-front-opt=single-oblig
  pied-pip=on
  oblig-pied-pip-noun=on
  pied-pip-adp=on
  wh-inv-matrix=on
  wh-inv-notsubj=on
section=clausal-comp
  comps1_ques=ques
  comps2_ques=prop
section=lexicon
  noun3_name=wh
  noun3_inter=on
  noun3_det=imp
  noun3_stem1_orth=who
  noun3_stem1_pred=_person_n_rel
  noun3_stem2_orth=what
  noun3_stem2_pred=_thing_n_rel
  verb3_name=wonder
  verb3_valence=trans,comps1
  verb3_stem1_orth=wonder
  verb3_stem1_pred=_wonder_v_rel
  verb4_name=think
  verb4_valence=trans,comps2
  verb4_stem1_orth=think
  verb4_stem1_pred=_think_v_rel
  det2_name=which
  det2_inter=on
  det2_stem1_orth=which
  det2_stem1_pred=_which_q_rel
  adv1_name=wh-loc
  adv1_stem1_orth=where
  adv1_stem1_pred=_place_a_rel
```

7.1.2 Questionnaire validation

The purpose of validation of choices that the user makes via the questionnaire is predominantly to prevent the customization system from failing ungracefully or, more specifically, from creating grammars which do not work (e.g. have constraints which do not unify). The system, introduced by Drellishak (2009b), also displays this information to the user via the questionnaire so they know what they need to change. Sometimes, validation also reflects linguistic (typological) restrictions on what we think is not possible in languages (Zamaraeva et al., 2020).

The validation module for constituent questions which I added makes two typological predictions (items 1–2) and otherwise makes a number of insufficient or self-contradictory specifications impossible (items 3–10). In particular, the system disallows the user to:

1. Choose auxiliary inversion in constituent questions while not also choosing it for polar questions.
2. Choose auxiliary inversion in embedded clauses but not in matrix clauses.[4]
3. Make choices regarding multiple question phrase fronting and at the same time disallow multiple question phrases in one clause.
4. Make any choices regarding constituent questions and not include a single interrogative word (e.g. a question pronoun, determiner, adverb, or verb).
5. Make pied-piping-related choices without also making fronting choices at the same clause level.
6. Mark any pied-piping choice as obligatory without actually saying pied-piping is possible.
7. Say constituent questions are *in situ* while also saying there is obligatory or optional fronting.

---

[4]English *wh*-subjects are special (i)–(ii), and the library does allow the user to model them, which can be seen from the web questionnaire (at the bottom of Figure 7.1). This part of the analysis is work in progress and I do not present it here, although the degree to which it covers English can be seen from §8.2.

(i) Who arrived?

(ii) What did you see?

8. Say auxiliary inversion does not apply to *wh*-subjects while not actually choosing inversion in at least matrix clauses.

9. Choose focus marking on question words while not specifying any contrastive focus marker on the Information Structure page.

10. Choose the interrogative verbs option while not actually specifying any lexical type for interrogative verbs, and vice versa.

I also added more validation code for the Lexicon page. It mostly concerns making sure the user did not forget to specify adposition position with respect to the noun, adverbial semantic relations, and so forth. An example of what a validation error looks like in the questionnaire is presented in Figure 7.2.

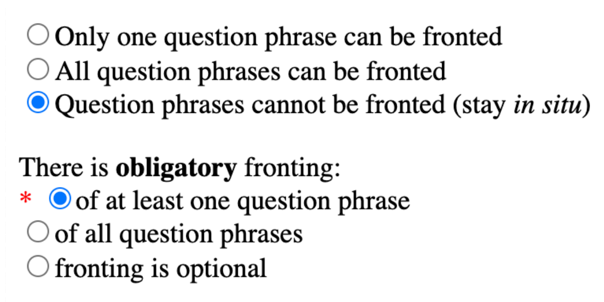


Figure 7.2: The web questionnaire validation error. Hovering over the asterisk will display the error message, such as *"In situ and obligatory fronting are not compatible choices."*

7.2 Question phrases and lexical items

As summarized in §6.1, question words covered by the constituent questions library include question pronouns (367)–(369), question determiners (370), and question adverbs (371).

(367) **What** did you do? [eng]

(368) **Who** did you see? [eng]

(369) **Who** saw **whom**? [eng]

(370) In **which** city do you live? [eng]

(371) **Where** did you go? [eng]

The specification for question words which the user needs to supply via the questionnaire includes their orthography, inflection, and part of speech — in addition to the fact that they are special, question words. The questionnaire for nouns/pronouns and determiners and, crucially, the overall Lexicon questionnaire and customization structure already existed in the system (Drellishak, 2009b). To accommodate question words, I introduce to the Lexicon page a checkbox 'interrogative', so as to allow some words to simply be marked as such in the questionnaire. First of all, it allows me to maximally reuse the existing parts of the customization system. At the same time, analytically, this means that, while an interrogative lexical item such as a question pronoun may have special qualities, there is nothing about it that should preclude it from being a subtype of a generic noun; similarly for determiners and adverbs. This adds to the evidence that the Lexicon portion of the system (including the questionnaire, the core, and the customization logic) was designed by Drellishak (2009b) thoughtfully in the first place and it is mostly possible to extend the existing implementation in a straightforward way.[5]

Question pronouns

Figure 7.3 shows the part of the Lexicon questionnaire web page which I updated for question pronouns. The questionnaire in Figure 7.3 is filled out for English but it will be no different, apart from the orthography, for any language that uses question words referring to persons and things.[6]

[5]In many languages, indefinite pronouns are homophonous with interrogative pronouns. Indefinite pronouns are not currently supported in the Matrix but the analysis would likely involve additional lexical entry at the level of the grammar. At the level of the questionnaire, it would be possible to use the same field and to mark a pronoun as both interrogative and indefinite (which would be translated into two separate lexical entries by the system).

[6]Persons and things are prototypical referents for question pronouns; however, the questionnaire allows the user to enter any name for the referent.

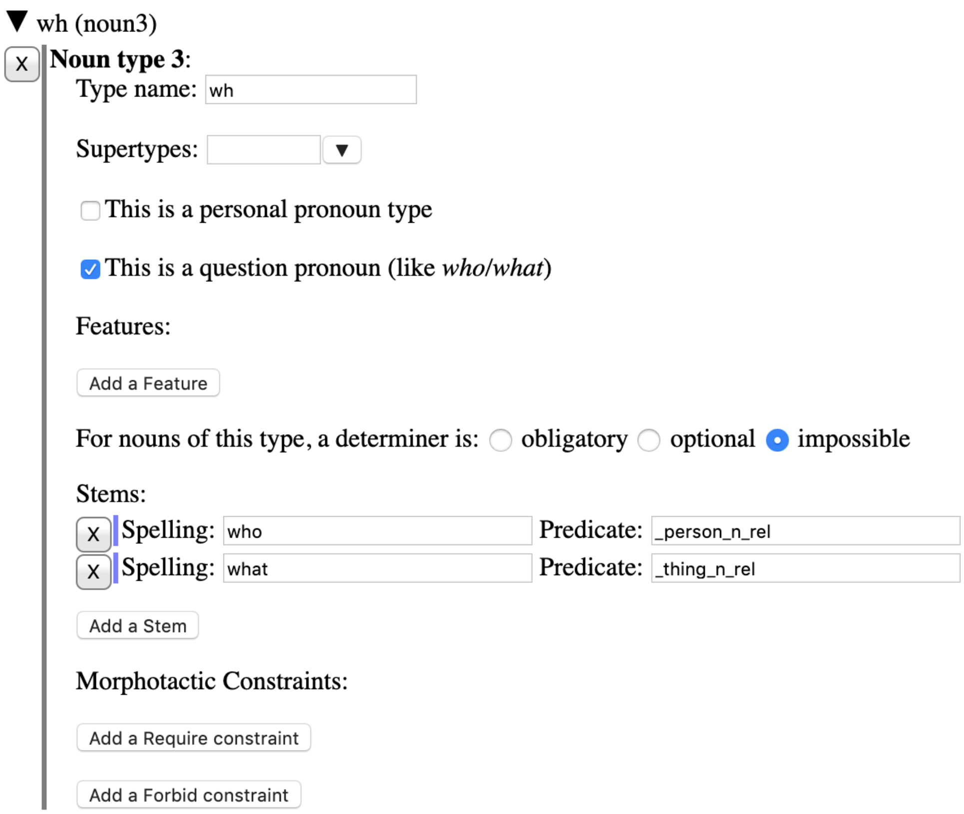


Figure 7.3: The web questionnaire filled out for English *wh* pronouns

From the specification generated by the questionnaire (372), the system will create lexical entries (373).

(372)
```
noun3_name=wh
noun3_inter=on
noun3_det=imp
noun3_stem1_orth=who
noun3_stem1_pred=_person_n_rel
noun3_stem2_orth=what
noun3_stem2_pred=_thing_n_rel
```

```
(373) what := wh-pronoun-noun-lex &
        [ STEM < "what" >,
          SYNSEM.LKEYS.KEYREL.PRED "_thing_n_rel" ].

      who := wh-pronoun-noun-lex &
        [ STEM < "who" >,
          SYNSEM.LKEYS.KEYREL.PRED "_person_n_rel" ].
```

These lexical entries created automatically by the customization system are instances of a new lexical type, *wh-pronoun-noun-lex* (153) which I add to the Matrix core; any grammar which covers constituent questions will include it. I make some straightforward additions to the existing `lexicon.py` customization code in order for such lexical entries to appear. The changes mostly have to do with recognizing the "interrogative" check mark and associating it with the *wh-pronoun* supertype for the entry. Having such lexical entries contributes to the semantics as illustrated by Figure 6.1 repeated here as Figure 7.4. Note the which_q quantifier, which comes from the core

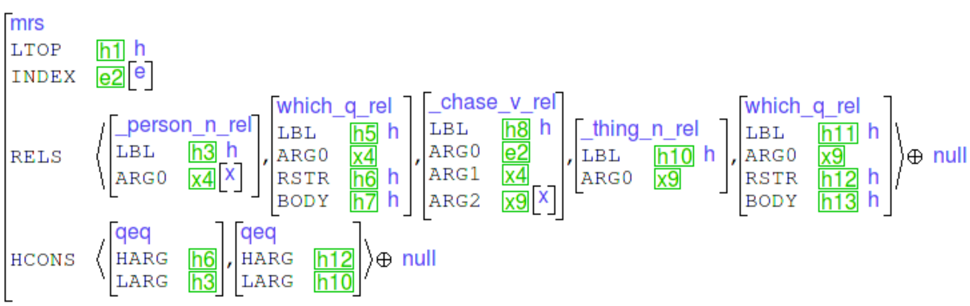


Figure 7.4: The semantic structure for the sentence *Who chases what?*.

type (153), the relevant portion of which is repeated below as (374), and the custom noun relation (e.g. _person_n_rel), which comes from the questionnaire, i.e. from the user.

(374)
$$\begin{bmatrix} \textit{wh-pronoun-lex} \\ \text{SYNSEM} \begin{bmatrix} \text{LOCAL} \begin{bmatrix} \text{CONT} \begin{bmatrix} \text{RELS|LIST} & \left\langle \boxed{3}\begin{bmatrix}\text{LBL} & \boxed{0} \\ \text{ARG0} & \boxed{1}\,[\textit{ref-ind}]\end{bmatrix}, \begin{bmatrix}\textit{quant-relation} & \\ \text{PRED} & \text{which\_q\_rel} \\ \text{RSTR} & \boxed{2}\end{bmatrix}\right\rangle \\ \text{HCONS|LIST} & \left\langle \begin{bmatrix}\text{HARG} & \boxed{2}\\ \text{LARG} & \boxed{0}\end{bmatrix}\right\rangle \end{bmatrix}\end{bmatrix} \\ \text{LKEYS|KEYREL}\ \boxed{3}\begin{bmatrix}\text{LBL} & \boxed{5}\\ \text{ARG0} & \boxed{4}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

There is no additional logic required in the customization system beyond the linking between the custom noun relations in the questionnaire and in the placeholders of (374); that linking was already in place. Enhancing the lexicon with question pronouns represents one of the simplest additions to the Grammar Matrix.

Question determiners

Figure 7.5 shows the questionnaire filled out for the English determiner *which.* Like with pronouns, languages will differ here only with respect to the orthography; so long as a language has something that it makes sense to analyze as a question determiner, it will be possible to elicit all necessary information about it using the same questionnaire form.

The resulting semantics for question determiners is exemplified by Figure 7.6. Unlike the semantics showed in Figure 7.4, which is very similar, the quantifier here is supplied by the determiner lexical entry, while the noun only has a _cat_n_rel relation. The quantifier predicate is custom; it can be which, or how.many, or other question quantifier predicate. The semantic link between the quantifier and the noun is ensured by the core *wh-determiner* type which was presented in Chapter 6 as (159). The lexical entry is customized like other determiners, by the existing lexicon customization code. The features are agreement features; agreement between determiners and nouns was already implemented in the system.

7.2.1 Adverbs (question and not)

As discussed in §6.3.3, I add to the Grammar Matrix support for manner and location-in-time/space adverbs (*quickly, here, there, today*) so as to be able to support their question counterparts (*how,*

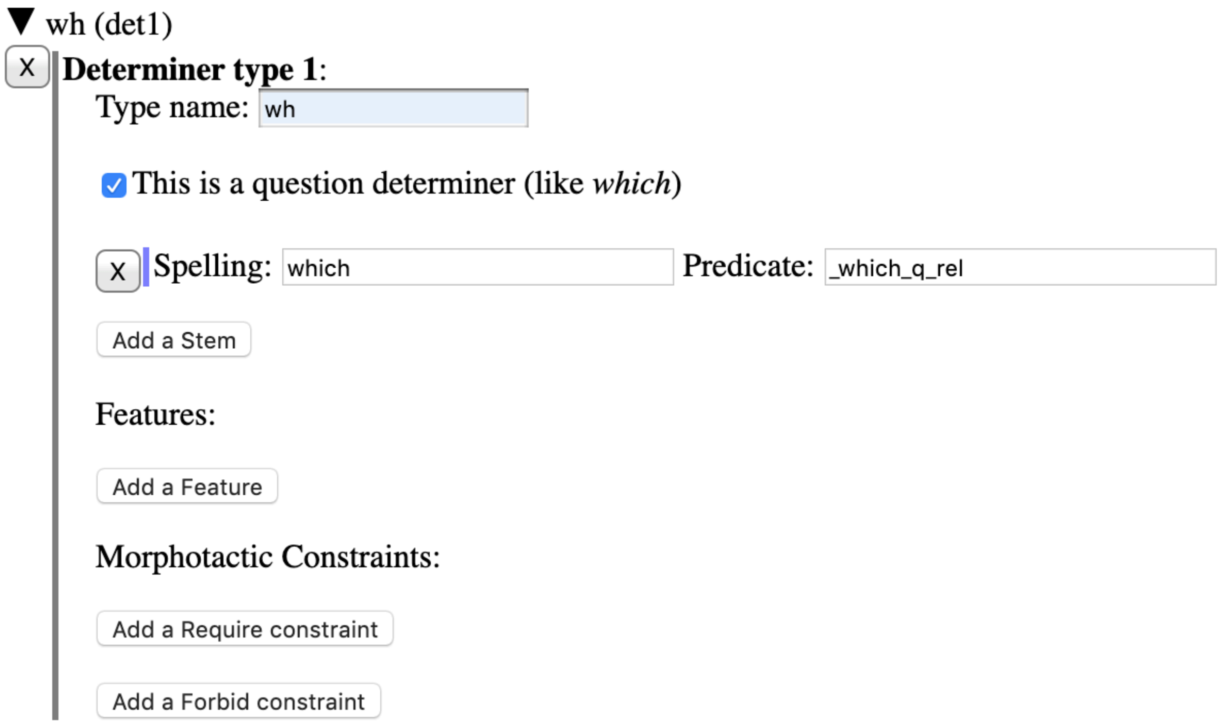


Figure 7.5: The web questionnaire for *wh* determiners

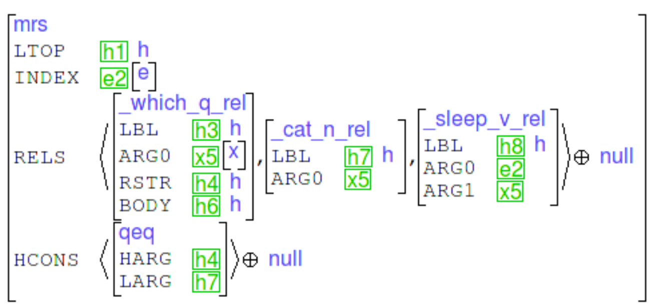


Figure 7.6: The semantic structure for the sentence *Which cats sleep?*.

where, when). Now there is an option in the questionnaire to add adverbs (just like nouns, determiners, and other parts of speech), and adverbs, like pronouns and determiners, can be marked as interrogative (Figure 7.7).

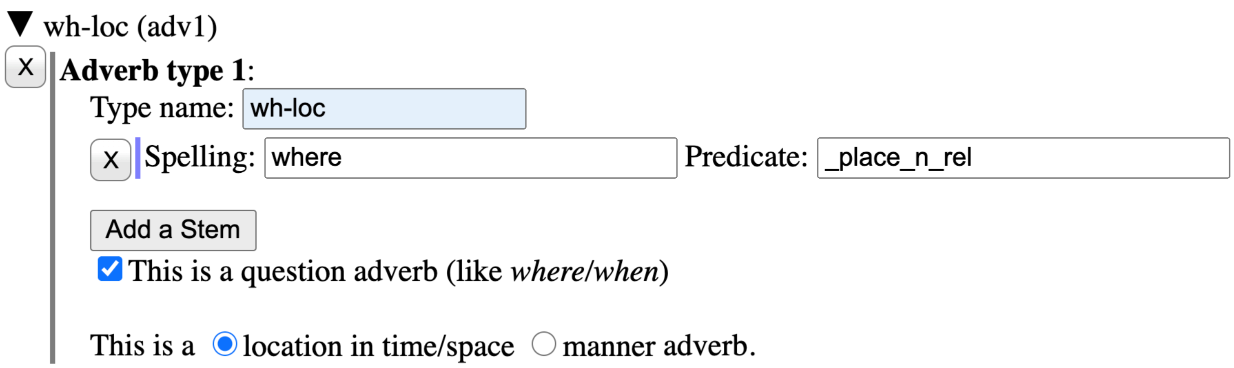


Figure 7.7: The web questionnaire for *wh* adverbs

Adverbs present a case where some types in the grammar fragments presented earlier in Chapter 6 are core and some are not. All of the types presented earlier in (375) and repeated below in (375) are core:

(375) *adverb-lex-item*

loc-adv-lex-item *manner-adv-lex-item* *wh-adv-lex-item* *non-wh-adv-lex-item*

But in a grammar of English, there will be a custom type for lexical entries like *where* (376)–(377):

(376)
```
wh-loc-adverb-lex := loc-adverb-lex-item & wh-adverb-lex.
```

(377)
```
where := wh-loc-adverb-lex &
  [ STEM < "where" >,
    SYNSEM.LKEYS.KEYREL.PRED "_place_n_rel" ].
```

The custom type called *wh-loc-adverb-lex* (376) does not have any constraints which are not found in the core types; rather, it combines the constraints of two core types, the one for the location adverbs (167) and the one for question adverbs (166). The custom lexical entry for *where* belongs to this type; this is ensured by the programmed interface between the questionnaire and the customization system. In an actual structure (with the supertypes' RELS constraints spelled out), the type licenses (378), which results in semantics as illustrated by Figure 6.2 repeated here as Figure 7.8.[7]

(378) [*wh-loc-adverb*
SYNSEM [LOCAL|CONT|RELS|LIST ⟨[*arg12-rel* PRED loc_nonsp_rel, ARG1 [1], ARG2 [0]], [*arg0-rel* ARG0 [0]], [*quant-relation* PRED which_q_rel, ARG0 [0]]⟩
NON-LOCAL|QUE|LIST ⟨[0]⟩]]

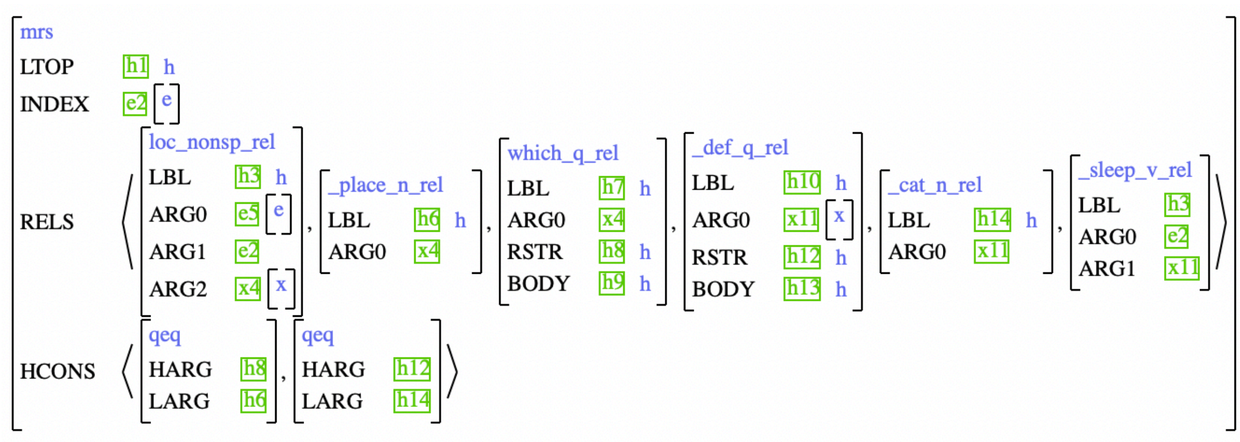


Figure 7.8: The semantic structure for the sentence *Where do the cats sleep*.

7.2.2 Adpositions

As discussed in §6.1, a lexical type for adpositions is necessary to work with questions that contain PP constructions (379).

(379) **In** which city do you live? [eng]

Figure 7.9 shows the section for adpositions which I add to the Matrix web questionnaire. The lexical entries specified this way are instances of the new core type presented earlier as (171). There is no customization required here apart from linking the specific orthographies

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[7] Custom relations like _place_n_rel are supplied via the questionnaire and in a fully specified structure, take the place of *arg0-rel*.

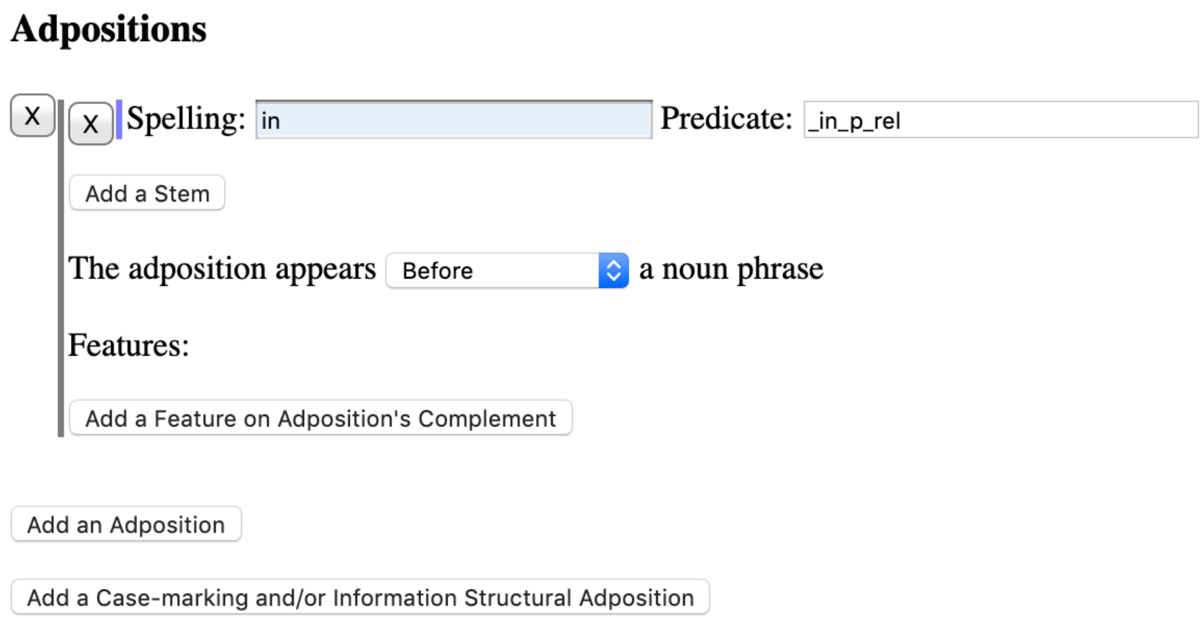


Figure 7.9: The web questionnaire for adpositions

to the supertype and specifying the adposition entry as pre- or postposition. As mentioned in §6.1, this analysis does not capture the difference between pre- and post-modifiers; to model this difference, additional customization will be required. This remains future work.

7.2.3 Summary for question word customization

The previous section described the customization for question words as a part of the constituent questions library for the Grammar Matrix. I make it possible for the user to specify question pronouns, determiners, and adverbs in the web questionnaire. I add also adpositions, in order to be able to test the analyses of question words with a wider range of data. The main purpose of the new core lexical types which I add is to introduce a dependency between the event and the referent of the question word by virtue of having nonempty QUE-list (§4.1.3). Table 7.2 summarizes customization for question words; I treat customization with respect to predication orthography (the PRED value in lexical entries) as trivial and do not include it in the table.

Specification	Types	Reference	Core?	New?	Customized features
ques. pronoun	*wh-pronoun-lex*	(153)	yes	yes	none
ques. determiner	*wh-determiner-lex*	(159)	yes	yes	none
	wh-adverb-lex	(166)	yes	yes	
ques. adverb	*loc-adv-lex*	(167)	no	yes	RELS
	manner-adv-lex	(168)	no	yes	

Table 7.2: Question words customization summary

7.3 Focus marking on question words

As discussed in §2.5.1, in some languages, e.g. in Malagasy (380), question words can bear overt focus marking.

(380) amin = inona no manasa lamba Rasoa
with = what FOC wash clothes Rasoa
'With what did Rasoa wash the clothes?' [mlg] (Dryer, 2013b; Keenan and Li, 1976)

The analysis for focus marking generally is provided by the information structure library (Song, 2014). In Chapter 6, there is no illustrative analysis for this phenomenon. I do however provide some basic customization for focus marking of question words in the system which I present here. Essentially, this involves just adding the relevant information structure focus-marking types (modifiers) from the information structure library in response to the choices made via the constituent questions portion of the questionnaire (Figure 7.10).

When a focus marker is specified on the Information Structure questionnaire subpage, the customization system adds to the grammar the type *infostr-marking-mod-lex* (Song, 2014). If the choice is made as in Figure 7.10, no further work is required to account for the focus marking in (380); the analysis will be as in Song 2014, p. 301 and question words will be modified by the focus marker just like other words. If, on the other hand, the box checked in Figure 7.10 remains unchecked and at the same time, a focus marker is specified for other purposes, the type output by the information structure library will have a constraint preventing it from attaching to *wh*-words (381); it is the same WH feature which is used to model the distribution of question particles, and the exact same mechanics is used as with the second position clitics (which are also

Other choices

☐ Only one question phrase is allowed per sentence.

☐ Constituent questions are marked morphologically (specify lexical rules on the Morphology page).

☑ Question words may bear overt focus marking (specify on Information Structure page).

☐ Interrogative verbs (add appropriate entries on the Lexicon page).

If you specified Auxiliary-Subject inversion for polar questions, does it also happen in constituent questions?
☐ yes, in matrix clauses
☐ also in embedded clauses with constituent questions
☐ but not in questions about subjects.

Figure 7.10: The web questionnaire for the non-fronting choices regarding *wh*-questions

modifiers; §6.7.2). Table 7.3 summarizes the customization.

(381) $\begin{bmatrix} \textit{infostr-marking-mod-lex} \\ \text{SYNSEM|LOCAL|CAT|HEAD|MOD } \left\langle \begin{bmatrix} \text{LOCAL|CAT|WH|BOOL } - \end{bmatrix} \right\rangle \end{bmatrix}$

Specification	Types	Core?	New?	Custom features
foc. mkg on ques. words	*infostr-marking-mod-lex*	no	no	none
no foc. mkg on ques. words	*infostr-marking-mod-lex*	no	no	WH|BOOL –

Table 7.3: Focus marking customization summary

7.4 Clause-embedding verbs

The clausal complements library (Zamaraeva et al., 2019) previously did not support the distinction between verbs which embed questions (382) and verbs which embed propositions (383).

(382) I wonder what the cats chase. [eng]

(383) I think that the cats chase the dogs. [eng]

I implement this distinction as discussed in §6.2, and, at the level of the questionnaire, this required me to simply add a checkbox choice: does a particular clausal complementation strategy (which, by design of the clausal complements library, is associated with a verb lexical type) concern embedding questions or does it concern embedding propositions? This is shown in Figure 7.11.[8] If it is both (384)–(385), the user of the questionnaire is expected to create two separate strategies

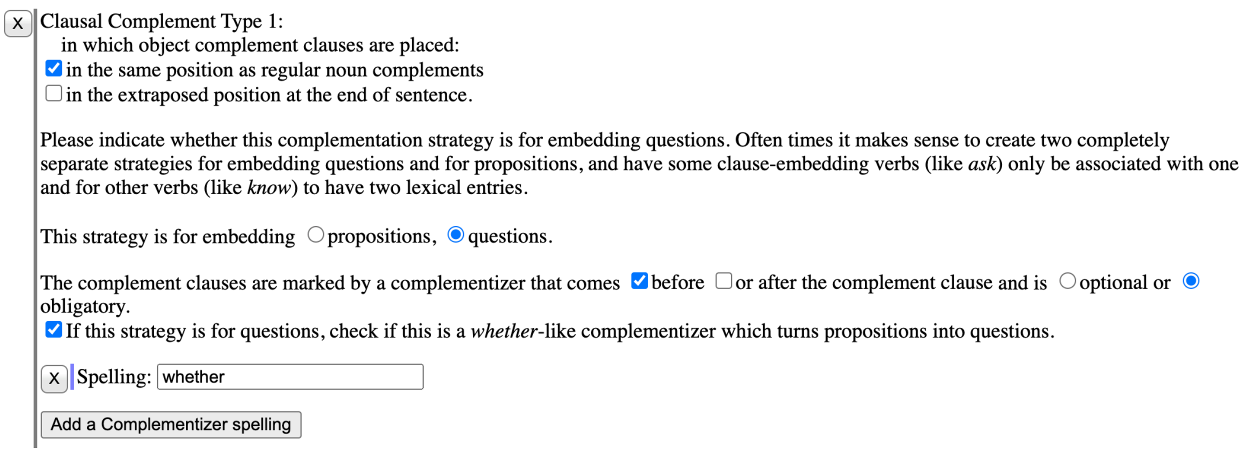


Figure 7.11: The web questionnaire for embedded questions, filled out for English

and have two homophonous clause-embedding verbs, e.g. two lexical entries for the English *know*.

(384) I know what the cats chase. [eng]

(385) I know that the cats chase the dogs. [eng]

The customization happens at the level of the verb lexical subtypes (from which the specific lexical entries inherit, as with all other parts of speech). For question-embedding verbs, (186) will be added to the grammar by the customization system and the lexical entries will inherit from that type; for proposition-embedding verbs, (187) will be added, as summarized in Table 7.4. Recall from §6.2 that I do not provide a full account for the contrast between proposition-embedding and question embedding verbs; the resulting grammars will overgenerate. Improving the analysis is

[8] I do not talk here about complementizers like the English *whether*, as they are not relevant to constituent questions. There is some support for them in the system which was tested with English data to the extent presented in §8.2.

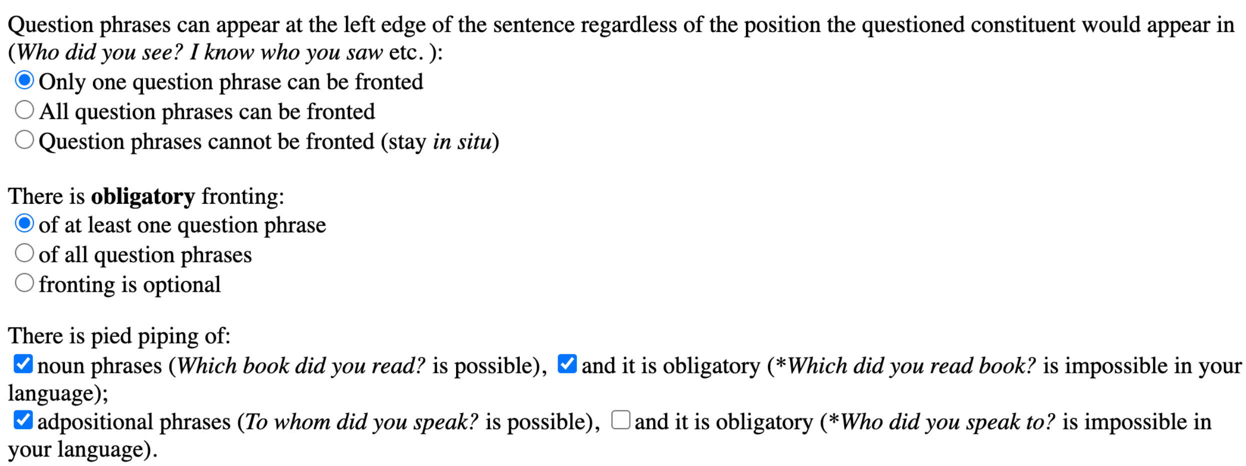
part of future work.

Specification	Types	Core?	New?	Custom features
verb embeds ques.	*clause-embed-verb*	yes	no	COMPS|SF *ques*
verb embeds prop.	*clause-embed-verb*	yes	no	COMPS|SF *prop*

Table 7.4: Clause-embedding verbs customization summary

7.5 The position of question phrases

In Chapter 6, I presented an analysis of English-style single obligatory fronting (§6.3); an analysis of *in situ* languages like Japanese (§6.4); and an analysis of Russian-style multiple fronting, treated as optional (§6.5.1, §6.5.2). The portion of the questionnaire that exposes the fronting choices to the user is presented in Figure 7.12. (Note that the "no multiple questions" choice is actually part of the "Other choices" region shown earlier in Figure 7.10.)


Question phrases can appear at the left edge of the sentence regardless of the position the questioned constituent would appear in (*Who did you see? I know who you saw* etc.):
Only one question phrase can be fronted
All question phrases can be fronted
Question phrases cannot be fronted (stay *in situ*)

There is **obligatory** fronting:
of at least one question phrase
of all question phrases
fronting is optional

There is pied piping of:
noun phrases (*Which book did you read?* is possible), and it is obligatory (**Which did you read book?* is impossible in your language);
adpositional phrases (*To whom did you speak?* is possible), and it is obligatory (**Who did you speak to?* is impossible in your language).

Figure 7.12: The web questionnaire for fronting choices, filled out for English.

In addition to the illustrative languages presented in Chapter 6, I created 13 pseudolanguage grammars which test various combinations of this portion of the questionnaire. The summary is presented in Table 7.5. The top rows of the table are pseudolanguages; the last two rows (separated by a horizontal line) represent illustrative languages (here and in the following tables of this kind).

Front	Frt. oblig.	Emb. in situ	Piped-P NP	PP NP oblig	Pied-P PP	PP PP oblig	Other
sg	oblig	no	no	no	no	no	SVO, no multiple ques
sg	oblig	no	no	no	no	no	SOV, no multiple ques
sg	oblig	no	no	no	no	no	VSO, no multiple ques
sg	oblig	no	no	no	no	no	free WO, no multiple ques
sg	oblig	no	no	no	no	no	free WO, multiple ques
sg	opt	no	no	no	no	no	SVO, multiple ques
sg	opt	no	no	no	no	no	SOV, multiple ques
in situ	–	–	no	no	no	no	OVS, multiple ques
sg	oblig	no	yes	yes	yes	yes	VOS, multiple ques
sg	oblig	no	yes	yes	yes	no	VOS, multiple ques
sg	opt	yes	no	no	no	no	SVO, multiple ques
multi	all oblig	no	no	no	no	no	SVO
multi	one oblig	no	no	no	no	no	SVO
RUS: multi	opt	no	yes	no	yes	yes	free, mult. ques, case, PNG arg top, cl. embed, adj., polar
ENG: sg	oblig	no	yes	yes	yes	no	SVO, mult. ques, case, PNG cl. embed, adj., polar

Table 7.5: Portions of the questionnaire (columns) tested by each language (rows), in combination

The customization (summarized in Table 7.6) is concerned first of all with adding to the customized grammar the appropriate question-forming phrase structure rule. That is the rule which realizes the long-distance dependency (§4.1.1). If fronting is possible, the *wh-ques-phrase* subtype of the filler-gap rule is added (204); if the language is strictly *in situ*, it is not added, but the *in-situ-phrase* unary rule (217) is added instead. This ensures that an *in situ* grammar will never license a sentence with a dislocated constituent in it, and an obligatorily-fronting grammar will never license a question where a *wh*-word is not dislocated. For optionally fronting languages, both the *wh-ques-phrase* and the *in-situ-phrase* are added. For singly-fronting languages, the *wh-ques-phrase* rule is further constrained with respect to the length of the SLASH list, as discussed in §6.3.3. In multiply-fronting languages, this additional constraint is not added, to allow the rule to apply recursively, as illustrated in §6.5.1. The MODIFIED feature serves to prevent multiple adjunct extraction, as explained in §6.5.1.

One customization option which was not presented in Chapter 6 is obligatory multiple fronting (the case of e.g. Bulgarian). This is achieved by customizing the *wh-ques-phrase* to insist that

Specification	Types	Ref.	Core?	New?	Custom features
single oblig. front.	*wh-ques-phrase*	(204)	no	yes	SLASH < >
	subj-, obj-, adj-ex.	(234)–(237)	no	no	none
multi oblig. front.	*wh-ques-phrase*	(204)	no	yes	HDR|QUE < > MODIFIED *hasmod*
	subj-, obj-, adj-ex.	(234)–(237)	no	no	none
single opt. front.	*wh-ques-phrase*	(204)	no	yes	SLASH < >
	in-sutu-phrase	(217)	no	yes	none
	subj-, obj-, adj-ex.	(234)–(237)	no	no	none
multi opt. front.	*wh-ques-phrase*	(204)	no	yes	MODIFIED *hasmod*
	in-sutu-phrase	(217)	no	yes	HDR|L-QUE –
	subj-, obj-, adj-ex.	(234)–(237)	no	no	HDR|L-QUE –
in situ (no front.)	*in-sutu-phrase*	(217)	no	yes	none

Table 7.6: The position of question phrases customization summary

the head daughter's QUE list is empty (386). This means simply that the filler-gap construction will not be possible if there is a non-extracted, non-dislocated *wh*-word anywhere below (see e.g. example (256a) to see why that is the case; recall from §4.1.1 that daughters' nonlocal features are appended on the mother). At the same time, no other phrase structure rule will license the sentence because of the *root* conditions (75); the QUE list will not be empty and so the sentence will not be licensed.

(386) $\begin{bmatrix} \textit{wh-ques-phrase} \\ \text{HEAD-DTR|SYNSEM|NON-LOCAL|QUE|LIST } \langle\, \rangle \end{bmatrix}$

The second set of rules relevant here are the extraction rules (§6.3.1). If any of the fronting options are picked in the questionnaire, all of the extraction rules will be added to the grammar by the customization system such that the long-distance dependency can be introduced.[9] In multiple optional fronting languages, the L-QUE feature is customized in these rules in order to prevent spurious ambiguity as explained in §6.5.2.

The summary of the customization logic related to pied-piping choices (§2.5.3;§6.3.5; §6.5.3)

[9]This means, the system currently predicts that if any argument or adjunct can front, they all can. Implementing finer constraints on fronting is beyond the scope of this work.

is presented in Table 7.7. Obligatory noun pied-piping is provided with no further stipulation by the analysis of obligatory fronting as presented in §6.3.1; there is no way a noun could be "stranded" without its determiner because there is nothing in the grammar that would extract the determiner. The correct semantics is ensured by the feature QUE. On the other hand, there is nothing to prevent a complement to be extracted from an adposition's COMPS list, which is optional pied-piping of adpositions. Languages which allow "stranded" nouns require a determiner extraction rule. Languages which do not allow "stranded" adpositions can easily rule that out by constraining the complement extraction rule to not apply to them.

Specification	Types	Reference	Core?	New?	Custom features
oblig. noun	*wh-pronoun-le x*	(153)	yes	yes	none
opt. noun	*ex-det-phrase*	(269)	no	yes	none
oblig. adp.	*ex-comp-phrase*	(235)	no	no	HDR|HEAD +*nvjrcdmo*
opt. adp.	*ex-comp-phrase*	(235)	no	no	none

Table 7.7: pied-piping customization summary

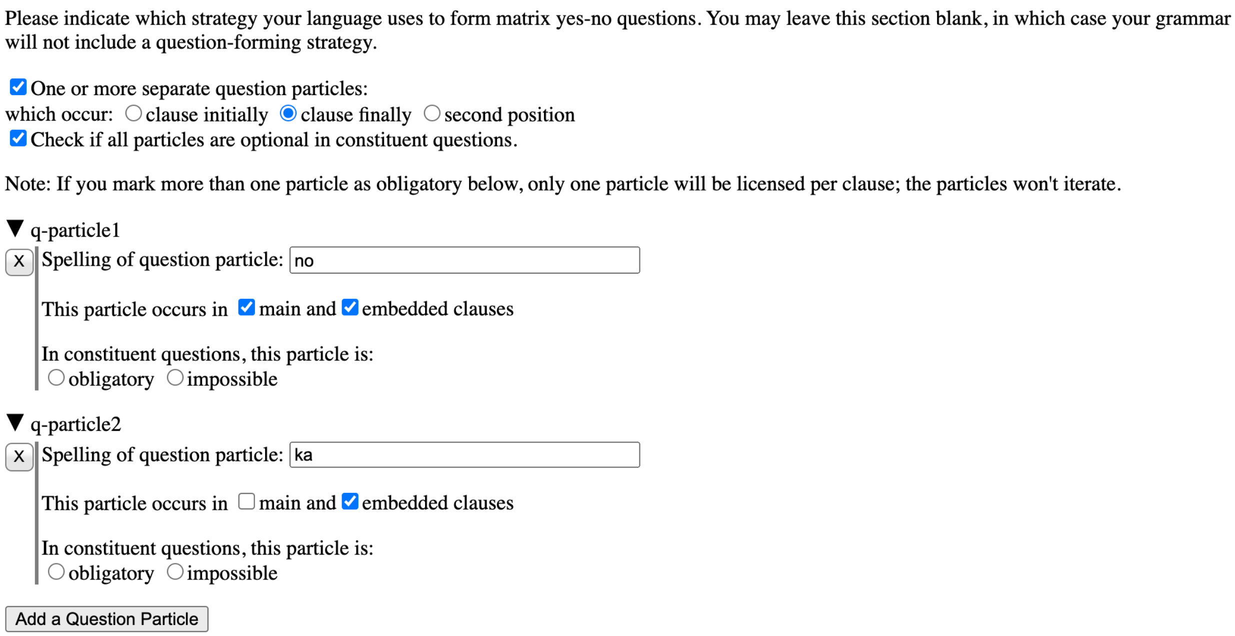
7.6 Question particles

The illustrative analyses for languages with question particles were presented in §6.7. Those analyses capture the following typological space: question particles occur in polar and constituent questions, in main and embedded clauses, and may be obligatory or not.

The questionnaire for question particles (Figure 7.13) is part of the Matrix Yes/No Questions page and was added originally by Bender and Flickinger (2005). I revamp the questionnaire as presented in Figure 7.13, to serve also the constituent questions needs. The user can enter multiple particles to model languages like Japanese where *no* and *ka* have different distribution, according to Miyagawa (1987).

In the Grammar Matrix, particles which are possible in polar questions are always optional;

[10] Any particle can be straightforwardly made impossible in polar questions by constraining its complement to be WH +. Modifying the Matrix polar questions questionnaire in this respect was beyond the scope of this work.



Please indicate which strategy your language uses to form matrix yes-no questions. You may leave this section blank, in which case your grammar will not include a question-forming strategy.

☑ One or more separate question particles:
which occur: ○ clause initially ◉ clause finally ○ second position
☑ Check if all particles are optional in constituent questions.

Note: If you mark more than one particle as obligatory below, only one particle will be licensed per clause; the particles won't iterate.

▼ q-particle1
X Spelling of question particle: no

This particle occurs in ☑ main and ☑ embedded clauses

In constituent questions, this particle is:
○ obligatory ○ impossible

▼ q-particle2
X Spelling of question particle: ka

This particle occurs in ☐ main and ☑ embedded clauses

In constituent questions, this particle is:
○ obligatory ○ impossible

Add a Question Particle

Figure 7.13: The web questionnaire for question particles, filled out for Japanese.

obligatory polar question particles or particles which are only possible in constituent but not in polar questions are not supported.[10] Therefore my analysis of question particles with respect to optionality/obligatoriness only concerns particles which occur in constituent questions. As for polar questions, the user can specify whether a particle occurs only in polar, only in constituent questions, or in both. The user can also choose from three supported positions for the particle: clause-initial, clause-final, or second position. Table 7.8 presents the specifications of the Mandarin Chinese [cmn] particle *ma*, the Japanese [jpn] *ka* and the Japanese *no*, and the Russian [rus] *li*, respectively. Japanese and Russian are two of my illustrative languages; I did not compile a Mandarin test suite but I test the typological combination for *ma* with a pseudolanguage. The complete test coverage for question particles is summarzed in Table 7.9.

The summary of the main aspects of the customization logic for question particles is presented in Table 7.10. The two key features here are WH and MC, and the most relevant core types include the *in situ* phrase structure rule and the lexical types for the particles themselves. Under

	polar	*wh-*	polar	*wh-*	polar	*wh-*	polar	*wh-*
main	opt	imposs	opt	imposs	opt	opt	opt	imposs
embed	opt	imposs	opt	opt	opt	opt	opt	imposs
	ma		*ka*		*no*		*li*	

Table 7.8: Mandarin *ma* (Fan, 2018) and Japanese *ka* and *no*, as analyzed in Miyagawa 1987, and Russian *li*

position	all opt	num part	main	embed	oblig	imposs	other
init	–	1	yes	yes	yes	–	in situ, OSV
init	–	2	yes	yes	yes	yes	in situ, OSV
2nd	–	1	yes	yes	yes	–	in situ, VFIN
JPN: fin	yes	2	yes	yes	–	–	SOV, case, adnom. poss, PNG
RUS: 2nd	–	1	yes	yes	yes	no	see above

Table 7.9: Portions of the questionnaire (columns) tested by each language (row), in combination

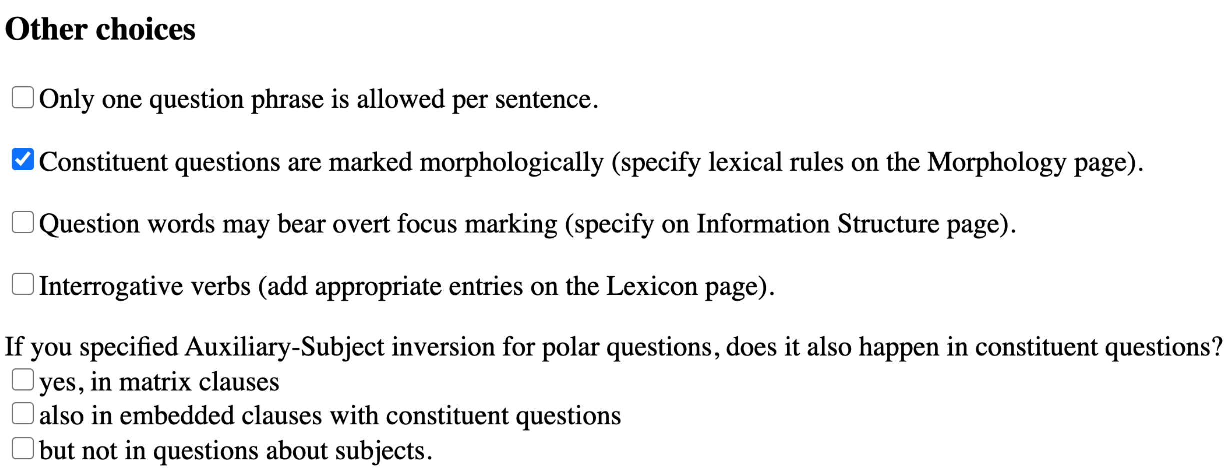
the analysis presented in §6.7.3, whether the language uses second position or clause final/initial question particle, the particle is made obligatory in constituent questions by the MC constraint on the *in situ* phrase (hence the single row for such languages). I did not test fronting languages with particles; without testing, I merely suggest the *wh-ques-phrase* would take the place of the *in situ* rule.

Specification	Types	Ref.	Core?	New?	Custom features
clause-final or init.	*qpart-comp-lex*	(291)	no	no	none
2nd pos.	*ques-clitic-lex*	(299)	no	yes	none
	non-local	(304)	yes	no	YNQ
	basic-binary-phrase	(116)	yes	no	L-PERIPH
	int-cl-phrase	(305)	no	yes	none
	in-situ-phrase	(217)	no	yes	none
obligatory	*in-situ-phrase*	(217)	no	yes	MC –
only in embed.	*qpart-comp-lex*	(291)	no	no	MC $\boxed{1}$ COMPS|MC $\boxed{1}$
only in polar	*qpart-comp-lex*	(291)	no	no	WH|BOOL –
	ques-clitic-lex	(299)	no	yes	

Table 7.10: Question particles customization summary

7.7 Morphological marking of questions

The goal of my analysis of morphological marking of constituent questions is to cover languages like Yukaghir [yux] (327) and Chukchi [ckt]. In terms of the Constituent Questions portion of the questionnaire, there is only a checkbox (shown in Figure 7.14). Checking that box is tied to



Other choices

☐ Only one question phrase is allowed per sentence.

☑ Constituent questions are marked morphologically (specify lexical rules on the Morphology page).

☐ Question words may bear overt focus marking (specify on Information Structure page).

☐ Interrogative verbs (add appropriate entries on the Lexicon page).

If you specified Auxiliary-Subject inversion for polar questions, does it also happen in constituent questions?
☐ yes, in matrix clauses
☐ also in embedded clauses with constituent questions
☐ but not in questions about subjects.

Figure 7.14: Checkbox for morphological marking in constituent questions questionnaire

checking a similar box on the Yes/No questions page (Figure 7.15). This assumes that where there is a morphological marking for constituent questions, there will also be morphological marking for polar questions.[11] While separate paradigms for polar and constituent interrogative moods are not widely attested (Haspelmath, p.c.), I do implement such a possibility (see §6.8). The user can create a lexical rule which is only for constituent question marking (Figure 7.16).

I tested morphological marking in combination with the *in situ* strategy (fronting impossible), although I do not claim any typological correlations here. The test coverage is summarized in Table 7.11. The obligatoriness of marking can be modelled using the existing functionality of the morphotactics library (O'Hara, 2008; Goodman et al., 2015).[12]

[11] I was not able to find a reference for this because typological literature rarely considered these markings separately.

[12] This is done by marking the interrogative position class as obligatory and specifying a contrasting obligatory position class (e.g. for "indicative mood"), possibly with a zero-marking lexical rule.

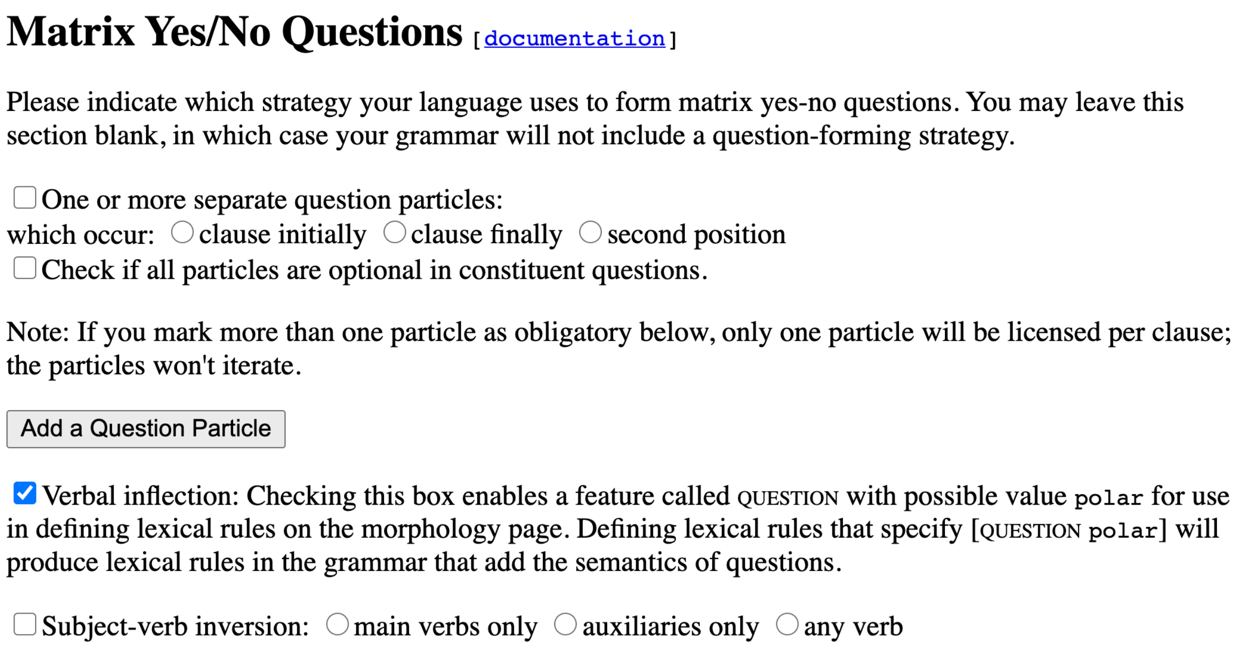


Figure 7.15: Checkbox for morphological marking in Yes/No questions questionnaire

polar	wh	separate	oblig	other
yes	yes	yes	yes	SVO; in situ
yes	yes	no	no	VOS; in situ; no multi
YUX:yes	yes	no	no	free wo; in situ; case; agr; infostr; neg; arg-opt

Table 7.11: Portions of the questionnaire (columns) tested by each language (row), in combination

The customization logic for languages with morphological marking of questions is summarized in Table 7.12. A different set of lexical rules is added to the grammar depending on whether or not the language uses two separate inflectional paradigms for polar and for constituent questions (the latter specification seeming very rare if not unattested). No special customization of the lexical rules is required (beyond the linking of the rules to the orthographies). In other words, the type hierarchy (which is the grammar) is customized at the level of the rule (as in whether a rule is included or not), not at the level of the feature (as in adding a custom feature value).

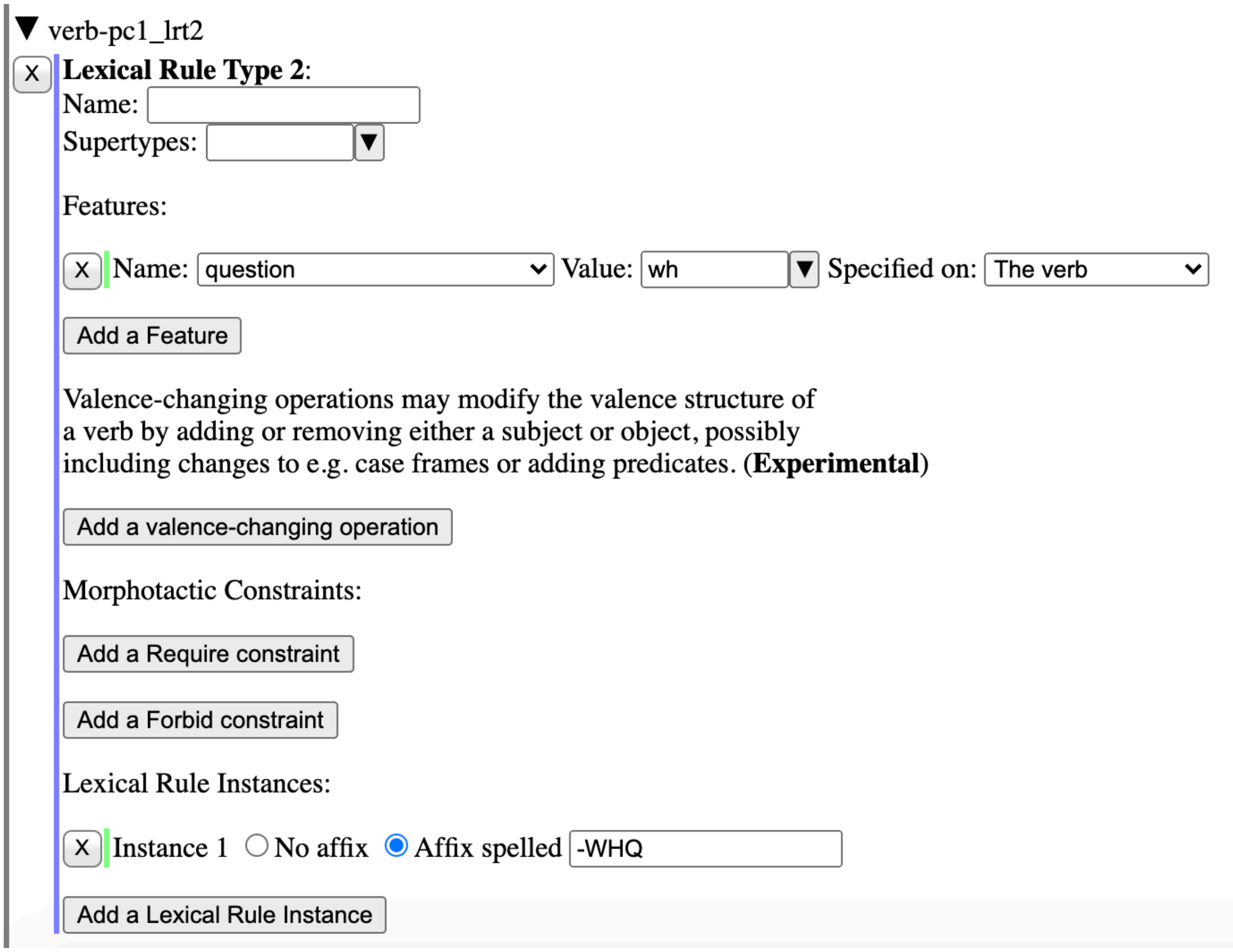


Figure 7.16: Lexical rule specification for morphological marking

Specification	Types	Ref.	Core?	New?	Custom features
Same mkg	*interrog-lex-rule*	(348)	no	yes	none
for polar and *wh-*	*indicative-lex-rule*	(348)	no	yes	none
Separate paradigms	*indicative-lex-rule*	(348)	no	yes	none
	polar-lex-rule	(355)	no	yes	none
	wh-subj-lex-rule	(356)	no	yes	none
	wh-obj-lex-rule	(357)	no	yes	none

Table 7.12: Morphological marking customization summary

7.8 Interrogative verbs

The customization related to interrogative verbs (§6.9) is done primarily in the lexicon portion of the customization system, although the user is currently also expected to check the box in the "Other choices" part of the Constituent Questions page (Figure 7.17).[13]

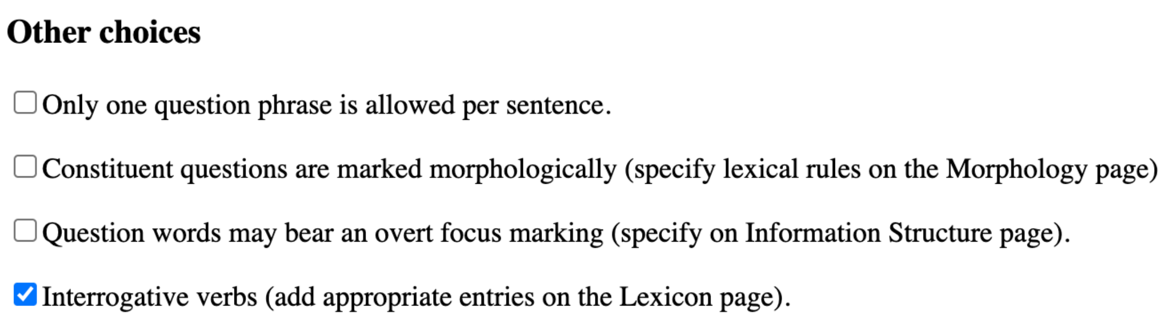


Figure 7.17: Checkbox for interrogative verbs

In the lexicon, the user specifies, in addition to the usual orthography and any features (e.g. CASE could be specified for a full-form lexicon, etc.), what kind of implicit predicate the interrogative verb has (Figure 7.18; §6.9).

A lexical entry added as in Figure 7.18 is translated by the customization system code as (387).

(387)
```
mik := be-what-interrogative-verb-lex &
[ STEM < "mik" >,
  SYNSEM [ LKEYS.KEYREL.PRED "_be_v_rel",
        LOCAL.CONT.RELS.LIST < [ ],[ ],[ PRED "_person_n_rel" ] > ] ].
```

The lexical entry in (387) is of type *be-what-interrogative-verb-lex* which is a custom-named type; the customization system will ensure that this custom-named type is a subtype of *three-rel-itrg-verb* (364).[14] If, on the other hand, the user specifies a "location in time/space" or "manner"

[13] Checking the box for interrogative verbs on the Constituent Questions subpage actually does not fulfil any purpose other than displaying a general typological statement. Perhaps this checkbox should simply be removed in future redesigns of the questionnaire.

[14] This type may contain verbs meaning *be.who* as well as *be.what*.

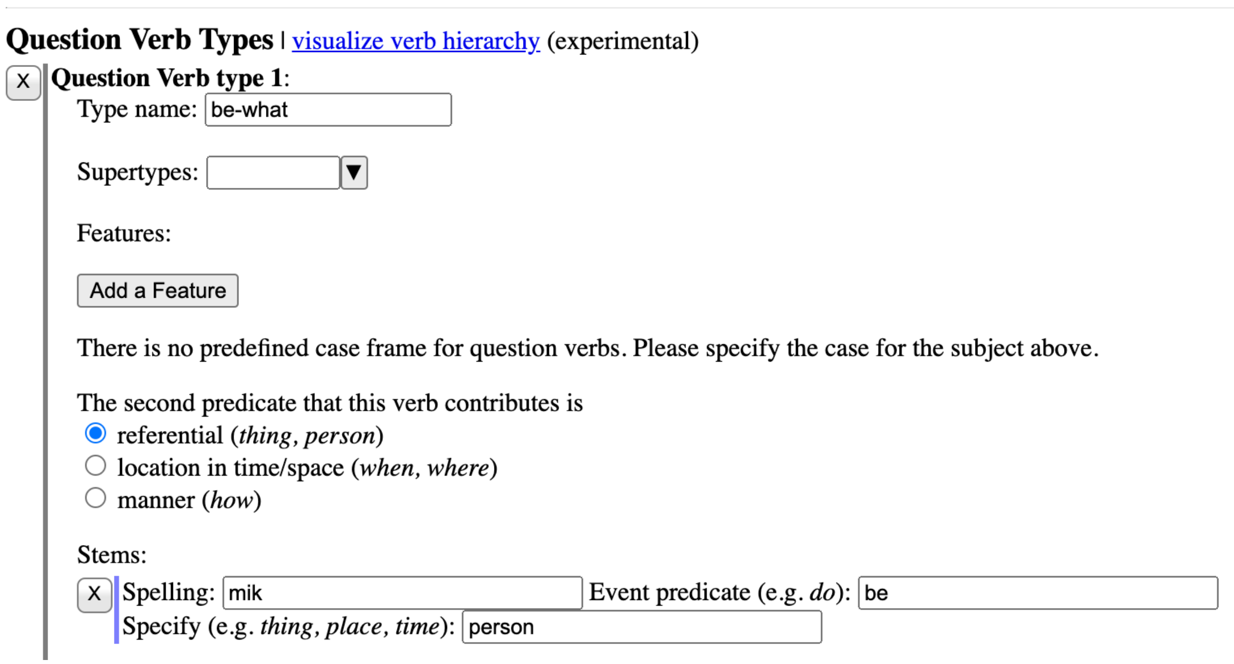


Figure 7.18: An entry for an interrogative verb in the Lexicon

interrogative verb, then the customization system will make the lexical entry a subtype of *four-rel-itrg-verb* (365), to include appropriate predications, as explained in §6.9. This logic is customized in Table 7.13.

Specification	Types	Ref.	Core?	New?	Custom features
do/be.what,etc. verb	*three-rel-itrg-verb*	(364)	no	yes	none
go.where,etc. verb	*four-rel-itrg-verb*	(365)	no	yes	none

Table 7.13: Interrogative verbs customization summary

7.9 Interim summary

The previous sections summarized how analyses such as the ones presented in Chapter 6 can now be obtained automatically with the new constituent questions library of the Grammar Matrix. I gave examples of how the questionnaire which I created can be filled out, referred back to major aspects of the HPSG analyses as necessary, and provided tables which broadly present the customization logic which I added to the system for each phenomenon (positioning of the question phrase, marking questions with particles, morphological marking, and interrogative verbs). In the next section, I discuss issues pertaining to interactions between the analyses of several phenomena which came to light in the context of this work.

7.10 Interactions of questions with other phenomena in the Matrix

One of the most important features of implemented grammars in general and the Grammar Matrix system in particular is that analyses of different phenomena literally interact with each other. Every grammar will have some account of basic word order, case system, person marking, etc., and if there is anything in any of those analyses which is incompatible with a new analysis that is being introduced, it will become obvious because the system will break. The sections below present several such cases and explain how I addressed them.

7.10.1 Coordination

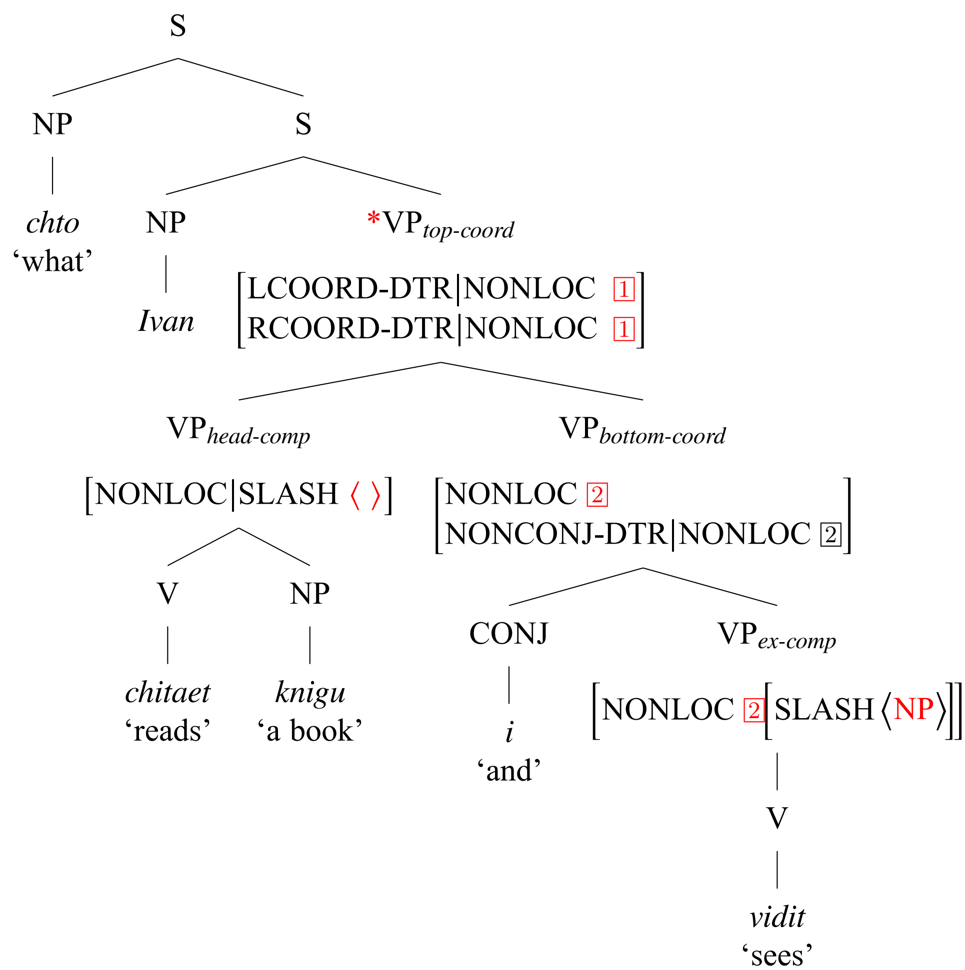
At the core of most HPSG analyses of coordination are two main ideas: (i) coordination structures are non-headed; and (ii) daughters in such structures exhibit a kind of parallelism, captured in structure-sharing (Abeillé and Chavez, in press). With respect to constituent questions, then, the issue is what coordination phrase structure rules should do about their nonlocal features.

In this work, I implement several changes related to nonlocal features in the coordination rules originally implemented for the Grammar Matrix by Drellishak and Bender (2005). Previously, the type *coord-phrase* type from which many other coordination rules inherit their constraints identified all nonlocal features of the mother with the head daughter's (389). In combination with *bottom-coord-phrase*, a type used to combine conjunction words with conjuncts, which identifies the nonlocal features of the non-conjunction-word daughter with the mother (390), this ensures, in particular, that (388) is ruled out (391), since SLASH is part of the non-local features along with QUE and REL (§3.1).

(388) *Что Иван читает книгу и видит?
*Chto Ivan chitaet knigu i vidit?
what.ACC Ivan.NOM read.3SG.PRES book.ACC CONJ see.3SG.PRES
Intended as sounding like: ‘*What does Ivan read a book and see?’[rus]

(389)
$$\begin{bmatrix} \textit{coord-phrase} & \\ \text{SYNSEM|NON-LOCAL} & \boxed{1} \\ \text{LCOORD-DTR|NON-LOCAL} & \boxed{1} \\ \text{RCOORD-DTR|NON-LOCAL} & \boxed{1} \end{bmatrix}$$

(390)
$$\begin{bmatrix} \textit{bottom-coord-phrase} & \\ \text{SYNSEM|NON-LOCAL} & \boxed{1} \\ \text{NONCONJ-DTR|NON-LOCAL} & \boxed{1} \end{bmatrix}$$

(391)


While the SLASH identity that is part of the NON-LOCAL identity in (389) correctly rules out

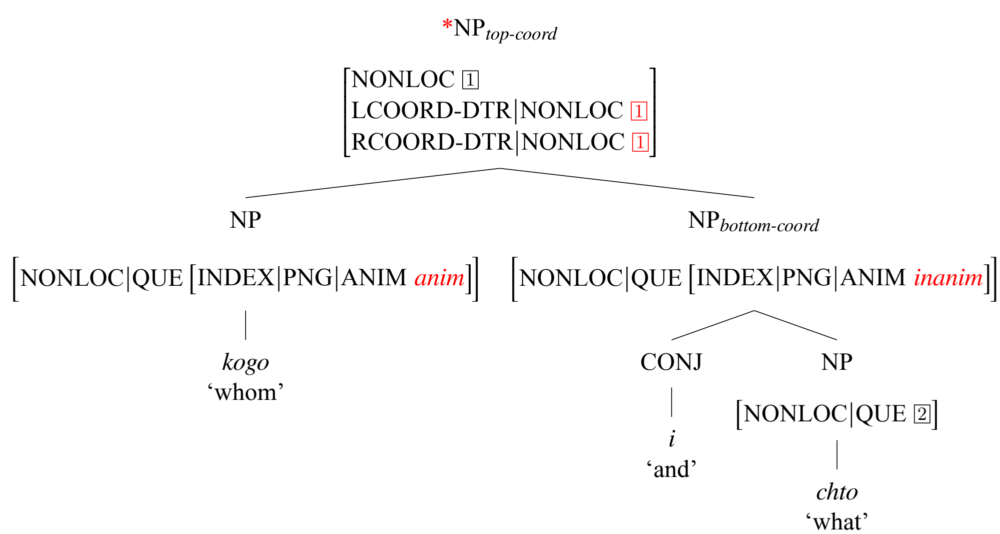
(388), the QUE identity leads to incorrect results with respect to (392).

(392) Кого i что Иван видит?
Kogo i chto Ivan vidit?
who.ACC CONJ what.ACC Ivan.NOM see.3SG.PRES
'Whom and what does Ivan see?' [rus]

(392) Кого и что Иван видит?
Kogo i chto Ivan vidit?

In (392), the two coordinated question phrases have different PNG values (specifically, different ANIMACY). This means the phrase structure rule that combines them into a constituent cannot insist that its daughters' QUE values are identical; a question phrase's QUE value generally refers to the index of the entity which is the answer to the question (153) and PNG is part of the the INDEX. This situation is illustrated by (393).

(393)



Note that a (strange) sentence like (394) would be parsed by a grammar insisting on the two QUE values being the same. However this would be undesirable because the resulting semantic representation would be broken; it would represent the two different entities denoted by the two noun phrases as having the same intrinsic argument (as illustrated in Figure 7.19; note the ARG0 is the same on both _thing_n_rel entities, which is wrong as they are two different things).

(394) Что и что Иван видит?
Chto i chto Ivan vidit?
what.ACC CONJ what.ACC Ivan.NOM see.3SG.PRES
'What and what does Ivan see?' [rus]

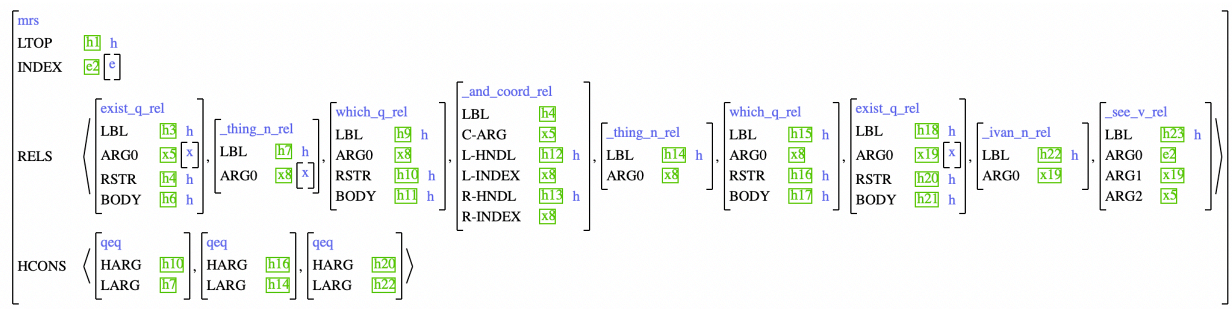


Figure 7.19: A wrong semantic representation for (394).

I propose the following revised analysis of coordination for the Matrix. I relax the QUE constraint in top coordination phrases (which are all subtypes of (389)), and now it passes up one of the daughter's QUE while still identifying SLASH and REL (395).

(395)
$$\begin{bmatrix} \textit{coord-phrase} & \\ \text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix}\text{SLASH } \boxed{1}\text{, REL } \boxed{2}\text{, QUE } \boxed{3}\end{bmatrix} \\ \text{LCOORD-DTR}|\text{NON-LOCAL} & \begin{bmatrix}\text{SLASH } \boxed{1}\text{, REL } \boxed{2}\end{bmatrix} \\ \text{RCOORD-DTR}|\text{NON-LOCAL} & \begin{bmatrix}\text{SLASH } \boxed{1}\text{, REL } \boxed{2}\text{. QUE } \boxed{3}\end{bmatrix} \end{bmatrix}$$

(396)
$$\begin{bmatrix} \textit{s-coord-phrase} & \\ \text{SYNSEM}|\text{NON-LOCAL} & \boxed{0} \\ \text{LCOORD-DTR}|\text{NON-LOCAL} & \boxed{0} \\ \text{RCOORD-DTR}|\text{NON-LOCAL} & \boxed{0} \end{bmatrix}$$

The QUE values should still be accounted for, but I suggest that it should be done not at the level of the main supertype (395) but rather at the level of subtypes, such as the phrasal types for sentence and vp-coordination. The identity which used to be on the general *coord-phrase* supertype is now pushed down to vp- and sentence coordination rules (396), in particular to prevent ambiguity in sentences like (397) which would otherwise be licensed by coordinating not only two filler-gap constructions (398) but also a filler-gap construction and a complement-head

[15]Note that this particular ambiguity arises only under the assumption that the complement-head rule allows *wh*-phrases as nonhead-daughters; see §2.5.1 for the discussion on this assumption.

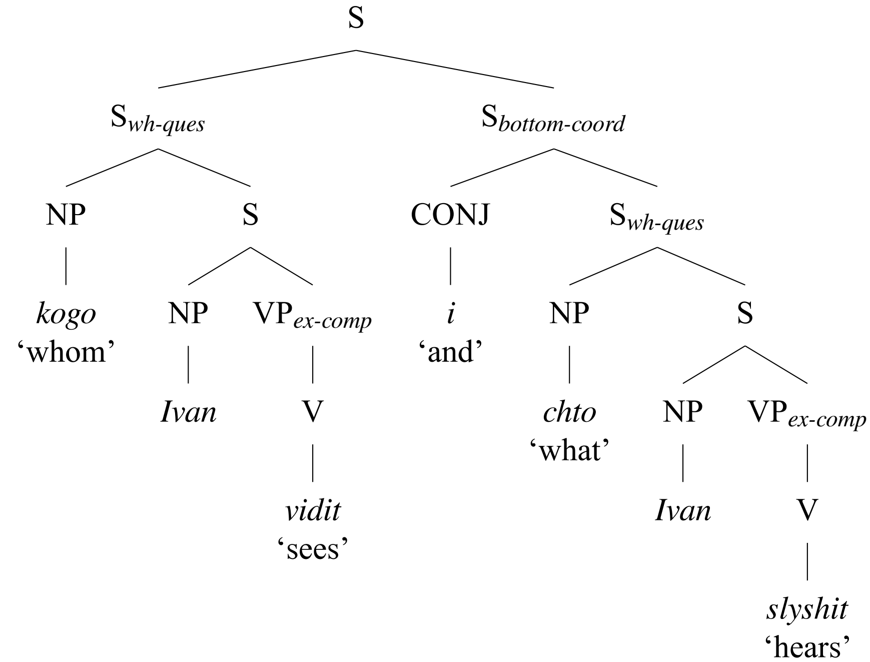
construction (399).[15]

(397)

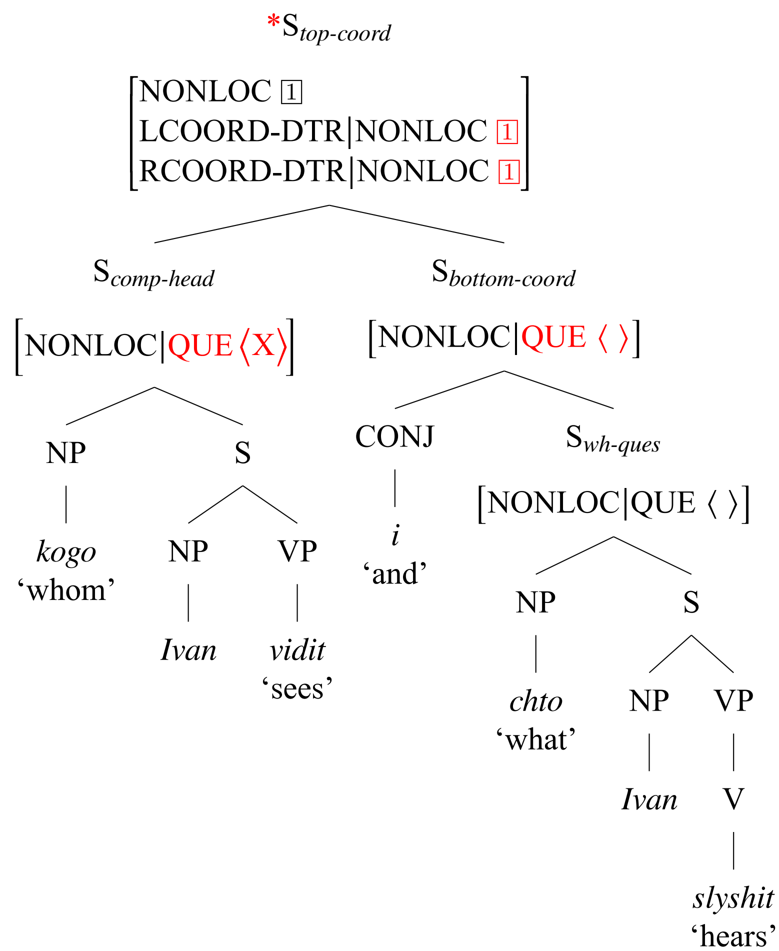
Кого	Иван	видит	и	что	Иван	слышит?
Kogo	Ivan	vidit	i	chto	Ivan	slyshit?
who.ACC	Ivan.NOM	see.3SG.PRES	CONJ	what.ACC	Ivan.NOM	head.3SG.PRES

'Who is Ivan seeing and what is Ivan hearing?' [rus]

(398)



(399)



Not identifying noun coordinands with respect to QUE solves the problem of incorrectly ruling out (392) but it is not an ideal solution because it then predicts that (400) is grammatical. A better analysis, accounting for both (392) and (400), remains future work.

(400) *Студента и кого Иван видит?
*Studenta i kogo Ivan vidit?
student.ACC and WHO.ACC Ivan.NOM see.3SG.PRES
Intended: 'Whom does Ivan see in addition to the student?' [rus]

On adverb-coordination rules,[16] QUE is left underspecified to license sentences like (392) and (401).

[16] I add adverb coordination phrasal types, e.g. *adv-coord-phrase*, as part of this work, however there is no section dedicated to them in this document. They can be found in `matrix.tdl`.

(401) Где и когда он купил машину?
Gde i kogda on kupil mashinu?
where and when 3SG.NOM.MASC buy.SG.PST.MASC car.sg.acc
'Where and when did he buy the car?' [rus]

7.10.2 Modification

As discussed in §6.1.2, some adpositions (402) can modify both noun and verb phrases.

(402) Иван видит женщину **в** фильме
Ivan vidit zhenschinu **v** filme
Ivan.NOM see.3SG woman.ACC IN film.PREP
"Ivan sees the woman in the film." [rus]

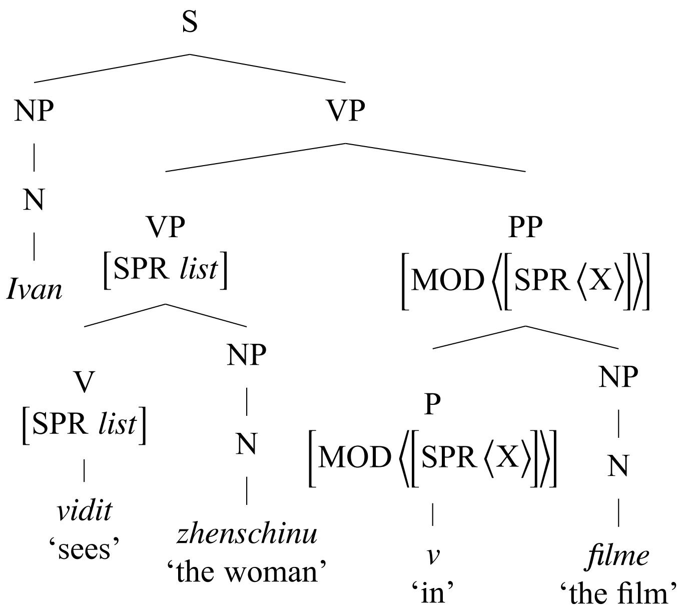
Constraining adpositions to attach to nouns before determiners (§6.1.2) and testing this lexical type in interaction with not only noun phrases but also verb phrases led to some revisions related SPR and SPEC constraints in the entire Matrix system.[17] These revisions are described in this section.

SPEC was erroneously underspecified in *basic-filler-phrase*'s mother, *basic-head-subj-phrase*'s mother and head daughter, *basic-bare-np-phrase*'s mother and daughter, *basic-extracted-comp-phrase*'s mother and daughter, *basic-extracted-subj-phrase*'s mother, *extracted-adj-phrase-simple*'s mother, and in the *conj-lex* lexical supertype. This used to not pose problems because the SPR value was overconstrained on a number of lexical items, verbs, in particular. While verbs normally do not take specifiers, constraining their SPR lists to be empty complicates the analysis of adpositions which modify nouns as well as verbs. In fact, the SPR value of verbs must be underspecified in order for them to be modified by the same PPs which modify nouns (this is because the adposition must constrain the element on its MOD list to be SPR-nonempty, otherwise ambiguity arises in analyses for sentences like (402) due to the modifier attaching both below (404) and above (405) the bare NP rule). I fix this issue by removing the SPR constraints and adding SPEC constraints throughout the system, which includes the core and the customization system,

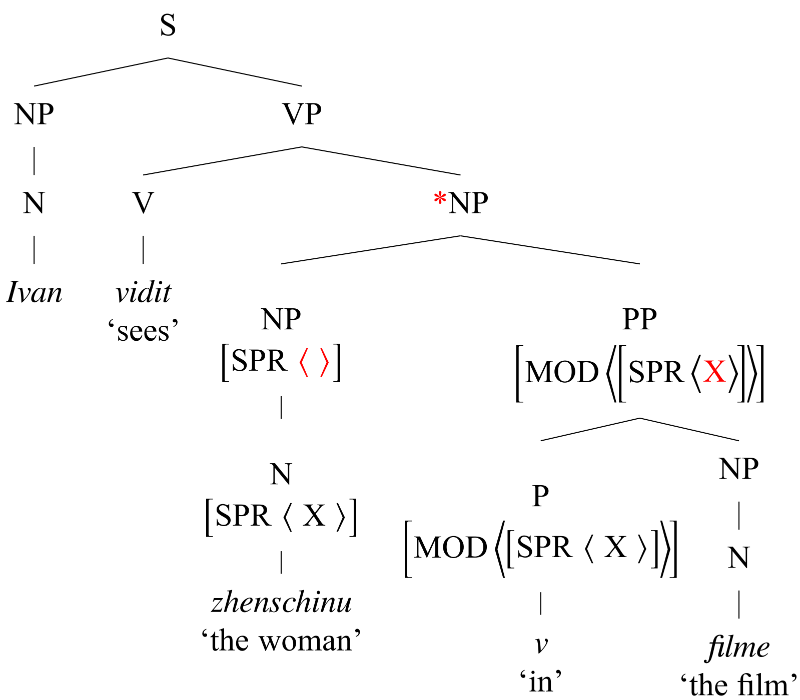
[17] SPR is the HPSG feature which is used by nouns to select for determiners; SPEC allows determiners to constrain some of the properties of nouns for which they serve as specifiers (Pollard and Sag, 1994).

particularly the adnominal possession library, the auxiliaries library, and the lexicon.

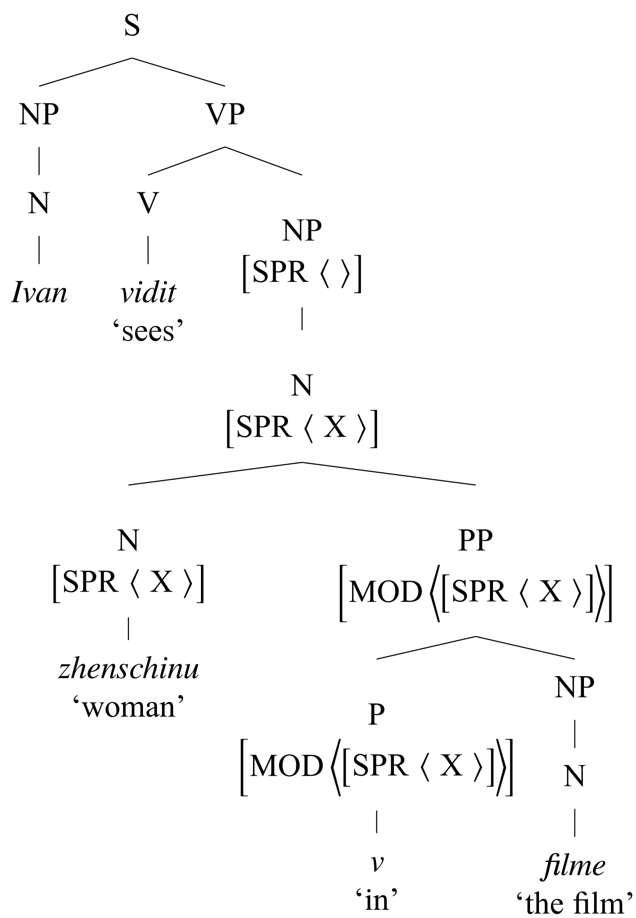
(403)



(404)



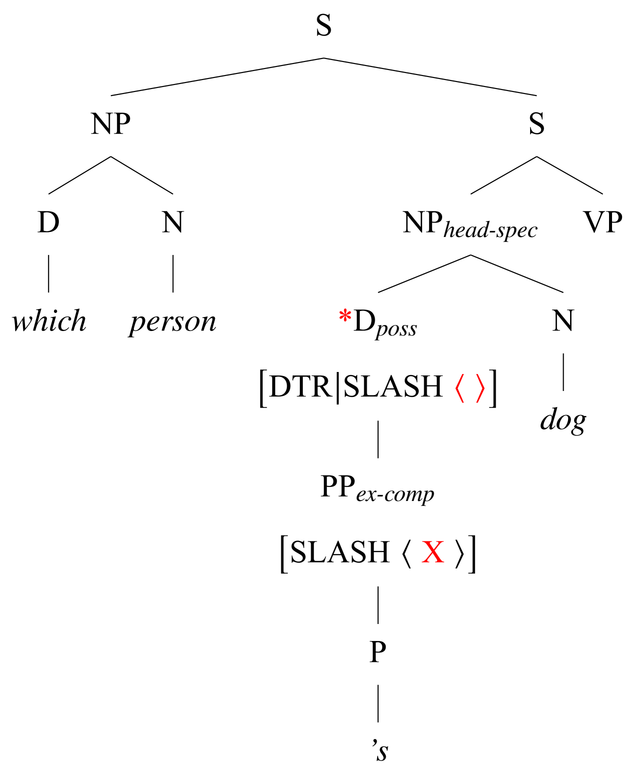
(405)



7.10.3 Adnominal possession

While testing sentences like *Which person’s dog sleeps?* (406), it surfaced that some of the phrasal and lexical types from the adnominal possession library (Nielsen, 2018) were underconstrained with respect to nonlocal features. In particular, the unary rule which turns a possessive phrase into a specifier did not constrain its daughter’s SLASH list to be empty. This led to parse trees with wrong semantic structures, such that the dog is the possessor of the person, instead of the other way around (406):

(406)



In (406), the possessive unary rule must be prevented from taking the mother of the extracted complement rule as the daughter,[18] which is easily done by stipulating that the possessive unary rule only takes unslashed structures as daughters.[19]

7.10.4 Focus marking

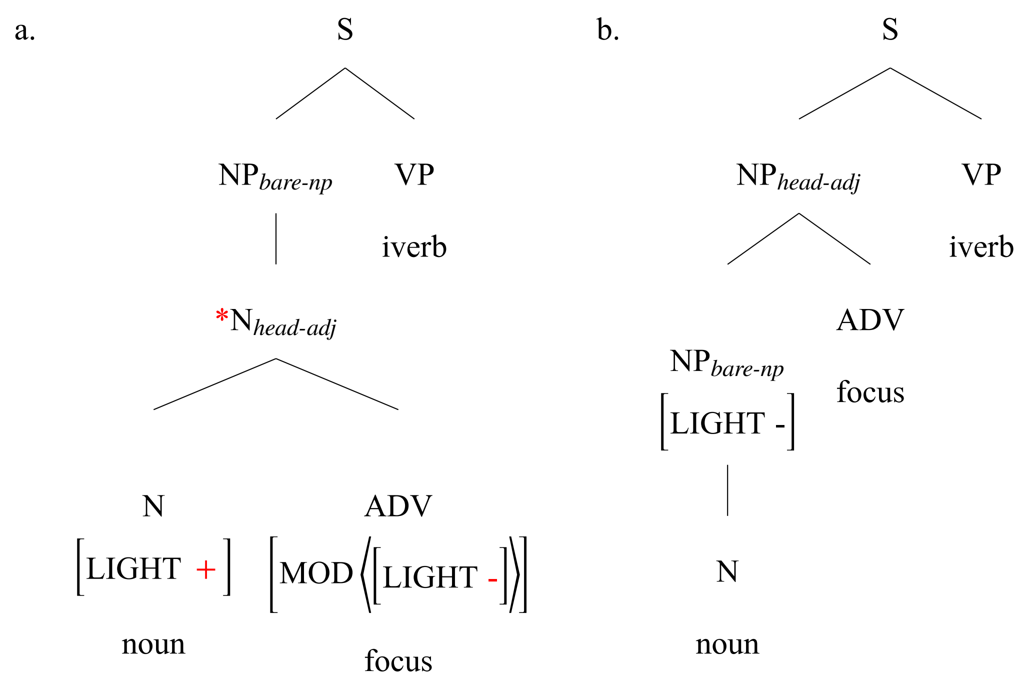
The information structure library manipulates the LIGHT feature (Abeillé and Godard, 2001; Song, 2014) to rule out spurious structural ambiguity in analyses. This feature is generally used to indicate whether or not the constituent is more like a single word ([LIGHT +]) or more like a phrase ([LIGHT −]). In the information structure questionnaire, the user must specify whether the focus marker modifies nouns or verbs. If it can modify both, the information structure library

[18]Note that while the same tree would have been ruled out by saying that the extracted complement rule does not take adpositions as daughters, that would be wrong because it would make optional pied-piping of adpositions impossible (§6.3.5).

[19]Later in the evaluation stage (§8.5, it turned out that I failed to systematically fix the nonlocal features in the adnominal possession as well as in some other libraries. They are underspecified in many places still.)

would previously create two homophonous particles, one for nouns and one for verbs. The one for verbs would be constrained to modify [LIGHT +] structures and the one for nouns [LIGHT −] structures. The latter constraint was used to ensure that the particle applies only above the bare NP rule but not both below (407a) and above (407b).

(407)

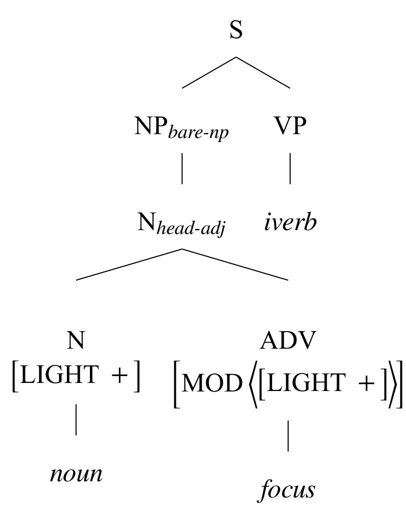


The above analysis which admits (407b) and rules out (407a) is hard to generalize to constituent questions because question words never go through the bare NP rule and therefore such a focus marker would never modify them. In fact, the above analysis actually relies on the fact that the bare NP rule is underspecified with respect to LIGHT in the Matrix core. In other words, in (407b), under the old information structure analysis, the value of LIGHT in fact becomes − (*minus*) because of the constraint on the focus marker's MOD element, *not* because of the bare NP rule! Fortunately, this analysis can be easily changed without negative impact on the rest of the system.

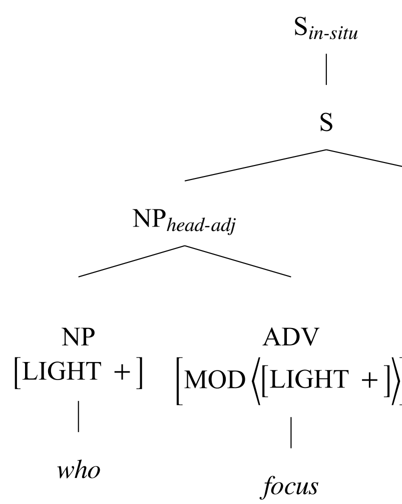
I make changes in the information structure library so that it now anticipates an additional user choice, namely that the focus marker is or is not possible on question words. If it is, the customization system makes sure the marker will be modifying [LIGHT +] daughters and the bare NP rule will be constrained to be [LIGHT −].[20] The analysis is then as follows (408a)–(408b). Analysis (407b) is ruled out (409).

(408)

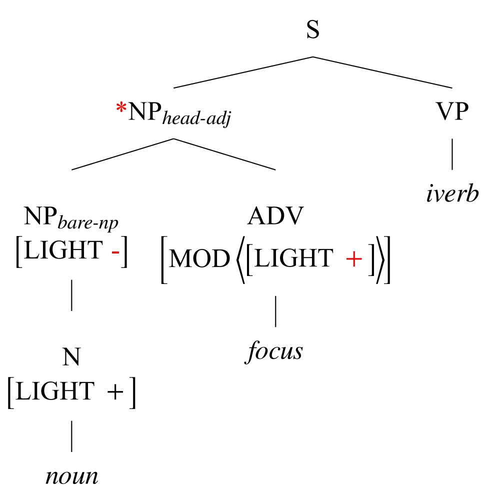
a.



b.



(409)



[20]Emily M. Bender thinks that the bare NP rule should in fact always be [LIGHT −]; I tried making that change in the Matrix core but it broke some of the regression tests. It is possible that the problem is in the tests themselves;

7.10.5 Summary

The previous sections presented a summary of changes associated with the new constituent questions library but implemented in other libraries. The next four sections (which can be safely skipped by readers uninterested in the technicalities of DELPH-IN JRF) talk about infrastructural changes I introduce into the system.

7.11 The analysis and the Matrix infrastructure

In order to support the analyses presented in Chapter 6, I performed infrastructural changes throughout the system which I review below. The changes are of three kinds. First, current work led to adopting a new type *append-list* (§3.2.1) for nonlocal features and subsequently to abandoning the lexical threading assumptions (§4.1.2) in the entire Grammar Matrix system. The "append-ful" and lexical threading-free Matrix is a contribution of this dissertation and, with respect to the dissertation, is the biggest change to the system as a whole (§7.11.1)–(§7.11.2). Second, I added to the Matrix core types (written by Guy Emerson) which allow encoding logical operations (§7.11.3). I use these types to support my analysis of question particles, in particular (§6.7). Finally, I add two new types of parameterized lists (§7.11.4) to support my analysis of optional fronting (§6.5.2).

7.11.1 Replacing diff-lists with append-lists

As discussed in §3.2.1, append lists allow for a much simpler grammar writing where nonlocal features are involved. It was thus decided between the participants of the Grammar Matrix project that I should completely replace all difference lists in the Matrix with append lists. I started with merging into the core (`matrix.tdl`) a new type hierarchy for *append-list* from the sample grammar provided by Guy Emerson (Emerson, 2017, 2019).[21] Then I replaced all uses

investigating this is future work.

[21] As a reminder to the reader, the full system, with all the types and all the files, can be downloaded from `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`.

of difference lists in the core and in the customization system with *append-list*. Anywhere where difference lists were used, I simply replaced the `<! !>` syntax with `LIST < >`, to ensure correct parsing of the TDL code. I changed the definition of the *non-local* type to have *append-list*-valued features (410)–(411).

(410)
```
non-local := OLD-non-local-min &
  [ SLASH diff-list,
    QUE diff-list,
    REL diff-list ].
```

(411)
```
non-local := non-local-min &
  [ SLASH append-list,
    QUE append-list,
    REL append-list ].
```

Replacing difference lists with *append-list* further required me to implement a change to the customization system TDL parser (`tdl.py`). The parser is used in particular to put together substructures emitted by different parts of the system. For example, if the word order library outputs a structure for *head-subj-phrase* and then another library stipulates additional constraints in the same rule, the TDL parser will merge the substructures instead of outputting two separate ones (which would be wrong and would lead to either overwriting one of the rules or to a broken grammar). This TDL parser of course also merges structures containing list-valued features, but, previously it was never called to merge two lists. A special function in the TDL parser used to perform the merge for difference lists (previously used for nonlocal features), and as for normal lists, they were previously only used for valence features and it was assumed that they never need to merge. But append lists have normal lists inside them, so now they need to be merged. Any list ends with an element whose REST value (77) is *null*; this *null* needs to be discarded in the case another list is appended, which is what I implement as illustrated in (412)–(413).[22]

[22]The actual code can be found in `tdl.py` lines 750–753 `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`. The nulls are not normally present in the output TDL though they in principle

(412)
```
LIST1: 1->2->null
LIST2: 3->4->null
MERGED LIST: 1->2->3->4->null
```

(413)
```
list1 := [ C-CONT [ RELS.LIST < noun-relation > . null ] ]
list2 := [ C-CONT [ RELS.LIST < quant-relation > . null ] ]
merged-list :=
[ C-CONT [ RELS.LIST < noun-relation, quant-relation > . null ] ]
```

7.11.2 Unraveling lexical threading

One of this dissertation's contributions is a lexical threading-free version of the entire Grammar Matrix system. In Zamaraeva and Emerson (in press),[23] we offer two alternative analyses of Russian multiple question phrase fronting, one with the lexical threading assumption and one without. Each option has its advantages and disadvantages, and for the purposes of the Grammar Matrix, it was decided between the Grammar Matrix project members that the second option is preferable.

In terms of the advantages, lexical threading makes possible an elegant analysis of *easy*-adjectives (Sag et al. 2003, p.439, Flickinger 2000), which would otherwise require additional phrasal rules; the analysis of morphological marking of questions is also easier (see §6.8). However, the combination of *append-list* and lexical threading makes the analysis of VP coordination more problematic, because the analysis of coordination in the Matrix does not expect that the non-local features of the coordinands can differ in their computation history. Guy Emerson explains in Zamaraeva and Emerson (in press):

> "With lexical threading, both the "input" and "output" of the append operation are accessible in the feature structure, e.g. by looking at a VP's SLASH and SUBJ|...SLASH. However, if adjuncts are not included in lexical threading, then there can be any number of append operations between the SLASH and SUBJ|...SLASH. Even if two

could be; I am presenting them here for readers' convenience.

[23]Some content of this section was published as Zamaraeva and Emerson (in press).

> coordinated VPs have compatible values for SLASH|LIST and SUBJ|...SLASH|LIST, they may have incompatible values for SLASH and SUBJ|...SLASH, which means that more care is required in writing coordination rules."

Finally, lexical threading complicates the analysis of multiple fronting, leading, in particular, to positing multiple adjunct extraction rules, as discussed in Zamaraeva and Emerson (in press) and also in §6.5.1. Without lexical threading, we can give a simple account of multiple extraction of arguments and adjuncts in the context of flexible word order and have no issues with coordination while also gaining in parsing speed, as multiple adjunct extraction rules are costly for the parser performance.[24]

Making the Grammar Matrix lexical threading-free involved the following changes at the levels of both the lexical and the phrasal type hierarchy. First, as discussed in §4.1.2, all lexical types previously implemented lexical threading by inheriting from one of the supertypes like (130) repeated here as (414).

(414)
$$\begin{bmatrix} \textit{basic-two-arg-lex-item} & \\ \text{ARG-ST} & \left\langle \begin{bmatrix} \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{1}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{2}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{3}\ ! \rangle \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{4}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{5}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{6}\ ! \rangle \end{bmatrix} \end{bmatrix} \right\rangle \\ \text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \langle !\ \boxed{1}, \boxed{4}\ ! \rangle \\ \text{REL} & \langle !\ \boxed{2}, \boxed{5}\ ! \rangle \\ \text{QUE} & \langle !\ \boxed{3}, \boxed{6}\ ! \rangle \end{bmatrix} \end{bmatrix}$$

In combination with the type *gap* (415), inheriting from (414) meant a transitive verb could state that it had an argument that was actually a *gap* and so was expected to appear not in its usual place (for lexical items with different valence, similar types as (414) were posited and used). The phrase structure rules such as head-subject or head-complement need not say anything about the nonlocal features because they were already constrained, via one of their supertypes (87), namely *head-valence-phrase*, to propagate the head daughter's nonlocal values.

[24] In Zamaraeva and Emerson (in press), we compare two analyses of Russian multiple fronting, with and without lexical threading. On the Russian test described in §8.3.2 and with the LKB parser run on a MacBook Pro 2015 laptop with 16GB memory and 3.1GHz Intel Core i7 processor, Analysis 1 speed is 1.47 seconds per sentence on

(415) $$\begin{bmatrix} \textit{gap} & \\ \text{LOCAL} & \boxed{0} \\ \text{NON-LOCAL} & \begin{bmatrix} \text{REL}|\text{LIST} & \langle\,\rangle \\ \text{QUE}|\text{LIST} & \langle\,\rangle \\ \text{SLASH} & \begin{bmatrix} \textit{append-list} & \\ \text{LIST} & \langle\boxed{0}\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

I replace (130) and similar types with a simple supertype stating that all nonlocal features of a lexical item are empty (416):

(416) $$\begin{bmatrix} \textit{non-local-none-lex-item} & \\ \text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix} \text{SLASH}|\text{LIST} & \langle\,\rangle \\ \text{REL}|\text{LIST} & \langle\,\rangle \\ \text{QUE}|\text{LIST} & \langle\,\rangle \end{bmatrix} \end{bmatrix}$$

Most lexical items will now inherit from this type. There is no longer any in-built relationship between a lexical item's nonlocal features and its arguments'.

On the other hand, the phrasal types such as head-subject and head-complement as well as head-modifier now explicitly append the NON-LOCAL features of the daughters. This, in combination with getting rid of types like (130), eliminates the lexical threading mechanism from the system. Instead, I posit the supertypes (200)–(201) repeated here as (417)–(418) and have most phrasal rules inherit from one of them. Of course, extraction rules and the filler-gap rule do not inherit from these types; instead they either append an item to the existing SLASH list (like the extraction rules which are presented in §6.3.1) or subtract an item from it (419).

average; Analysis 2 speed is 0.39 seconds.

(417)
$$\begin{bmatrix} \textit{binary-non-local-phrase} & \\ \text{ARGS} & \left\langle \begin{bmatrix} \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH} & \boxed{1} \\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH} & \boxed{4} \\ \text{REL} & \boxed{5} \\ \text{QUE} & \boxed{6} \end{bmatrix} \end{bmatrix} \right\rangle \\ \text{SS}|\text{NLOC} & \begin{bmatrix} \text{SLASH}|\text{APPEND} & \left\langle \boxed{1}, \boxed{4} \right\rangle \\ \text{REL}|\text{APPEND} & \left\langle \boxed{2}, \boxed{5} \right\rangle \\ \text{QUE}|\text{APPEND} & \left\langle \boxed{3}, \boxed{6} \right\rangle \end{bmatrix} \end{bmatrix}$$

(418)
$$\begin{bmatrix} \textit{unary-non-local-phrase} & \\ \text{DTR}|\text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \boxed{1} \\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3} \end{bmatrix} \\ \text{SYNSEM}|\text{NON-LOCAL} & \begin{bmatrix} \text{SLASH} & \boxed{1} \\ \text{REL} & \boxed{2} \\ \text{QUE} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

(419)
$$\begin{bmatrix} \textit{filler-gap-phrase} & \\ \text{SLASH} & \boxed{1} \\ \text{ARGS} & \left\langle \boxed{2}, \begin{bmatrix} \text{SLASH}|\text{LIST} & \begin{bmatrix} \text{FIRST} & \boxed{2} \\ \text{REST} & \boxed{1} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

This analysis results in the same coverage over the test suites included in the Grammar Matrix as before, but without employing lexical threading in the lexicon and without relying on it in phrase structure rules.

7.11.3 Logical operations

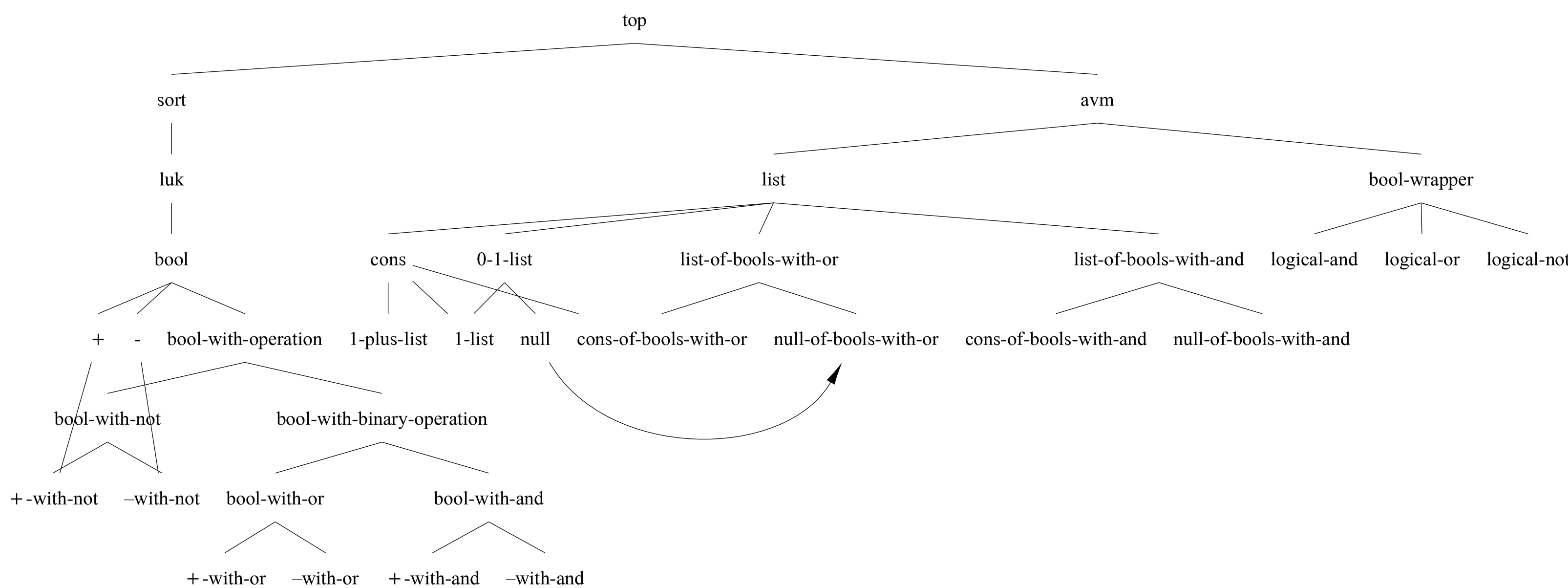
At the same time that Guy Emerson introduced *append-list* (Emerson, 2017, 2019), he also wrote a number of types which as a hierarchy, presented partially in (420),[25] represent computation of

[25]Recall from §3.4 that the Matrix core is one big hierarchy. So, everything else in the core is part of the same hierarchy as the portion presented in (420), and all presented types may have other children, which may be crucial for unification. For example, the type *null* works for representing empty lists because it does not have common

logical operations such AND, OR, and NOT, relying on lists.

descendant and therefore is not unifiable with all existing types for nonempty lists, namely *1-list* and *1-plus-list*. If I showed all parent-child relationships in the diagram, it would become completely unreadable. I resort to asking the reader to infer similar relationships from type names, e.g. the type *+-with-or* actually inherits from the type + just like *+-with-not* does. Same with the children of *cons* and *null*.

(420)


top
sort
avm
luk
list
bool-wrapper
bool
cons
0-1-list
list-of-bools-with-or
list-of-bools-with-and
logical-and
logical-or
logical-not
+
-
bool-with-operation
1-plus-list
1-list
null
cons-of-bools-with-or
null-of-bools-with-or
cons-of-bools-with-and
null-of-bools-with-and
bool-with-not
bool-with-binary-operation
+-with-not
–with-not
bool-with-or
bool-with-and
+-with-or
–with-or
+-with-and
–with-and

Below in (421)–(429) I provide the definitions of the types involved in the computation of the logical OR. It is not necessary for readers interested mainly in the syntactic analyses to understand the full mechanics of the computation; I provide the types because at the time of this writing, there is no other exposition of them apart from the Matrix code itself. The point is, with these types, it is possible to compute a logical OR between two boolean values inside an HPSG grammar, which I make use of in §6.6.

(421) $\begin{bmatrix} \textit{bool-wrapper} & \\ \text{BOOL} & \textit{bool} \end{bmatrix}$

(422) $\begin{bmatrix} \textit{list-of-bools-with-or} & \\ \text{FIRST} & \textit{top} \\ \text{REST} & \textit{list} \\ \text{OR-RESULT} & \textit{bool} \end{bmatrix}$

(423) $\begin{bmatrix} \textit{null-of-bools-with-or} & \\ \text{FIRST} & \textit{null} \\ \text{REST} & \textit{null} \\ \text{OR-RESULT} & - \end{bmatrix}$

(424) $\begin{bmatrix} \textit{bool-with-operation} & \\ \text{RESULT-BOOL} & \textit{bool} \end{bmatrix}$

(425) $\begin{bmatrix} \textit{bool-with-or} & \\ \text{RESULT-BOOL} & \textit{bool} \\ \text{OTHER-BOOL} & \textit{bool} \end{bmatrix}$

(426) $$\begin{bmatrix} \textit{cons-of-bools-with-or} & \\ \text{FIRST} & \begin{bmatrix} \textit{cons} & \\ \text{BOOL} & \begin{bmatrix} \textit{bool-with-or} & \\ \text{OTHER-BOOL} & \boxed{1} \\ \text{RESULT-BOOL} & \boxed{2} \end{bmatrix} \end{bmatrix} \\ \text{REST} & \begin{bmatrix} \textit{list-of-bools-with-or} & \\ \text{OR-RESULT} & \boxed{1} \end{bmatrix} \\ \text{OR-RESULT} & \boxed{2} \end{bmatrix}$$

(427) $$\begin{bmatrix} \textit{+-with-or} & \\ \text{RESULT-BOOL} & + \\ \text{OTHER-BOOL} & \textit{bool} \end{bmatrix}$$

(428) $$\begin{bmatrix} \textit{–with-or} & \\ \text{RESULT-BOOL} & \boxed{1} \\ \text{OTHER-BOOL} & \boxed{1} \end{bmatrix}$$

(429) $$\begin{bmatrix} \textit{logical-or} & \\ \text{BOOL} & \boxed{1} \\ \text{OR} & \begin{bmatrix} \textit{list-of-bools-with-or} & \\ \text{OR-RESULT} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

From the above, I only need to directly use the type *logical-or* (429) in order to be able to perform the OR operation in the grammar. In particular, I use OR in situations where some higher clause only cares whether or not a *wh*-word was present somewhere in the clause but not about its specific position (see §6.6).

7.11.4 Parameterized lists: Canonical list and non-wh-list

Parameterized lists are lists which place constraints on what kind of elements can be on them. Thus, in the Grammar Matrix, *olist*, for *o*ptional element *list*, is a list of elements which can be dropped, such as dropped subjects or objects, for the argument optionality analysis in the Matrix (Saleem, 2010).

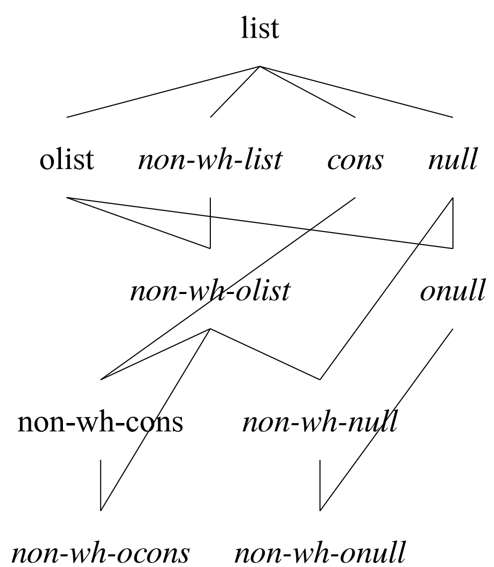
I add to the Matrix core two new list subtypes, one for lists of *canonical* elements, in other words nongap elements, and another for lists of *non-wh* elements. I use both to avoid spurious ambiguity as described in §6.5.2.[26]

Non-wh-list is a list of elements whose QUE list is empty (430):

(430)
$$\begin{bmatrix} \textit{non-wh-cons} & \\ \text{FIRST} & \begin{bmatrix} \textit{synsem} \\ \text{NON-LOCAL.QUE.LIST } \langle\, \rangle \end{bmatrix} \\ \text{REST} & \textit{non-wh-list} \end{bmatrix}$$

The hierarchy for this new type (431) closely models the *olist*. Its function is discussed in §6.8.2.

(431)



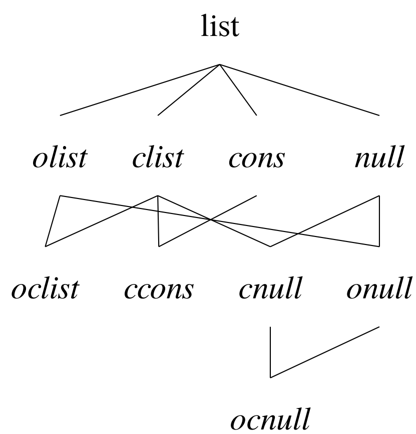
Canonical-list is a list of elements which are not of type *gap*. This means the list can be empty or it can contain actual non-extracted elements.

[26] Both lists were suggested by Emily M. Bender as part of our discussion of ambiguity in adjunct extraction (§8.3.4).

(432) $\begin{bmatrix} \textit{ccons} & \\ \text{FIRST} & \textit{canonical-synsem} \\ \text{REST} & \textit{canonical-list} \end{bmatrix}$

The hierarchy for this new type closely models other list hierarchies.

(433)



One type that is missing from this hierarchy that is present for other types of lists is a type which would inherit from both *ccons* (nonempty canonical list) and *ocons* (a list of optional canonical elements). Introducing such a type causes issues in the system while not adding it so far did not introduce any — none of the grammars required it — and, deciding what to do about this missing type remains future work. The function of *clist* is discussed in §6.5.2.

This concludes the summary and description of what infrastructural changes I made to the Matrix core to accommodate constituent questions cross-linguistically. I presented these types separately here because describing them involves technical detail which would likely distract from the discussion of the linguistic analyses.

7.12 Chapter summary

This chapter described the main aspects of implementing the constituent questions library for the Grammar Matrix. Throughout the chapter, I made references to illustrative analyses presented in Chapter 6, including to specific types used in those analyses. Here, I focused on how such analyses can be obtained through the Grammar Matrix system. The input to the system is the specification which is elicited via the web questionnaire. The output are customized grammars (such as the ones presented as illustrative in Chapter 6); in this chapter, I described the customization logic which chooses which types relevant to constituent questions to add to the grammar and which constraints to add to those types, depending on the particular language specification. The next chapter describes testing and evaluation of this Matrix library.

Chapter 8

TESTING, EVALUATION, AND ERROR ANALYSIS

In this chapter, I present the details of testing the analyses and the customization system presented in Chapters 6–7. The methodology of test-driven development and evaluation of new libraries on held-out language families is described in Chapter 5; here, I will focus on the specifics pertaining to each language I looked at. All pseudolanguage grammars have perfect coverage and zero overgeneration over their respective test suites, and I do not dedicate much space to them here (but see §8.2). The first half of the chapter (§8.3) is dedicated to the illustrative languages' test suites and the newly updated system's performance on those test suites given those specifications. I refer to the grammars for illustrative languages as *development grammars*, because they were informing my analyses and design. In the second half of the chapter, I present the evaluation of the new library on five held-out languages (which furthermore are from different language families than each other and the illustrative languages) (§8.5). I provide error analysis associated with both illustrative and held-out languages. All specifications and test suites can be downloaded along with the Grammar Matrix version associated with this dissertation.[1]

8.1 Notes on evaluation metrics

The evaluation metrics used here are *coverage*, *overgeneration*, and *average ambiguity*. *Coverage* is the percentage of grammatical sentences which were parsed by the grammar. *Overgeneration* is the percentage of ungrammatical sentences included in the test suite which were parsed by the grammar. *Average ambiguity* is the average number of trees (readings) assigned to sentences by the grammar. Ideal coverage is 100%; ideal overgeneration is 0. There is no ideal number for ambiguity, as ambiguity can be meaningful (a sentence can indeed have more than one reading),

[1] `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`

although very high ambiguity is hardly ever justified, especially for small grammar fragments. For small test suites, the percentages are less indicative on their own, and in such cases I indicate the exact number of items.

All pseudolanguage grammars have ideal coverage and overgeneration over the respective test suites, and the ones that feature adverbs have some spurious ambiguity associated with underspecified modifier attachment (unrelated to the analysis of constituent questions). All of the illustrative grammars included in this study except for the Russian grammar have 100% coverage; Japanese and English also have 0 overgeneration. All grammars that include adverbs have the same type of ambiguity due to underspecified adverb attachment. The test suite for Russian is much larger than the others, and includes more types of sentences, compared to the other test suites. For example, the very small Chukchi test suite does not even have any ungrammatical examples in it (it was not clear to me how to construct them; that test suite only intends to test for a few basic constructions with interrogative verbs, mainly that the correct semantics is obtained from the lexical entry). But the larger and the more varied the test suite, the less coverage and the more overgeneration a grammar fragment will have over it — both because it is a fragment and because I do not claim that the analyses are perfect at this stage (see also §9.4 for discussion).

8.2 Pseudolanguages

Since pseudolanguages exist only as combinations of choices that are available through the web questionnaire along with the constructed test suites, it made sense to summarize how many pseudolanguages I used and what kind, in the section in which I describe the new web questionnaire page. Please refer to Tables 7.5, 7.9, 7.11 for the details. All these grammars have perfect coverage and no overgeneration, as mentioned above. As for ambiguity, I discuss the same kind of ambiguity that is present in pseudolanguage grammars in §8.3.2 below.

8.3 Illustrative languages

I used five illustrative languages. In terms of ways of forming constituent questions, they represent: fronting, single obligatory (English [eng]) and multiple optional (Russian [rus]); *in situ* questions with optional particles (Japanese [jpn]); morphological marking of questions (Yukaghir [yux]), and interrogative verbs (Chukchi [ckt]). Table 8.1 presents the illustrative test suites and the system results on these test suites.[2] The third column shows the number of grammatical

Language	Family	Gram./ungram.	Cov%	Overgen%	Avg. ambig	Phenomena
Russian	Indo-European	186/87	78.5	6.9	1.79	Optional multiple fronting, second position particles, case, free word order, coordination embedded clauses
English	Indo-European	27/23	100	0	1.11	Single obligatory fronting, subject-auxiliary inversion embedded clauses
Japanese	Japonic	7/3	100	0	1.14	*In situ*, optional particles embedded clauses
Yukaghir	Yukaghiric	10/14	100	7.1	1.1	Morphological marking, focus case
Chukchi	Chukotko-Kamchatkan	6/0	100	n/a	1.33	Interrogative verbs

Table 8.1: Illustrative languages test suites

and ungrammatical items in each test suite; then coverage (the percentage of grammatical items parsed) and overgeneration (the percentage of ungrammatical items parsed) is given, and then average ambiguity (the average number of tree structures assigned by the grammar). Because of the size of the test suite, the discussion of the Russian grammar provides me with the bulk of material for this part of the chapter. But for each illustrative and evaluation language, I give details on the test suite, explain some decisions that I made for the specification where there was anything non-straightforward, and then categorize the items which the grammar obtained with the current system gets wrong (*error analysis*). I start with English because I expect English examples to be the most accessible to most readers, and so starting with English should make the remaining discussion clearer.

[2]Table legend. *Gram./ungram.:* The number of grammatical and ungrammatical items in the test suite; *cov%:* The percentage of correctly parsed grammatical sentences; *overgen%:* The percentage of admitted ungrammatical sentences; *avg. ambig.:* Average number of trees per sentence (ambiguity can be meaningful or spurious). See also §8.1 for details on what the numbers represent.

8.3.1 English development grammar

I used English as a development grammar primarily to implement and test single obligatory fronting, starting from the analysis as in the ERG and adapting it to the cross-linguistic needs of the Grammar Matrix. I also used English to develop and test an analysis of subject-auxiliary inversion, however that remains work in progress, and while the test suite does contain examples of subject-auxiliary inversion, no analysis of it was presented in Chapter 6. There is not much to say in terms of error analysis for the English grammar and test suite; the coverage and the over-generation are perfect, and there are no ambiguity issues which would be specific to the analysis of English. I use the space dedicated to the English test suite to explain what to expect from the following sections and how to interpret test suite summaries.

Test suite

The contents of the test suite are presented in Table 8.2. The left column contains an informal description of the type of sentence, followed by an illustrative example. The right three columns contain the number of such examples in the test suite, including ungrammatical ones.

Table 8.2: English development test suite

Phenomenon	**Gram.**	**Ungram.**	**Total**
Simple propositions *The cats sleep/The cats chase the dogs*	2	0	2
Polar question *Do cats sleep?/Do you think the cats sleep?*	3	0	3
Question about subj. of intransitive matrix clause *Who sleeps?/*Sleep who?*	1	1	2
Ques. about subj. of transitive matrix clause *Who chases the dogs?/Who does chase the dogs?*	1	1	2

Continued on next page

Table 8.2 – continued from previous page

Phenomenon	Gram.	Ungram.	Total
Ques. about object of tran. matrix clause *What do the dogs chase?/*What the dogs chase?*	1	1	2
Ques. about adjunct of intran. matrix clause *Where do the dogs sleep?/*Where the dogs sleep?*	1	1	2
Ques. about adj. of tran. matrix clause *Where do the dogs chase the cats?* *The dogs chase the cats where?*	1	2	3
Ques. about subj. and obj. of tran. matrix clause *Who chases what?/*Who what chases?*	1	3	4
Ques. about argument or adj. of tran. matrix clause *Who chases what where?/*Where who what chases?*	1	1	2
which subj. of intran/tran. clause *Which cat sleeps?/*Which sleeps cat?*	2	1	3
which obj. of intran. clause *Which cats do the dogs chase?/*Which cats dogs chase?*	1	2	3
which adj. of intran. clause *Which house do the cats sleep in?* **Which do the cats sleep in house*	2	2	4
Embedded proposition *I think that the cats sleep.*	1	0	1
Embed. ques. about subj. *I wonder who sleeps?/I wonder who does sleep?*	1	1	2
Embed. ques. about obj. *I wonder what the dogs chase?/I wonder, what do the dogs chase?*	1	1	2
Fronted ques. about subj. of embed. clause, *think* vs. *wonder*	1	3	4

Continued on next page

Table 8.2 – continued from previous page

Phenomenon	Gram.	Ungram.	Total
*Who do you think sleeps?/*Who do you wonder sleeps?*			
Front. ques. about obj. of tran. embed. clause. *What do you wonder whether the cats chase?/* **What do you wonder that the cats chase?*	2	1	3
Front. ques. about adj. of intran. embed. clause *Which house do you think the cats sleep in?* *In which house do you think the cats sleep?* **Which do you think the cats sleep in house?*	4	2	6

Table 8.2 demonstrates that my test suites are not exhaustive. For example, I only include a single example of an embedded proposition in English, not testing for all the ungrammatical word orders, and there are certainly more ungrammatical combinations of words that could be constructed in other cases as well. Simply put, since I did not use any robust methodology to construct the illustrative test suites, it is not possible to say how exactly it relates to constituent questions in English (see also §9.4 for discussion).[3] The situation is different with evaluation (held-out) languages; there, the compilation of the test suites was fully systematic with respect to the reference grammars (§8.5). In contrast, the main purpose of the illustrative test suites is to assist in the development of the analyses. There will however be both grammatical and ungrammatical constructions which are relevant to this library which remain untested simply because the test suite is imperfect and incomplete. Still, the test suites show exactly the extent to which the grammar is guaranteed to cover the phenomenon; it may or may not cover more than that.

[3]Compiling a test suite using a corpus would be an interesting undertaking but it needs to be a separate study because it requires a different level of complexity of the lexicon and the morphological component of the grammar. The present test suites' purpose is to test a grammar fragment intended to cover a particular range of syntactic patterns. For this reason, corpus examples would need to be modified to a minimal vocabulary. Still, using a corpus would be an improvement overall because then there would be some information on the frequency of examples.

Language	Family	Gram./ungram.	cov%	overgen%	avg. ambig	Phenomena
English	Indo-European	27/23	100	0	1.11	Single obligatory fronting, subject-auxiliary inversion embedded clauses

Table 8.3: English coverage and overgeneration

Coverage and overgeneration summary

Ambiguity: Adjunct attachment

The ambiguity in the English development grammar comes from the underspecified adjunct attachment. In short, adjuncts can modify a V, a VP, or an S which at least sometimes will be spurious, and my library does not attempt to solve this problem. I provide examples of this in §8.3.4 where I describe in detail the ambiguity issues that I have in the Russian grammar.

8.3.2 Russian development grammar

Russian ended up being my biggest development grammar, both because I was building the test suite using my native knowledge of Russian and because Russian features free word order and what appears to be optional multiple fronting, giving rise to lots of possible grammatical sentences which I wanted to test. This test suite also contains a larger number of interacting phenomena, and I did not expect to have a 100% coverage or a 0% overgeneration on such a large test suite within the scope of this dissertation. In this sense, the point of the test suite is also to guide future work.

Test suite

I compiled the Russian development test suite (Table 8.4) as follows. I included at least one example of every syntactic pattern I could think of (in the months which I spent working on this grammar) related to constituent questions. Additionally, I included propositions illustrating basic syntactic patterns (e.g. free word order). The test suite presents a fairly wide variety of patterns in this sense, although I did not systematically use any corpus.

Phenomenon	Grammatical	Ungrammatical	Total
All	187	86	273
Proposition	8	0	8
Proposition with adjunct	2	3	5
Question about subject of matrix clause	14	8	22
Question about object of matrix clause	15	6	21
Question about adjunct of matrix clause	20	12	32
Multiple questions in matrix clause	14	5	19
Embedded proposition	13	5	18
Embedded question	20	12	32
Multiple embedded questions	5	1	6
Long-distance question	18	4	22
Multiple long-distance questions	30	5	35
Questions to both matrix and embedded clause	7	9	16
Second position clitic (polar)	8	9	17
Negation	7	0	7
Coordination	6	7	13

Table 8.4: Russian development test suite. Each example is counted only once for the purposes of the table.

There is one aspect of the test suite, already explained with respect to English above, which is important enough to reiterate and to keep in mind when interpreting the evaluation numbers. The number of similar items (e.g. sentences illustrating the same pattern but with animate vs. inanimate nouns) is not representative of the frequency with which these patterns occur in the language. The test suite was not compiled using any corpus statistics. That it contains a large number of complex clauses for example is due mainly to the combinatorics; there are different kinds of clause-embedding verbs, and in addition to that there are different types of embedded clauses, and furthermore there is the additional dimension of which question phrases are fronted. This is why there are many sentences of this kind in the test suite, not because they are common in Russian.

Test suite decisions: V-initial word order

This and the following section address some decisions regarding my grammaticality judgments for some of the sentences in the test suite. For example, in Russian, V-initial questions like (434) are usually judged ungrammatical while V-initial order is clearly grammatical in other Russian constructions (435).[4]

(434) ??Идет кто?
Idet kto?
walk.3SG.PRES who.NOM
Intended: 'Who is coming?'

(435) Идет Иван
Idet Ivan
walk.3SG.PRES Ivan.NOM
'Ivan is coming.'

Note that (436), which is very similar to (434), is grammatical as a constituent question, and so is (437).[5]

(436) А (это) идет кто?
A (eto) idet kto?
And (this) walk.3SG.PRES who.NOM
'And who is that that's coming?' [rus]

[4]Though Dyakonova (2004) suggests that V-initial syntax is special to certain registers or genres, e.g. in folktale narration. Without having conducted a study, I believe that V-initial syntax is certainly characteristic of folktales (and is not characteristic of e.g. newspapers), but I am not convinced that it is not found elsewhere, especially if everyday spoken language is considered, as opposed to written corpora.

[5]There is a very famous example of such structure in Russian classical literature, namely (i). Even though it is poetry, I do not think this is an example of a special poetic syntax. I cite it here for those who are familiar with the work; they will be able to very easily imagine the type of context in which such examples are in fact common.

(i) А судьи кто?
A sudji kto?
And judge.PL.NOM who.NOM
'And who are the judges?' [rus] (Griboyedov, 1974 (1823, p. 69)

(437) Идет какой человек?
Idet kakoi chelovek?
walk.3SG.PRES which.NOM person.NOM
'Which person is coming?'

In (436), a combination of discourse markers seems necessary to make it grammatical; (437) contains an example of what Pesetsky (1987) calls *D-linked wh*-phrases (*какой человек*), noticing that question referents quantified by determiners like *which* seem to have fewer restrictions in where they may appear in the clause.

Because the discourse difference between (434) and (436) as well as (437) is not currently possible to model in the Grammar Matrix, I do not aim to model it. Furthermore, because I am not convinced that (434) is ungrammatical, I include all such sentences, including (434) as grammatical in the test suite (although I mark the ones like (434) them with question marks, which has no effect on how the system computes coverage and overgeneration but is useful for manual review).

Test suite decisions: Complex sentences

In terms of sentences containing embedded clauses, I constructed the Russian test suite using primarily three clause-embedding verbs: *думать* ('think'), *знать* ('know'), and *спрашивать* ('ask'). The verb *думать* ('think') embeds only propositions (438)-(440).[6]

(438) Я думаю, что Иван приехал.
Ya dumayu chto Ivan priehal.
1SG think.1SG that Ivan.NOM arrive.PAST.MASC
'I think that Ivan arrived./Do I think that Ivan arrived?' [rus]

(439) *Я думаю, кто приехал
*Ya dumayu kto priehal.
1SG think.1SG who.NOM arrive.PAST.MASC
Sounds like: 'I think who arrived' [rus]

[6] In the examples, I use the "sounds like" comment instead of "intended", to indicate that it is hard to say what the intended reading could be but that the example seems similar to the suggested English string in what sort of grammaticality judgment it is likely to invoke.

(440) ?Я думаю, что КТО приехал?
?Ya dumayu chto KTO priehal.
1SG think.1SG that who.NOM arrive.PAST.MASC
Sounds like: 'I think that who arrived?' [rus]

Знать ('know') can embed both propositions and questions (441)-(443).

(441) Я знаю, что Иван приехал.
Ya znayu chto Ivan priehal.
1SG know.1SG that Ivan.NOM arrive.PAST.MASC
'I know that Ivan arrived./Do I know that Ivan arrived' [rus]

(442) Я знаю, кто приехал./?
Ya znayu kto priehal.
1SG know.1SG who.NOM arrive.PAST.MASC
'I know who arrived./Do I know who arrived?' [rus]

(443) ?Я знаю, что КТО приехал?
?Ya znayu chto kto priehal.
1SG know.1SG that who.NOM arrive.PAST.MASC
Sounds like 'I know that who arrived?' [rus]

Finally, *спрашивать* ('ask') can only embed questions (444)-(446).

(444) *Я спрашиваю, что Иван приехал.
*Ya sprashivayu chto Ivan priehal.
1SG ask.1SG that Ivan.NOM arrive.PAST.MASC
Sounds like: 'I ask that Ivan arrived.' [rus]

(445) Я спрашиваю, кто приехал./?
Ya sprashivayu kto priehal./?
1SG ask.1SG who.NOM arrive.PAST.MASC
'I ask who arrived./Did I ask who arrived?' [rus]

(446) *Я спрашиваю, что КТО приехал?
*Ya sprashivayu chto kto priehal.
1SG ask.1SG that who.NOM arrive.PAST.MASC
Sounds like: 'I ask who that arrived?' [rus]

The complementizer *что* ('that') is optional in Russian, however its presence makes the difference between propositional and interrogative embedded clauses clearer, especially in fronting contexts. I include examples with (440) and without (439) the complementizer in all contexts, but my grammaticality judgments are not all uniform across such examples and represent my intuitions rather than an established opinion on such examples in the field of syntax. Generally, this part of the test suite represents an area of Russian syntax the study of which would benefit from additional corpus and/or speaker studies, because the judgments are not that easy to establish.

Consider (439) and (440). (439) is ungrammatical in the sense that it does not have a reading where the thinking is done about a question. It is possible to construct this kind of sentence with a reprise sort of reading, or a parenthetical *think*. In Russian, such readings are more salient with discourse markers. It is possible and common to add as many as three discourse markers (*ну, а, -то*) to such a sentence, to emphasize the type of reading (447).

(447) **Ну**, **а** ты думаешь, КТО приехал**-то**?
Nu, a ty dumayesh, KTO priehal-to?
Well and 2SG think.2SG who.NOM arrive.PAST.MASC-TOP
'Well, and who is it, you think, that arrived?' [rus]

(440) may sound strange out of context but is routinely produced and sounds better than (439), possibly because of the *chto* ('that') complementizer which is associated with propositions.

The situation with extraction from clauses embedded by *думает* ('think'), *знает* ('know'), and *спрашивает* ('ask') is even less clear. Long-distance *wh*-questions in Russian may be infrequent, with some literature contending that they are not possible (Stepanov and Stateva, 2006). However I have observed myself producing such constructions,[7] and have have found examples on the web, such as (448) below, where the future tense on the embedded verb *будет* ('be') clearly indicates that *ты думаешь* ('you think') is not used parenthetically here:

(448) И кто ты думаешь будет третьим?
I kto ty dumaesh budet tretjim?
And who.NOM 2SG.NOM think.2SG.PRES be.3SG.FUT third.INSTR
'And who do you think will be the third [in the group]?' [rus] (Galikhin, 2017, loc.246)

[7] I myself produced such a construction on May 13 2020, in a conversation with my friend. I was telling my friend about my mother who keeps suggesting to me, somewhat repetitively, that, once I finish my dissertation, I will have an easier time finding a job. Reacting to this, I said to my friend, in Russian: "What does she think that I do every day?" ("Чем, она думает, что я занимаюсь каждый день?"). My WhatsApp archives contain other examples of what clearly is naturally produced long-distance *wh*-questions in Russian.

I include examples like (449)–(454) as grammatical in the test suite, marking them by ? to indicate that I am not fully sure about how acceptable they are.[8]

(449)

Кто,	я	спрашиваю,	приехал?
Kto,	ya	sprashivayu,	priehal?
who.NOM	1SG	ask.PRES.1SG	arrive.PAST

'I ask who arrived.'

(450)

?Кто,	он	спрашивет,	приехал?
?Kto,	on	sprashivaet,	priehal?
who.NOM	3SG	ask.PRES.3SG	arrive.PAST

'He asks who arrived.'

(451)

?Кто,	ты	знаешь,	приехал?
Kto,	ty	znaesh,	priehal?
who.NOM	2SG	know.PRES.2SG	arrive.PAST

'Who do you know arrived?' [rus]

(452)

А	кто,	ты	наверняка	знаешь,	что	приехал?
A	kto,	ty	navernyaka	znaesh,	chto	priehal?
and	who.NOM	2SG	(for.sure)	know.PRES.2SG	(that)	arrive.PAST

'And who do you know for sure that they arrived?' [rus]

(453)

Кто,	ты	думаешь,	приехал?
Kto,	ty	dumaesh,	priehal?
who.NOM	2SG	think.PRES.2SG	arrive.PAST

'Who do you think arrived?' [rus]

(454)

?Кто,	ты	думаешь,	что	приехал?
?Kto,	ty	dumaesh,	chto	priehal?
who.NOM	2SG	think.PRES.2SG	that	arrive.PAST

'Who do you think that (they) arrived?' [rus]

Constructions like (449), which have first person subjects in the main clause, seem easier to accept than (450), which have third person subjects,[9] which indicates that in this case, it may be a rhetorical (parenthetical) construction and so a special mechanism may be involved. Whether

[8]Note that the commas here do not necessarily indicate parenthetical reading. They are obligatory in both parenthetical and nonparenthetical complex sentences in Russian writing.

[9]They are also more common in the Russian National Corpus (Grishina, 2006). I found 9 instances of a (449)-type construction and none of (450).

or not such sentences are examples of long-distance questions, I included them in the test suite as grammatical examples.

8.3.3 *Numeric test results and error analysis*

Table 8.5 shows the Russian grammar's coverage, overgeneration, and ambiguity with respect to the test suite which was summarized in Table 8.4 and some aspects of which were described above.

Coverage (%)	Overgeneration (%)	Ambiguity (readings per sentence)
147/187 (78.5)	6/86 (6.9)	1.79

Table 8.5: Russian development grammar statistics

The grammar cannot parse 40 grammatical sentences; parses 6 ungrammatical sentences;[10] and on average, provides 1.79 readings per parsed sentence. Some of this ambiguity is meaningful and some spurious. In general, there can be two different kinds of spurious ambiguity: two syntactic trees with the same semantic representation (in which case one of the trees is unwanted) and different semantic representations, one of which is unwanted. Below I discuss examples of all these issues, starting with overgeneration, then talking about the missing coverage, and finally summarizing the situation with ambiguity. Russian is the only test suite for which I go into a fairly high level of detail, as other test suites are smaller and do not give me the same amount of material (see also discussion in §9.4).

Overgeneration

The 6 ungrammatical sentences that the grammar parses can be put into three categories. I comment on each of the categories below.

[10] Recall that this does not include sentences marked with ? in the test suite.

Overgeneration type	# test items
Coordination and optional arguments	1
wh-adverb modifying matrix verb	2
Multiple *wh*-adjuncts in the front	3

Table 8.6: Russian grammar overgeneration summary

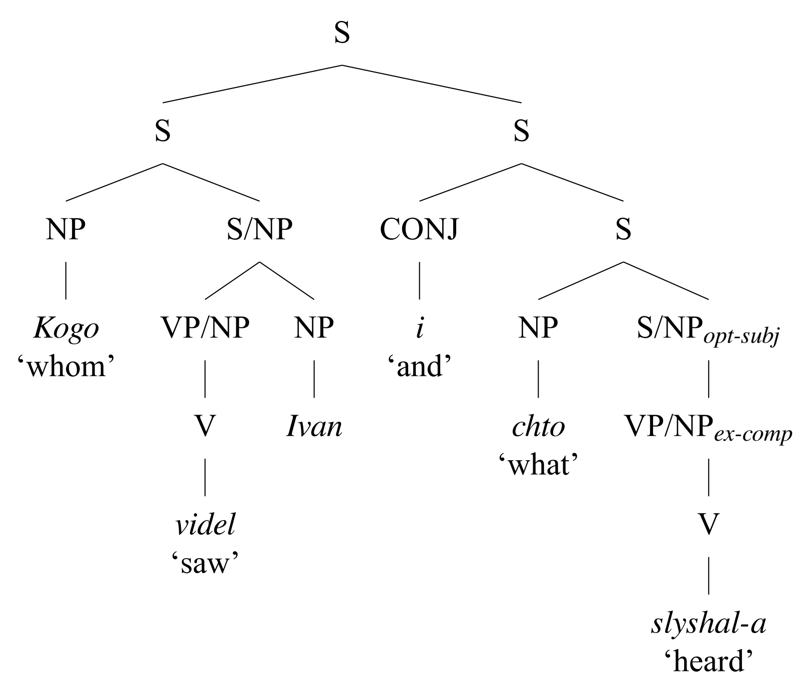
Coordination and optional arguments The first type of error that the Russian grammar is admitting is illustrated by (455).

(455)	*Кого	видел	Иван	и	что	слышал-а?
	*Kogo	videl	Ivan	i	chto	slyshal-a?
	who.ACC	see.PAST.3SG.MASC	Ivan.NOM	AND	what.ACC	hear.PAST.3SG-FEM

Sounds like: 'Who did Ivan see and what [did someone else] hear?'

The grammar assigns a reading to the ungrammatical (455), namely (456). In (456), the two clauses are coordinated, one with a masculine subject and one with a feminine subject. The subject in the first clause in overt (*Ivan*); the subject in the second clause is dropped.

(456)



Since the verb in the past tense generally agrees with its subject in gender, the difference in gender between the overt and the dropped subject is obvious, and Russian does not seem to allow S-coordination with argument drop, regardless of the word order (457)–(459).

(457) Иван$_i$ идет$_i$ и поет$_i$
Ivan$_i$ idet$_i$ i pojot$_i$
Ivan$_i$.NOM walk.3SG.MASC$_i$.PRES AND sing.3SG.MASC$_i$.PRES
'Ivan is walking and singing.' [rus]

(458) *Иван$_i$ идет$_i$ и поет$_j$
*Ivan$_i$ idet$_i$ i pojot$_j$
Ivan$_i$.NOM walk.3SG.MASC$_j$.PRES AND sing.3SG.MASC$_i$.PRES
Intended: 'Ivan is walking and somebody else is singing.' [rus]

(459) *Я иду и поет
*Ya idu i pojot
1SG walk.1SG.PRES and sing3SG.PRES.MASC
Intended: 'I am walking and somebody is singing.' [rus]

If the subject of one of the conjuncts is not overt and the subject of the other conjunct is, they better refer to the same entity (460).

(460) Кого видел Иван и что слышал?
Kogo videl Ivan i chto slyshal?
who.ACC see.PAST.3SG.MASC Ivan.NOM AND what.ACC hear.PAST.3SG
'Who did Ivan$_i$ see and what did he$_i$ hear?' [rus]

My analysis of coordination should be improved with respect to the above examples as well as the issue with coordinating a question phrase with a non-question phrase, mentioned in §7.10.1.[11]

Question adverb modifying the matrix verb is another overgeneration issue with the grammar. Consider sentence (461).[12]

[11] The issue with coordinating a question with a non-question phrase was pointed out to me by Emily M. Bender after I finalized the Russian test suite, and so the version of the Russian test suite associated with the dissertation does not contain examples like (i). The test suite will be updated for future projects.

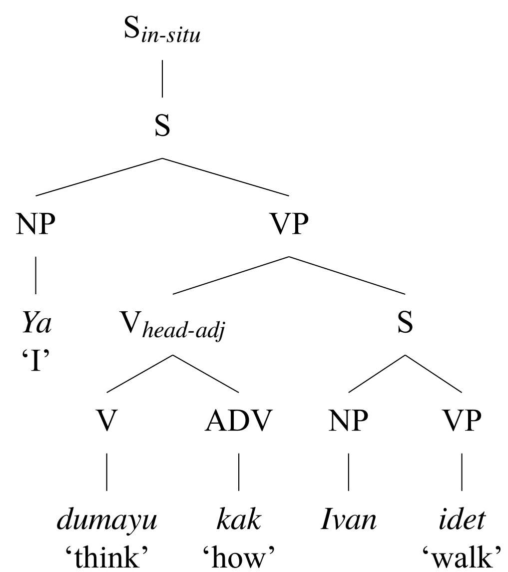
(i) *Студента и кого Иван видит?
*Studenta i kogo Ivan vidit?
student.ACC and WHO.ACC Ivan.NOM see.3SG.PRES
Intended: 'Whom does Ivan see in addition to the student?' [rus]

[12] Punctuation is ignored by all the grammars described here.

(461) *Я думаю, как Иван идет?
*Ya dumayu kak Ivan idet
1SG think.1SG HOW Ivan.NOM walk.3SG
Sounds like: 'I think how Ivan is walking?'

The reading the grammar assigns to (461) is given in (462). The *wh*-adverb there modifies the matrix verb, in this case *think*.

(462)



Readings like (462) largely appear nonsensical. It is hard to imagine a *wh*-adverb modifying the matrix clause verb in this way, although it is entirely possible to have another adverb there, such as one meaning *every day*:

(463) Я думаю каждый день, Иван идет
Ya dumayu kazhdyi den Ivan idet
1SG think.1SG every.day Ivan.NOM walk.3SG
'Every day I think Ivan is coming (lit.: walking)'

The situation with the *wh*-adverb taking this position is due to the underspecified attachment of adverbs in my analysis. On the other hand, it seems possible to ameliorate (461) by adding a complementizer and obtaining perhaps a kind of echo question reading (464):

(464) ?Я думаю КАК, что Иван идет?
?Ya dumayu KAK chto Ivan idet
1SG think.1SG HOW that Ivan.NOM walk.3SG
'And HOW is it that I think Ivan is coming?'

Echo questions however are not constituent questions and I do not consider such parses correct. Extending the support for adverbs in the Matrix to specifying the possible adjunct position with respect to the modificand (using the POSTHEAD feature (Flickinger, 2000, 2011)) will likely solve this problem.

More than one question adjunct at the front of the clause In general, multiple *wh*-adjuncts in the front of the clause seem to be ungrammatical in Russian (465) unless they are coordinated (466).

(465) *Где когда мы купили эти книги?
*Gde kogda my kupili eti knigi?
where when 1PL.NOM buy.PAST.1PL these book.PL.ACC
Sounds like: 'Where when did we buy these books?'

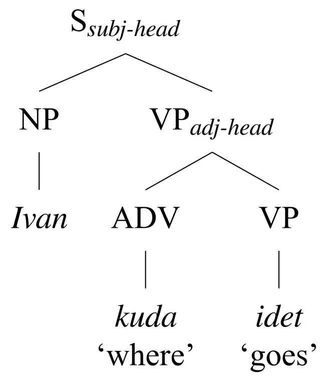
(466) Где и когда мы купили эти книги?
Gde i kogda my kupili eti knigi?
where and when 1PL.NOM buy.PAST.1PL these book.PL.ACC
'Where and when did we buy these books?'

Under my analysis however, which allows *in situ* question words including question adjuncts, ruling (465) out is difficult without also ruling out the typical (467).

(467) Иван куда идет?
Ivan kuda idet?
Ivan.NOM where go.PRES.3SG
'Where is Ivan going?'

To see why, consider first the derivation (468) for the grammatical (467).

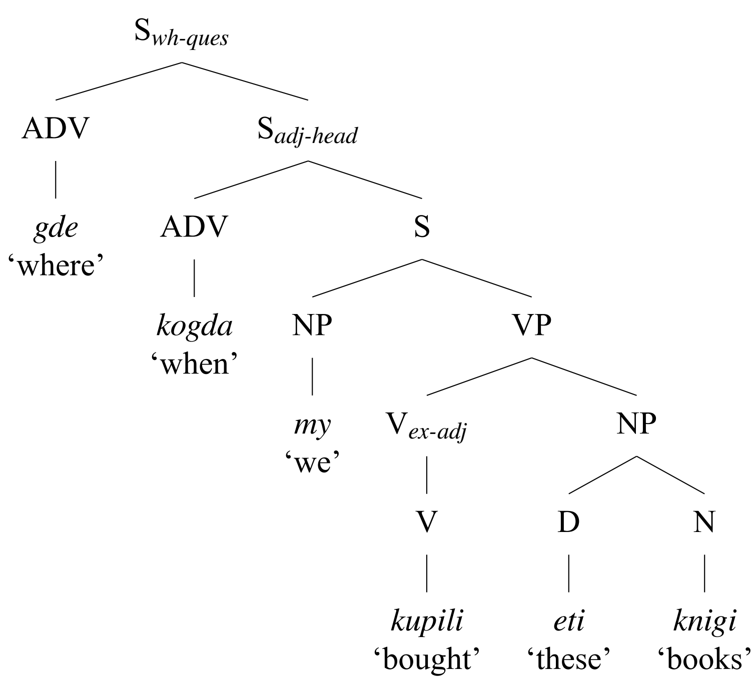
(468)



Note how, because, under my analysis, the top node in (468) is licensed by the subject-head rule, the VP node cannot be licensed via extraction and filler-gap (the filler-gap rule applications must be in the left periphery), and are licensed by the adjunct-head rule. This means, the adjunct-head rule allows *wh*-non-head daughters.

Consider now the derivation for (465) shown in (469).

(469)



Note that multiple adjunct extraction does not happen in (469); only one adjunct is ever extracted and the rest attach using ordinary adjunct-head. As shown above, in order for the grammatical (467) to be licensed under the same analysis, the adjunct-head rule must be able to take *wh*-non-head daughters, thus admitting (469). Assuming (465) is ungrammatical,[13] this problem calls for reanalysis of the *in situ* status of the question adjunct in (467) and of the concept of optional question phrase fronting as applied to Russian in this work (see also §9.2).

In summary, the Russian development grammar overgenerates with respect to multiple question adjuncts at the left periphery of the clause (although this is not due to the grammar actually performing multiple adjunct extraction); with respect to coordinated clauses which do not share a subject; and with respect to clauses where a question adjunct appears to modify the main verb post-positionally. The problem with coordination indicates an issue in the interaction of the analysis of argument optionality with coordination; it does not have anything to do with the analysis of constituent questions. The other two issues are a problem in the analysis of optional fronting (see also the discussion in §9.2).

Coverage

In Table 8.7, grammatical sentences for which the grammar does not assign a reading are categorized for the reason they are not parsing. Because this is a coverage issues table, all sentences included here are considered grammatical in the test suite, and all of them do not get any reading with the grammar. In other words, they represent the grammar's failure to capture the grammaticality of the patterns exemplified by such sentences. The third column indicates how many of the sentences, while included as grammatical in the test suite, I marked '?', meaning I was not fully sure of their grammaticality, particularly out of context. Note that while the total number of grammatical sentences which do not get any reading is 40, the total in column 2 does not add up to 40 because some examples are not admitted because of more than one issue, and such examples are counted more than once. Furthermore, these numbers do not correspond to the proportion of

[13] Recall from §6.5 that there are grammatical examples of multiple question adjuncts in the left periphery of the clause, e.g. (227).

each category in any corpus.

Phenomenon	tot.	of them, ‘?’	ex.
сколько (‘how many ... of X’) scrambling	2	0	(470)
в каком (‘in which ... X’) scrambling	5	0	(471)
Embedded *li*	8	0	(472b)
Focus particle modifying determiner	1	0	(473)
Coordination of different arguments	1	0	(474)
Coordination of argument and adjunct	2	0	(475)
Coordination of extracted and clause-final adjunct	1	0	(476)
Questions embedded by *что* (‘that’)	7	4	(652)
LD questions with *спрашивать* (‘ask’)	15	9	(653)
Clauses with *wh*-words embedded by *думать* (‘think’)	4	0	(654)

Table 8.7: Russian development grammar: Coverage issues

The first two rows in Table 8.7 are related to scrambling, which is a term for word order variation which is not specific to phenomena like *wh*-questions (Ross, 1967). In Russian, where the word order is generally quite free, the following sentences (470) and (471) are possible:

(470)	Иван	сколько	читает	книг?
	Ivan	skolko	chitaet	knig?
	Ivan.NOM	HOW.MANY	read.PRES.3SG	book.PL.PARTITIVE
	“How many books is it that Ivan is reading?” [rus]			

(471)	В какой	Иван	приехал	город?
	V kakoi	Ivan	priehal	gorod?
	IN which.SG.ACC	Ivan.NOM	arrive.PAST.3SG	town.SG.ACC
	‘In which town did Ivan arrive?” [rus]			

It is not immediately clear how to analyze (470) and (471) in the Grammar Matrix framework. One analysis would assume some kind of discontinuous noun phrases (*how many* + *books; which* + *town*), perhaps along the lines of what Bender (2010) suggested for Wambaya. The customization system does not support such an analysis for noun phrases at this time and introducing it is out of scope of this work. An alternative would be to analyze both sentences via extraction and filler-gap rules. Such an analysis is not readily available for (470) and (471) for separate reasons. In (470), the determiner *skolko* ('how many') cannot be analyzed as *in situ* because it had to be extracted from the NP *skolko knig*. However it cannot easily be considered extracted because it has a non-*w*h-word to its left, *Ivan*. In order to provide an extraction analysis for (470), *Ivan* needs to be considered extracted also, perhaps because of the information structure in the sentence. I did not fully explore the interaction of information structure and constituent questions in free word order languages because the information structure library (Song, 2014) does not provide a fully fledged analysis for free word orders. As for (471), an extraction analysis is not readily possible under the hypothesis that adpositions are heads in constituents like *v kakoi gorod*. This entire constituent serves as an adjunct modifying the main verb, *priehal*. But then only part of the adjunct should be extracted, somehow, leaving the noun *gorod* in place, while not allowing nouns to be modifiers of verbs. At the same time, the determiner would have to be extracted from the noun phrase which is the non-head in the constituent. The adposition then needs somehow to attach to the determiner, which is not a normal complement type for this adposition. In other words, (471) presents a challenge to the framework in general.

Eight more sentences with respect to which the grammar lacks coverage have to do with the second position clitic *li* and embedded clauses. I implemented the second position clitic following Emily M. Bender's analysis developed in the context of her grammar engineering class at University of Washington.[14] That analysis however only works for main clauses, as it relies on an edge feature (Miller, 1992) L-PERIPH as used by Song (2014). That edge feature as currently implemented has no awareness about clause boundaries; if a clitic is second position under this analysis, it can only appear in the second position relative to the whole string, as in (472a), and cannot appear in a second position relative to an embedded clause, as in (472b).

(472) a. Иван ли приехал?
Ivan li priehal?
Ivan.NOM Q arrive.PAST.3SG
"Is it indeed Ivan that arrived?" [rus]

[14] `http://courses.washington.edu/ling567/2017/lab6.html`

b. Я не знаю, Иван ли приехал
Ya ne znayu, Ivan li priehal
1SG.NOM NEG know.1SG.PRES Ivan.NOM Q arrive.PAST.3SG
"I don't know whether it is Ivan that arrived." [rus]

It seems like it should be possible to have the clause embedding context break the L-PERIPH transmission so as to fix this, although this means the L-PERIPH identity can no longer be constrained at the level of *basic-binary-phrase* (300). Rather, there would be a special head-complement rule for clause-embedding verbs, which is not an altogether unattractive analysis, given other special properties of clausal complements. But improving the analysis of second position clitics further was outside of the scope of this dissertation.[15]

Another particle-related issue accounts for yet another category of unanalyzed grammatical sentences in the Russian test suite. Specifically, *wh*-words in Russian can appear with the focus particle *же*:

(473) В какой же город Иван приехал?
V kakoj zhe gorod Ivan priehal?
IN which.SG.ACC town.SG.ACC Ivan.NOM arrive.PAST.3SG
"So which town is it that Ivan arrived to?" [rus]

Particles like this are generally available via the Grammar Matrix information structure library (Song, 2014) but with two limitations: (1) such particles will only attach to nouns and verbs (not determiners or adverbs); (2) such particles will not be second-position but will attach to a noun or a verb anywhere in the sentence. Improving the information structure library in this respect was outside the scope of this dissertation.

An important category of unsupported phenomena is coordinating extracted elements of different kinds, as in (474)–(475), and adjunct coordination illustrated in (476).

(474) Кто и кого видит?
Kto i kogo vidit?
who.NOM AND who.ACC see.3SG.PRES
"Who sees whom?" [rus]

[15] Recall that in the illustrative language for second position clitics, namely Russian, the clitics are not even used in constituent questions.

(475) Кто и в какой город приехал?
Kto i v kakoi gorod priehal?
who.NOM and in which.ACC town.ACC arrive.PAST
'Who arrived(, and) in which town?' [rus]

(476) Где Иван купил книгу и когда?
Gde Ivan kupil knigu i kogda?
where Ivan.NOM buy.past.masc book.ACC and when
'Where did Ivan buy the book and when?' [rus]

The coordination library (Drellishak and Bender, 2005) currently assumes that all coordinands must have the same relationship to the external head, and developing it so as to allow sentences like (474) was outside of scope of this work.[16] Examples like (476) have two things of the same kind coordinated but the word order is such that the coordination library also does not support them.[17]

The last three rows in Table 8.7 have to do with complex sentences. Chapter 6 presented a very limited analysis of the contrast between proposition-embedding and question-embedding verbs (§6.2). In actuality, the analysis includes an experimental usage of the WH feature intended to model some of the contrast between verbs like *think* and *ask* and in particular, to rule out sentences like the English **I ask Kim arrived* or **I think who arrived.* I did not present that aspect of the analysis in Chapter 6, because it is work in progress. However, the grammars which cover clausal complementation, including the Russian grammar, do contain this experimental analysis, and I discuss the results in detail in Appendix A.

[16]Chaves and Paperno (2007) offer an analysis of sentences similar to (474) as *hybrid* coordination, and their analysis could be implemented in DELPH-IN HPSG but would require postulating additional machinery. Another possibility is *pseudocoordination*; note that (474) is in fact difficult to translate with an *and* in English (while (475) and (476) pose no such translation problem). One might suggest that it is not coordination and that the Russian *i* ('and') there is for some other reason. Przepiórkowski (Patejuk and Przepiórkowski, 2019) argues against such an analysis.

[17]It does support (i) though; thanks to adverb coordination rules which I added to the library, modeling them off of other coordination rules.

(i) Где и когда Иван купил книгу?
Gde i kogda Ivan kupil knigu?
where and when Ivan.NOM buy.past.masc book.ACC
'Where did Ivan buy the book and when?' [rus]

In summary, the grammar customized for Russian using the updated Grammar Matrix system lacks coverage of scrambling, coordination of elements of different types, and a range of complex sentences. The analysis of complex sentences can be continued (see Appendix A), especially combined with a speaker study which would target the acceptability of long-distance questions in Russian. An analysis of scrambling will probably be related to further work on information structure (see also §9.2). A study of how QUE is handled in different coordinated constructions is needed to address the coordination issues.

8.3.4 *Error Analysis: Ambiguity*

The Russian grammar assigns 1.79 trees per sentence on average, and there are 77 sentences which have more than one reading. Some of this ambiguity is clearly meaningful, some is spurious, and for some, the situation is less clear. Spurious ambiguity comes in two types: (i) more than one syntactic tree leads to the same semantic representation, in which case one of the trees is spurious as is (though it can be the case that the analysis can be extended so as to ultimately contribute the valid differences in the semantics); (ii) or some of the MRS themselves may be invalid, meaning the semantic representation itself is wrong and unwanted. The most ambiguous sentence (477) has six readings of which two are definitely spurious.

(477)	Кто	спрашивает,	какие	книги	мы	где	видели?
	Kto	sprashivaet,	kakie	knigi	my	gde	videli?
	who.NOM	ask.PRES.3SG	which.PL.ACC	book.PL.ACC	1PL.NOM	where	see.PAST.1PL

‘Who is asking which books we say where?’ [rus]

I divided the examples of ambiguity into eight types, of which some illustrate ambiguity which is definitely meaningful; some illustrate ambiguity which would be meaningful if the analyses were extended to reflect the valid differences between semantic representations; and some illustrate ambiguity which is definitely spurious. These types of examples are presented in Table 8.8 along with the number of cases they are responsible for. As in Table 8.7, the total in column 3 does not add up to 77 because several issues may be present in the same sentence's analysis by the grammar.

Type of ambiguity	ex.	# items	Spurious?
Adjunct attachment to both nouns and verbs	(478)	6	No
Determiner may belong to either of two NPs	(480)	2	No
Noun syncretism in the lexicon	(481)	1	No
Adjuncts modifying *in situ* questions	(487)	9	Yes
S and VP coordination	(490)	1	Yes
Adjunct attachment to S, VP, and V	(485)	17	Yes
Embedded *in situ* question	(493a)	35	Likely Yes
Wh-adverb modifying matrix instead of embedded verb	(497)	9	Likely Yes
Determiner in focus	(495a)	11	Likely Not

Table 8.8: Summary of ambiguity in the Russian development grammar

Meaningful ambiguity

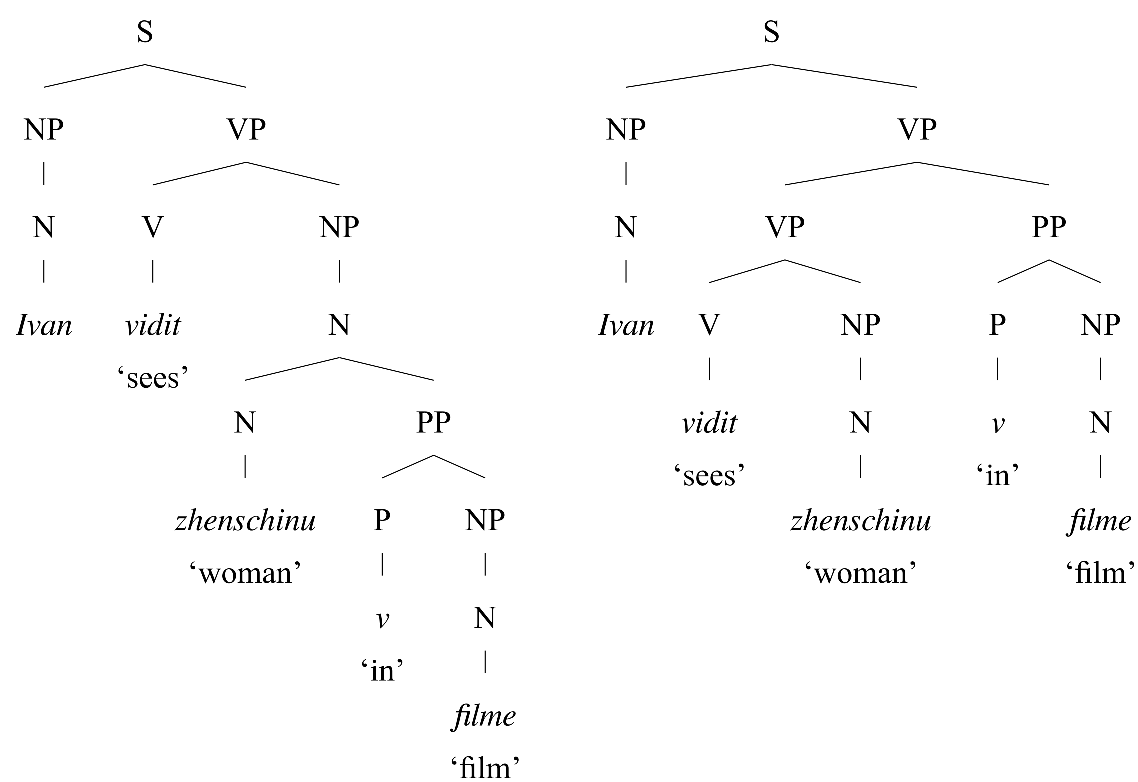
Meaningful ambiguity has to do with: (a) adjuncts modifying both nouns and verbs; (b) determiners which may belong to one of two NPs present in the sentence; and (c) syncretism of noun forms in the lexicon. In Table 8.8, these examples are marked 'No' in the rightmost column.

Adjunct attachment Some adjuncts, specifically PPs, can modify both verbs and nouns. So, for (478), my grammar assigns two meaningful trees, (479a)-(479b).

(478) Иван видит женщину в фильме
Ivan vidit zhenschinu v filme
Ivan.NOM see.3SG woman.ACC IN film.PREP
"Ivan sees the woman in the film." [rus]

(479)

a. b.



Determiner belonging to either NP in the sentence If there is more than one NP in the sentence and the determiner is extracted, it could belong to either NP, giving rise to valid ambiguity.

(480)

Какой	сон	видит	студент?
Kakoi	son	vidit	student?
which.NOM/ACC	dream.ACC	see.3SG	student.NOM

'Which dream does the student see?

Which student sees the dream?' (The second reading is possible with special emphasis on 'student' and deemphasis of 'dream')

Noun syncretism A type of ambiguity which has nothing to do with the analysis of constituent questions or extraction arises when there are syncretic forms which can be used in the object position. For example, in (481), the work *knigi* (book) could be SG.PARTITIVE and PL.ACC, both of which match the verb's requirements for its complement. The difference will be present in the semantic representation of the sentence, in the PNG (person, number, gender) properties of the variable referring to the 'book' relation.

(481) Книги мы где не видели?
Knigi my gde ne videli?
book.SG.PART/PL.ACC 1PL where NEG see.PAST.1PL
'Where did we not see books/part of a book?'

Meaningfully ambiguous examples account for about 10% of all examples which get more than one reading. Spurious ambiguity, reviewed below, accounts for the rest, although, as explained below, some of it represents lack of analysis rather than a wrong analysis.

Spurious ambiguity

In this section, I present examples of ambiguity for which there is little doubt that the sentence simply should not have the additional reading. This is in contrast to "potentially meaningful" analyses (next subsection) which are spurious as they are now but could be considered work in progress towards some meaningful analyses. In the Russian test suites, spurious ambiguity has to do with (i) clauses formed by the question-forming phrases such as the *in-situ-phrase* or the *filler-gap-phrase* which are then modified by an adjunct; and (ii) VP/S coordination. In Table 8.8, these examples are marked 'Yes' in the rightmost column.

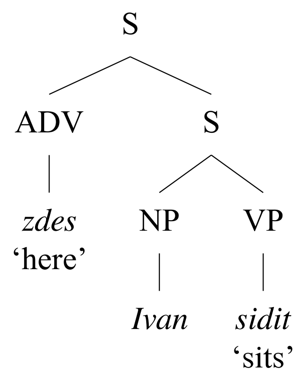
Adjuncts modifying S, VP, and V. Adjuncts can attach at the S-level, both because in sentences where an adjunct is modifying a verb, a subject may intervene between them (482)-(484), and also in coordinated sentences modified by an adjunct (483).[18]

[18] I am giving an English example of S-coordination for ease of reading. I do not have sentences like that in any of the test suites, as they are not constituent questions and did not come to my attention earlier as something that could be related to the analysis.

(482) Сюда Иван идет.
Suda Ivan idet
here Ivan.NOM go.3SG.PRES
'Ivan is coming (lit.: going) here.' [rus]

(483) Kim danced and Sandy sang in the club yesterday. [eng]

(484)



Allowing adjuncts to attach at the S-level, however, creates spurious ambiguity for sentences like (485), which is illustrated by (486a)–(486b).[19]

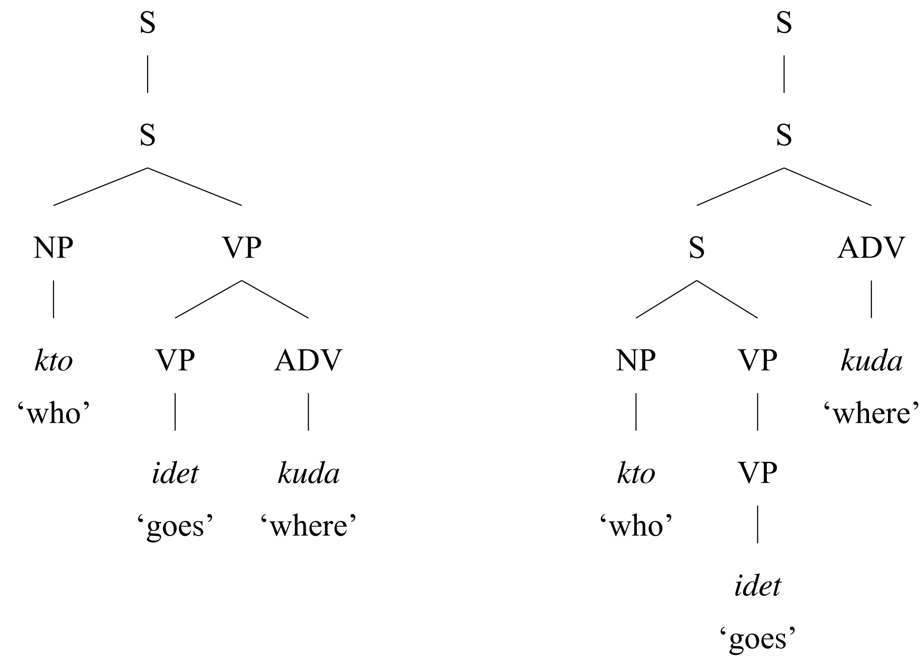
(485) Кто идет куда?
Kto idet kuda?
Who.NOM go.3SG.PRES where?
'Who is going where?' [rus]

---

[19]The contrast between (482) and (485) could perhaps be modelled as contrast between pre- and post-modifiers (§6.1.2), but S-coordination still requires that adjuncts attach to S.

(486)

a. b.



There is no good reason for the reading (486b) to exist; it is definitely spurious and should be eliminated in an improved version of the grammar, e.g. by disallowing S-clauses formed by the filler-gap rule from being modified.[20] Note that this problem will also go away if the analysis moves away from deeming questions like (485), with a question word non-fronted, canonical constituent questions. In other words, this is another region in the analysis which is affected by admitting the concept of optional question word fronting. If question words in constituent questions must be fronted, then (485) is not a constituent question and both (486a) and (486b) should be ruled out, and (485) should be analyzed differently altogether, perhaps preventing the ambiguity.

Similarly, the *in situ* clause should probably be precluded from taking modifiers. Without this,

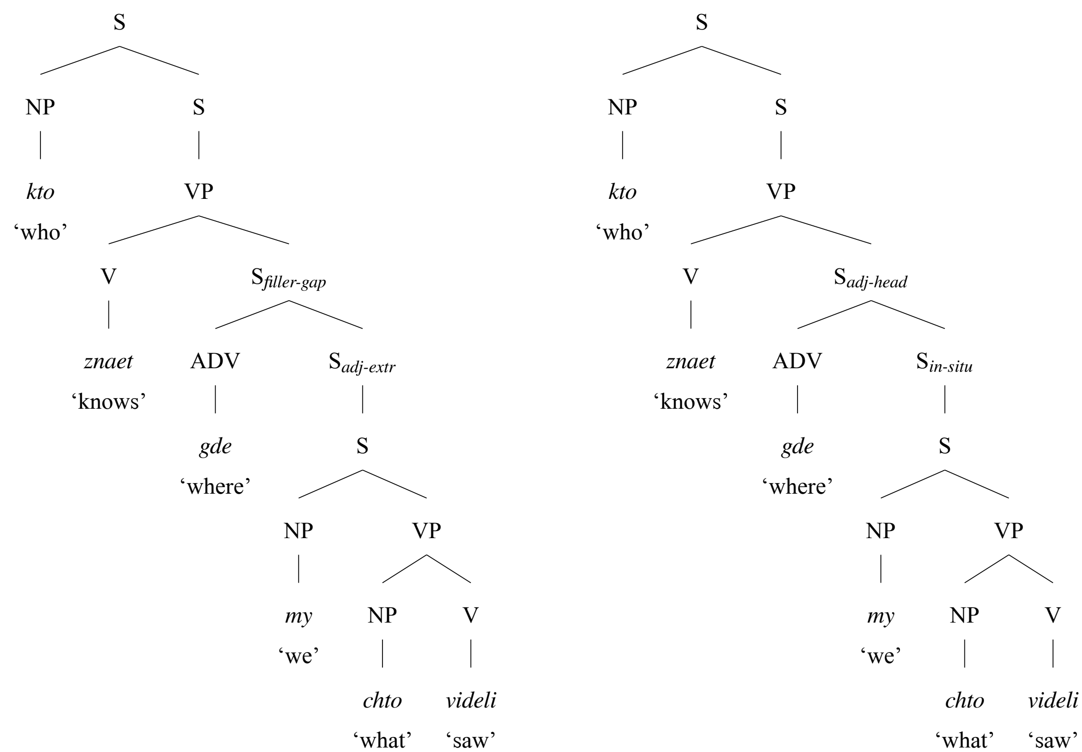
[20]There is currently no mechanism in place in the Matrix to distinguish filler-gap constructions from other phrases; in the ERG, there is an example of such a mechanism which works for English but will not necessarily generalize, using some properties of English subjects. In the Matrix, I imagine this would be done by the means of a new boolean feature which would be $-$ in all phrases except filler-gap phrases where it would be $+$.

the grammar assigns a spurious reading (488b) to (487).

(487) Кто знает, где мы что видели?
Kto znaet, gde my chto videli?
who.NOM know.3SG where 1PL what.ACC see.PAST.1PL
'Who knows what we saw where?' [rus]

(488)

a. b.



In simple clauses like (489), this situation is avoided using the L-QUE feature (§6.5.2) however as (487) shows, the solution does not generalize to complex clauses. Solving this issue is a future work.

(489) где мы что видели?
gde my chto videli?
where 1PL what.ACC see.PAST.1PL
'What did we see where?' [rus]

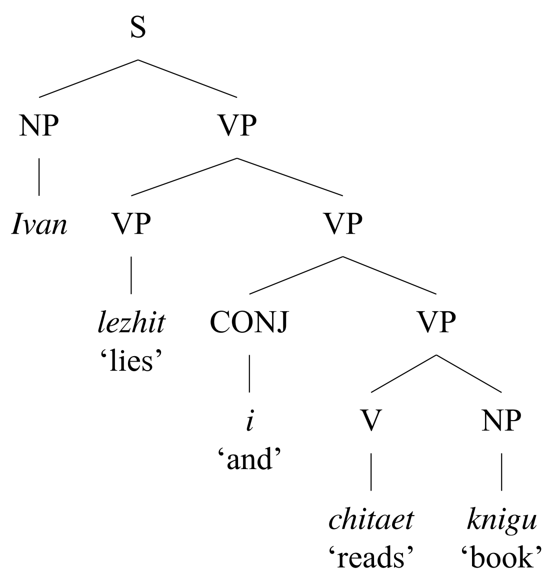
The S/VP coordination spurious ambiguity issue (see (456) above for a related discussion of overgeneration) arises in the Russian development grammar because of how the analysis of coordination interacts with the analysis of argument optionality. Specifically, (490) ends up being analyzed both as VP coordination (491) and S coordination (492), the subject of the second clause being analyzed as dropped in the latter case. The second reading (the person lying down and the person reading the book may be different people) is not a possible reading in Russian but addressing this issue is beyond the scope of this work.

(490)	Иван	лежит	и	читает	книгу
	Ivan	lezhit	i	chitaet	knigu
	Ivan.NOM	lie.3SG.PRES	CONJ	read.3SG.PRES	book.ACC

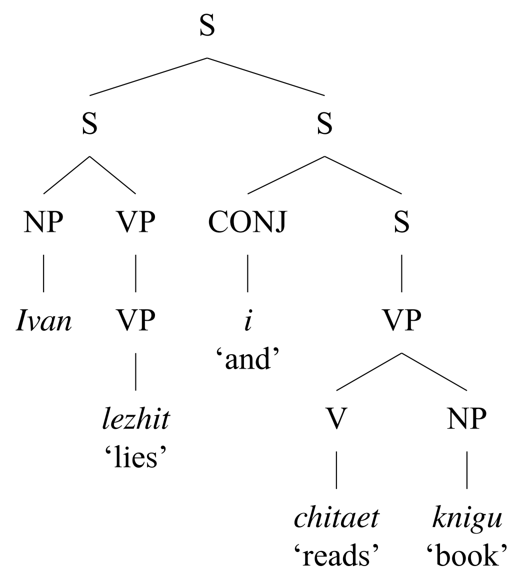
‘Ivan is lying down and reading a book.’ [rus]

‘*Ivan$_i$ is lying down and someone$_j$ is reading a book’ [rus]

(491)



(492)



Potentially meaningful ambiguity

This last section dedicated to Russian grammar discusses ambiguity which could in principle be meaningful provided that (i) further research is conducted on the data; and (ii) the analysis is developed further so as to reflect the semantic differences between the possible readings in the MRS. As it is, all of this ambiguity is spurious with respect to the grammar fragment, because for each example, it is either the case that all trees lead to the same MRS or there is an MRS that, in its present form, is not fully valid.

The ambiguity that I call here "potentially meaningful" has to do with: (a) the possibility of special information structure in embedded questions and the existence of *in situ* embedded questions in Russian; (b) determiner extraction; and (c) a *wh*-adverb modifying the matrix verb attaching from the right. In Table 8.8, the examples in this section are aggregated with comments 'Likely Not [spurious]' and 'Likely Yes'.

Information structure in embedded questions and in situ embedding The main source of ambiguity in the grammar is the combination of: the free word order; the assumption that there are *in situ* question phrases in Russian (optional fronting; §6.5.2); the assumption that subject-head and head-complement rules form clauses which have sentential force (SF) underspecified between question and proposition (*prop-or-ques*; §6.2). First, consider two possible readings of the same sentence presented in (493a)-(493b). Both these readings are fine; one is a proposition and the other is a polar question. The question is, however, is (493c) possible in Russian? Such sentences are hard to imagine out of context, but inserting a complementizer, for example, makes them sound better.[21]

(493) a. Я знаю, кто идет
Ya znayu, kto idet
1SG know.1SG who.NOM arrive.3SG
"I know who is coming." [rus]

b. Я знаю, кто идет?
Ya znayu, kto idet?
1SG know.1SG who.NOM arrive.3SG
"Do I know who is coming?" [rus]

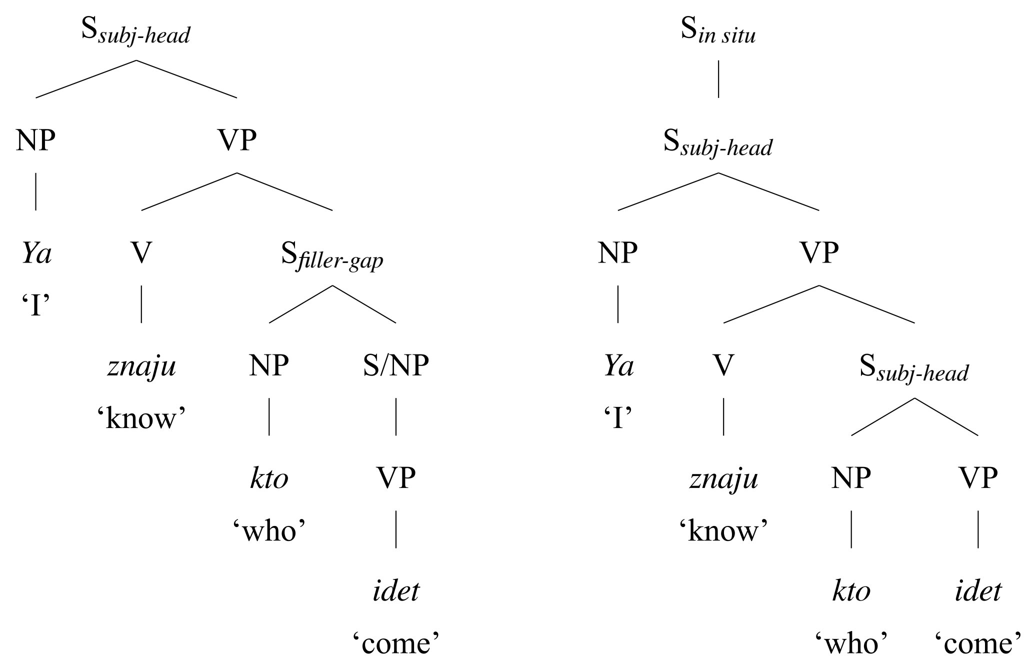
c. ?Я знаю, (что) КТО идет?
Ya znayu, (chto) KTO idet?
1SG know.1SG (that) WHO.NOM arrive.3SG
"Who do I know is coming?" [rus]

For sentences like the one illustrated by (493a)-(493c), two analyses are definitely desirable, one for a proposition and one for a polar question, both conveyed, via the underspecified SF value on the subject-head phrase, by (494a). A third analysis could potentially be defended to reflect the meaning of (493c). The grammar provides such an analysis (494b); its validity should be determined by an additional study dedicated to data like (493c).

[21] Note that sentences like (493c) are easy to interpret as echo questions but that is not what I mean here. I mean a situation where there is a certain information structure that puts a lot of emphasis on the question about the subject of the embedded clause, without it being a repetition of the previously made statement. Rather, such sentences seem to prepare the interlocutor for the special importance to the answer to the question, which the speaker is about to provide themselves. For example, if I am telling a story about a burglary and how I at first thought that it was my guest that was about to arrive and so did not expect a burglar, I might utter (493c), which in English would be something like *But, WHO do I at that point know that should be coming? Not a burglar! Kim is who I know was coming!*.

(494)

a. b.



Determiner extraction In Russian, pied-piping of nouns by determiners is not obligatory, so both (495a) and (495b) are possible:

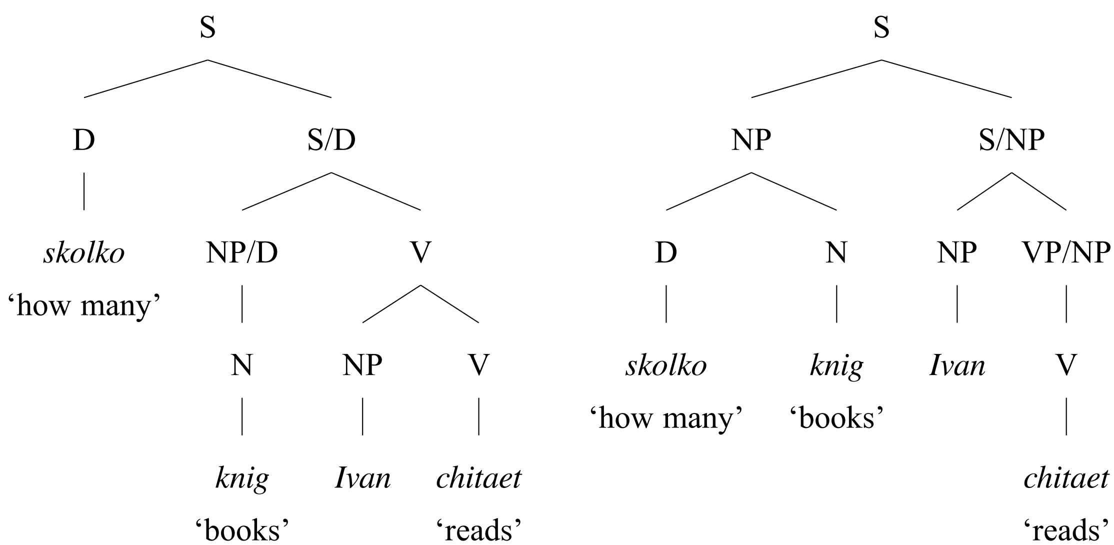
(495) a. Сколько книг Иван читает?
Skolko knig Ivan chitaet?
how.many book.PART Ivan.NOM read.PRES.3SG
"How many books is Ivan reading?" [rus]

b. Сколько Иван читает книг?
Skolko Ivan chitaet knig?
how.many Ivan.NOM read.PRES.3SG book.PART
"How many books is Ivan reading?" [rus]

Allowing the determiner to be extracted to license (495b), as explained in (§6.5.3), leads to ambiguity in (495a) which may or may not be meaningful in principle, pending further work with the data. My preliminary hypothesis is that, with a certain intonation and information structure, the sentence does have two readings, one with more and one with less emphasis on the determiner. In the grammar, this ambiguity remains spurious until the grammar fragment is extended to produce the appropriately different semantic structures. As is, both trees lead to the same MRS, which is not desirable.

(496)

a. b.



Question adverbs modifying the matrix verb where they are only expected to attach to the embedded question For sentences like (497), trees like (498a) appear undesirable (I would only like my grammar to produce (498b)), yet the grammar generates them.

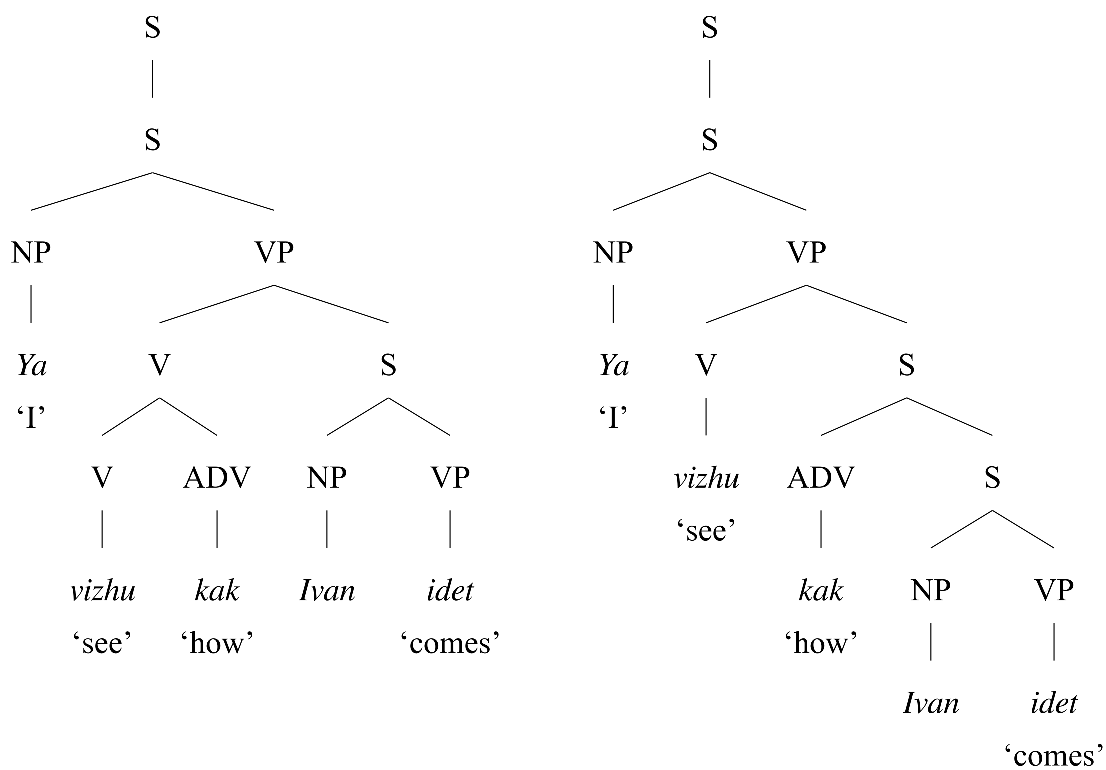
(497)	Я	вижу	как	Иван	идет
	Ya	vizhu,	kak	Ivan	idet
	1SG	see.1SG	HOW	Ivan.NOM	come.3SG

'I see how Ivan is coming.' [rus]

'??I see HOW (that) Ivan is coming?' [rus]

(498)

a. b.



Readings arising from (498a) appear nonsensical, although, as discussed previously in the overgeneration section, non-question-counterparts of such sentences are possible (463). This is another issue connected to the general analysis of adverb attachment, developing which further is beyond the scope of this work. This concludes the discussion of testing my analysis of consituent questions on the Russian test suite.

Interim summary

The Russian development grammar is the largest development fragment I used in the constituent questions library for the Grammar Matrix. I tested it on the test suite of 273 sentences, which is the largest test suite that I add to the Matrix regression testing system. The grammar fragment does not have perfect coverage or overgeneration, compared to other development grammars, which is expected given the size and diversity of the test suite. A major takeaway is the issues which result from the analysis of Russian fronting as optional and allowing *wh*-words in non-fronting phrase structure rules. As discussed in this section, this analysis leads to overgeneration and spurious ambiguity, and these results point towards an analysis more in line with Ginzburg and Sag's (2000) duplicate lexical entries for question words, where one entry is only for fronting contexts and the other only for *in situ* contexts. Another major area where analyses could be improved is hybrid coordination. Finally, the testing also helped identify areas in the Matrix which could be improved which are not in my constituent questions library: (1) the Matrix would benefit from a revised analysis of second position clitics (so that they can appear in embedded clauses); (2) an analysis of discontinuous noun phrases would make it possible to work with sentences like (157); (3) the coordination library should probably implement constraints on argument drop in S-coordination.[22] The next (smaller) sections discuss the rest of the test suites and how grammars created by the newly updated Matrix performed on them.

8.3.5 Japanese development grammar

The test suite of Japanese sentences which I used to test my analysis of particles is small and features few interacting phenomena. Its main purpose is to test a grammar for a language in which one particle is only possible in embedded clauses while another particle *no* is possible in both main and embedded clauses, and that both are clause-final and optional in constituent questions. The only interacting phenomenon that I am testing here in addition to particles, word order, and embedded clauses, is nominative–accusative case marking. The grammar output by the Matrix customization system for my specification of Japanese has 100% coverage and no overgeneration on this small test suite, and I uncover no problems with the existing analyses of question particles as presented in §6.7.

The organization of the test suite is presented in Table 8.9. The test suite essentially comes from Miyagawa 1987; some items I constructed by analogy.

[22] Also, (4) underspecified adjunct attachment creates spurious ambiguity, as one would expect, but this was not something I newly discovered in this work.

Phenomenon	Grammatical	Ungrammatical	Total
Question about subject of intran. matrix clause	2	3	5
Ques. about obj. of tran. matrix clause	2	0	2
Embed. ques. about obj. of intran. clause	3	0	3

Table 8.9: Japanese development test suite

8.3.6 Southern (Kolyma) Yukaghir development grammar

Kolyma Yukaghir [yux] (isolate) features a separate interrogative morphological paradigm, and I picked it as a development language for that reason, and also because I wanted to see whether my case analysis from Zamaraeva and Bender 2014 will interact well with my analysis of constituent questions. I did not reuse the test suite associated with Zamaraeva and Bender 2014 because that test suite was associated with a grammar engineering project where the Matrix was only used at the beginning and the test suite was intended to test the development that was done later by hand. The new, smaller test suite focusing on constituent questions which I put together and used for this dissertation is presented in Table 8.10. It tests morphological marking of questions interacting with Yukaghir focus case system. The test suite comes primarily from Maslova 2003, with the ungrammatical items constructed by me so as to violate the grammaticality constraints identified by Maslova (2003).

Test suite

The organization of the test suite is presented in Table 8.10.

Yukaghir person split

The interrogative paradigm in Yukaghir is not obligatory except when the question is about a non-focused peripheral participant (i.e. an oblique object or an adjunct) of a clause where the subject is 1st person (499a)-(499b).

Phenomenon	Grammatical	Ungrammatical	Total
Polar question	2	0	2
Ques. about subj. of intran. matrix clause	1	4	5
Ques. about subj. of tran. matrix clause	4	6	10
Ques. about obj. of tran. matrix clause	1	3	4
Ques. about adj. of tran. clause	2	2	4

Table 8.10: Yukaghir development test suite

(499) a. mit emd'e noŋōn kuded-ōk?
our younger.sibling what.for kill-1PL:ITRG
'What have we killed our younger brother for?' (Maslova, 2003, p. 153)

b. *mit emd'e noŋōn kuded-j?
our younger.sibling what.for kill-1PL:TR
(intended) 'What have we killed our younger brother for?' [constructed]

In other cases, both the interrogative and the indicative paradigm can be used (500a-500b).[23]

(500) a. rie-nunnu-k
walk-HAB-ITRG:2SG
'(Where) did you walk?' (Maslova, 2003, p. 208)

b. ejrie-nunnu-jek
walk-HAB-INTR:2SG
'(Where) did you walk?' [constructed]

Question phrases questioning the S/O constituent (the subject of the intransitive clause or the object of the transitive clause, but not the subject of the transitive clause (the A-participant)) are always in focus and the verb must be in the focus form and cannot be in the interrogative form (501). The A-participant cannot be marked for focus (Maslova, 2003, p. 336). Furthermore, the interrogative paradigm cannot be used with focused question words, so it cannot be used to form a question about the subject of the intransitive or the object of the transitive clause (503-504).

[23]Note that the translation of this verb is reminiscent of interrogative verbs (§6.9), but in this case this is not reflected in the gloss. In this case, I interpret the verb based on the gloss, as a normal intransitive verb with no implicit question semantics.

(501) lem-dik kes'ī-me
what-PRED bring-2SG:OF
'What have you brought?' (Maslova, 2003, p. 153)

(502) kin mit-kele qamie?
Who we-ACC help(ITRG:3SG)
'Who has helped us?' (Maslova, 2003, p. 491)

(503) *lem kes'ī-k
what bring-2SG:ITRG
(intended) 'What have you brought?' [constructed]

(504) *lem-dik kes'ī-k
what-PRED bring-2SG:ITRG
(intended) 'What have you brought?' [constructed]

Most of this data is handled in line with Zamaraeva and Bender 2014, by specifying separate inflectional paradigms not only for transitive and intransitive verbs but also for the person-focus split, using CASE constraints. While fairly complex, it can be done via the Matrix questionnaire[24] and results in 100% coverage over this test suite and rules out most of the tested impossible combinations except for one case (499b) described below. All ambiguity is due to underspecified adjunct attachment (as illustrated by Russian in (486a)–(486b)).

Coverage %	Overgeneration% (# items)	Ambiguity (readings per sentence)
100.0	7.1 (1)	1.1

Table 8.11: Yukaghir development grammar statistics

Overgeneration: Person split and questions about adjuncts

The only ungrammatical sentence from the test suite which is parsed is (499b). It is ungrammatical because it illustrates an adjunct modifying a sentence with a 1st person subject, and therefore it must use the interrogative inflection and cannot use a normal intransitive inflection. It is not

[24]Please refer to the downloadable materials: `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`.

obvious how to rule out sentences like (499b) using the customization system because there is no way to specify that a verb cannot have *wh*-adjuncts (but can have *wh*-arguments); it is the modifier that usually constrains the structure it modifies, not vice versa.

8.3.7 Chukchi development grammar

I use a specification of Chukchi and a small test suite from the language to test primarily interrogative verbs, but thanks to sentence (505) that I found in the Chukchi reference grammar (Dunn, 1999), I test also interaction with the valence change library, and another sentence (see Figure 6.7) allows me to test interaction with adnominal possession. Most examples are from Dunn 1999, one example is from Mackenzie 2009.

(505) ine- n- req -ēk -wʔiʔ
INE- N- do.what? -TH -TH
'What are you doing to me?' [ckt] (Dunn, 1999, p. 89)

Phenomenon	Grammatical	Ungrammatical	Total
Polar question	1	0	1
Ques. about subj. of intran. matrix clause	2	0	2
Ques. about obj. of tran. matrix clause	3	0	3

Table 8.12: Chukchi development test suite

This test suite is intended only to test that interrogative verbs yield correct semantic representations (such as shown earlier in Figure 6.7). There is no focus on any syntactic phenomena, and most of the examples I found were one-word sentences. As for specific decisions I had to make about the test suite, I interpret the word *mik* (506) as a verb rather than the question word *who*.

(506) mik-ənti
who?-3PL
"What are they called?" [ckt] (Dunn, 1999, p. 89)

This is because the language is said to have interrogative verbs generally; however this is just an experimental analysis for the purposes of testing the library. *Mik* could well be a nonverbal predicate, and for the purposes of a Chukchi analysis, additional work with data would be required.[25] The grammar has 100% coverage on the test suite; there are no ungrammatical sentences in the test suite so overgeneration does not apply.

8.4 Interim Summary

The above sections covered the results of testing I did for the constituent questions library on data from illustrative languages (§5.2). I developed the library while constantly testing it on these languages (test-driven development (§5.7)). This means, I had the opportunity to gradually improve the analyses and the computer program when coming across any undesirable behavior of the grammars exposed by the testing (however, in some cases I filed such issues to future work; see Appendix A). The next sections present the results of the testing on held-out languages (§5.10).

8.5 Evaluation grammars

I used five languages from different language families for evaluation. The next several sections describe the specifics of the process described in §5.10 which applies to all five. Then, I explain in more detail what I did with data from each of the languages and what the results were.

8.5.1 Choosing languages

I picked languages for evaluation as follows. I downloaded the full list of items available via the Language Description Heritage Open Access digital library.[26] I then ordered the entries randomly using the randomizing algorithm available in Google Sheets ("randomize range" under Data). I then went through the randomized list of titles, discarding any titles which (i) were in languages that I cannot fluently read; and that (ii) did not signify descriptive grammars (e.g. the title *Towards a theory of phonological alphabets* was discarded). The ones which did look like

[25]The same applies to my decisions to interpret something as an interrogative verb in evaluation languages, too (§8.5). An exception to that is Jalkunan (§8.5.10) about which Heath (2017) states that it has an interrogative verb.

[26]Accessed on January 26 2021 `https://ldh.clld.org/`

descriptive grammars and which I could read, I picked in the order in which they appeared in the randomized list. Next, I discarded the title if the language for which the grammar was written came from a language family[27] with which I was already working (so, if it came from one of the four language families that the illustrative languages came from, or one of the families that were used for examples in Chapter 2, or one one of the families already chosen for evaluation).[28] Finally, if the title was not discarded in any of the previous rounds, I checked whether the descriptive grammar is usable for my purposes (contains a section on constituent questions with examples). If the grammar did contain examples of constituent questions and a section describing how they are marked, I selected that language for evaluation. If the reference grammar did not contain any relevant material, I then looked for an available grammar from the same language family which did contain some. For example, the grammar on the randomized list was that of Kwak'wala [kwk] (Hall, 1889); instead, I used a grammar of Southern Wakashan languages (Makah [myh] and Nuuchahnulth [nuk]) by Davidson (2002), which contained a section on interrogatives with examples from Makah.

Thus, I end up with the five held-out languages (from held-out language families) presented in Table 8.13. Note that I have worked with two of the language families in Table 8.13 before, in the

Language	ISO-639-3	Family	Grammar
Apinajé	[apn]	Macro-Jê	Oliveira 2005
Makah	[myh]	Wakashan	Davidson 2002
Pacoh	[pac]	Austroasiatic	Alves et al. 2006
Paresi-Haliti	[pab]	Arawakan	Brandão 2014
Jalkunan	[bxl]	Mande	Heath 2017

Table 8.13: Evaluation (held-out) languages

[27]I used Glottolog `https://glottolog.org/glottolog/language` to look up which language family each language belongs to.

[28]Note that this criterion can mean different things: for example, I did not include Pashto [pus] (which came up first in my randomized list) because I have already worked extensively with Indo-European languages; however, I also did not include Bargam [mlp] (a Trans-New Guinea language) because I talk about Abui [abz] in Chapter 2 and in fact do not include an analysis of a Trans-New Guinea language in this work (for lack of time). This means that, I could expect a fairly good coverage on a Pashto test suite and a poor coverage on a Bargam test suite, but I included neither experiment.

context of evaluating the clausal complements library which I also developed for the Grammar Matrix (Zamaraeva et al., 2019). I even chose the exact same two languages, for which I already had good descriptive grammars (since the two languages from these two families which came up on the randomized list lacked actual resources). I never had looked at examples of constituent questions from these languages before, however, and so they can be considered held-out in this respect.

8.5.2 Compiling test suites

Searching for grammatical examples

Unlike the development (illustrative) languages, the held-out languages are usually languages which I do not know much about. I have either not worked with the data from them at all or, as in the case with Jalkunan and Paresi-Haliti, have worked with some data from these languages but never in the context of interrogatives. By definition, I have never seen an interrogative sentence from any of these languages in my life. This means I need to rely entirely on the reference grammars to obtain examples of interrogatives. However, in the context of this work it was not possible for me to read all of the grammars cover-to-cover. I read the grammars only minimally, so as to find examples of constituent questions and to understand how to fill out the Matrix questionnaire for the given language. To locate examples of interrogatives, I do the following:

1. Read the sections on interrogative constructions and question words in the grammar, if such sections are present.

2. Search the grammar PDF file for terms: *question*, *interrogative*, *speech act*.

3. Search the grammar for gloss terms: *who*, *what, where, when, why, how, which*.

The above procedure should yield most of the examples of interrogative constructions that the

[29] Of course, searching for e.g. *when* will yield also examples of clausal modifiers, and there will also be relative clauses. I do not include such examples; only constituent and polar questions. I include polar questions because

reference grammar contains, including both constituent and polar questions.[29] Note that step 3 can be somewhat time consuming because the search terms are very common English words, and the grammar is written in English. The way the search function works in the Mac Preview program, it is possible to see the context in which the term was found, and from the context, it is easy to see whether a given search match is part of an IGT or not.[30] This makes the last step possible in the context of this work and allows me to locate examples which are included in sections not necessarily dedicated to interrogatives (e.g. embedded questions). I included all constituent questions which I found in the reference grammars but not necessarily all polar questions; I only included a few polar questions in each test suite so as to illustrate the main strategy and any grammaticality contrasts related to e.g. the impossibility of the use of a question particle in constituent questions.

Modifying grammatical examples

Ideally, examples should be used exactly as given in the reference grammar. However, in some cases, the example contains so many other phenomena, some of which are not yet supported by the Grammar Matrix system, that it would make no sense to include the example in the test suite. If the sentence contains a relative clause, for instance, such an example will not be parsed by a customized Matrix grammar without manual additions. I carefully recorded all modifications and included the information in the sections corresponding to each language test suite (§8.5.6–§8.5.10).

Constructing ungrammatical examples

Authors of descriptive grammars do not typically include ungrammatical examples, so I have to construct most of them myself (as always, I record the provenance of each example, and if the example is included in this document, the provenance is clearly indicated). This is done

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my analysis of question particles (§6.7) is tied closely with the polar questions library.

[30]Occasionally, there can be an in-line example without an IGT. I only included such examples if I could infer, based on what I already knew about the language from studying other examples and reading the corresponding sections of the reference grammar, what the gloss should be. Otherwise such examples could not be included because there would be no way for me to enter the corresponding information into the Matrix questionnaire.

as follows. I read the sections in the reference grammar which are dedicated to or mention interrogatives, and/or which contain the grammatical examples that I picked. If the prose in the reference grammar suggests any grammaticality contrasts, I then construct ungrammatical examples based on that. The specifics for each test suite are included in the sections corresponding to each language.

8.5.3 Creating language specifications

The general process of creating language specifications is as follows. I read the sections of each reference grammar which described interrogative constructions or any phenomena I needed to understand something about which were present in the sentences selected in the test suite. In some cases, the description of the language phenomena in the reference grammar correspond directly to the Matrix questionnaire (e.g. the reference grammar of Apinajé (Oliveira, 2005) specifies "rigid SOV word order" (p. v)). In other cases, the mapping is less straightforward; I describe what choices I made as clearly as I can in the subsequent sections, for each language. All specifications and test suites can be downloaded in full from the project repository.[31]

I specify lexicons as full-form,[32] due to time constraints. I only specify morphological lexical rules for held-out languages where they are involved in marking questions. Ignoring much of the morphophonological analysis done in reference grammars is of course not ideal and decreases the generalizability potential of the analyses presented here, but modeling morphology in detail would add a prohibitive time cost to this work. As for phonology, I add multiple lexical entries for phonological variants, which allows me to test more sentences exactly as they come in the reference grammars.[33]

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[31] `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`

[32] A full-form lexicon consists of inflected forms (as opposed to lemmas which then are expected to go through morphological rules).

[33] An alternative would be to assume a morphophonological analyzer and to include only one normalized variant of each lexeme. This would result in a smaller, neater lexicon but would require to manually normalize the test sentences.

8.5.4 Aggregating results and treebanking

I then use the customization system with the additions described in Chapter 7 to create grammars automatically from the specifications. I load these grammars into the LKB system (Copestake 2002; §3.2) and run them on the test suites using the [incr tsdb()] system (Oepen 1999; §3.2). The result is automatically computed and stored information about each grammar's coverage, overgeneration, and ambiguity over the corresponding test suite. I then *treebank* each processed test suite (the items paired with the corresponding parses and MRSs) in order to validate the coverage.

Treebanking means selecting correct parses for sentences to which the grammar assigned more than one tree. It is important to not only look at coverage as reported directly by software such as [incr tsdb()], because that coverage is simply the number of sentences for which the grammar assigned a tree (any tree). The tree may be meaningless (lead to wrong semantics), and such parses should be subtracted from the coverage (Flickinger, 2011).

I used the Full Forest Treebanking tool (Packard, 2015) for this purpose. All results tables in the subsequent sections (such as Table 8.15) contain both "coverage" and "validated coverage", and the second number is more important because it does not contain any meaningless parses.

8.5.5 Summary of all test suites

The size and the typological profile for all evaluation test suites are summarized in Table 8.14. The legend for the table is the same as for Table 8.1. Then each test suite is addressed in a separate section below.[34]

In the error analysis sections dedicated to each language, I focus on the problems which were discovered, as documenting such problems is important for future work. The degree to which each grammar worked well is evident from the validated coverage and the list of phenomena included

[34]As a reminder to the reader, all specifications can be downloaded from `https://github.com/delph-in/matrix/releases/tag/Zamaraeva-dissertation`. The specifications are under `tests/regression/choices`; the test suites are under `tests/regression/txt-suites`. The Apinajé files are called `wh-test-apn` in both file folders. Files for other languages use their corresponding ISO-639 codes.

Language	ISO-639-3	Family	Gram./ungram.	Cov%	Overgen%	Avg. ambig	Phenomena
Apinajé	[apn]	Macro-Jê	17/2	82.3	0	8.9	single front.
Makah	[myh]	Wakashan	14/3	78.5	0	1.93	morphological,int. verbs
Pacoh	[pac]	Austroasiatic	26/4	84.6	50	1.6	single opt. front.
Paresi-Haliti	[pab]	Arawakan	64/3	56.0	66.7	31.65	single front., int. verbs
Jalkunan	[bxl]	Mande	33/5	78.8	33.3	3.25	*in situ*, particle, int. verbs

Table 8.14: Evaluation (held-out) test suites

in the description of the test suite but not mentioned in error analysis.

8.5.6 Apinajé (Macro-Jê)

Apinajé [apn] is a Macro-Jê language spoken in Brazil. The grammar sketch of this language written by Oliveira (2005) came up first on my randomized list of descriptive grammars and contained enough examples and information on constituent questions to be used directly for my purposes. I have found 14 glossed grammatical examples of questions (11 constituent, 3 polar). There were also two additional examples which did not have a gloss (the unglossed examples are both located in the glossary, not in the main grammar text) and so it would be hard for me to understand how exactly the sentence could be analyzed, so I did not include it in the test suite.

Overview

Apinajé is an SOV language (Oliveira, 2005, p. v,198). Polar questions are formed by intonation (507) or optionally with a clitic (508).

(507) na ka rĩ mẽ kapẽr ja ba
RLS 2.NOM DEM PL talk DEF.ART hear
'Did you hear what she said?' [apn] (Oliveira, 2005, p. 347)

(508) čo na ka ra a-tujaro?
Q RLS 2 ASP 2-pregnant
'Are you pregnant yet?' [apn] (Oliveira, 2005, p. 226)

Constituent questions are formed by fronting a question word (509)–(510).

(509) Taɲ = mɔ̃ na ka tɛ me ∅-ɔ?
how RLS 2 HAB PL 3-do
'How do you guys do this?' [apn] (Oliveira, 2005, p. 168)

(510) Wa = ʔõ na prɛ ∅-ipeč?
PL-INDF RLS PST 3-make
'Who made it?' [apn] (Oliveira, 2005, p. 167)

Oliveira (2005) does not provide any further details about the syntax of constituent questions in Apinajé and does not give any examples of sentences containing multiple question phrases.

Mood marking is present in most examples in the test suite, specifically realis and irrealis. There is also habitual aspect marking in some of the examples (509). The only tense marking present in the question examples is that for past tense (510). There are evidentiality markers in Apinajé; the only question example with such a marker is (511).[35]

(511) ɲɨ na wɛ õčwa?
which RLS HRS sleepy
'Which one is sleepy?' [apn] (Oliveira, 2005, p. 227)

There are a number of clitics and particles in Apinajé which perform a range of grammatical functions. In examples (509)–(511) above, *na, ka, tɛ, prɛ, wɛ* are all such clitics, so, person and number; tense, aspect, and mood; evidentiality are all marked in Apinajé with clitics.

As for the case system, Oliveira (2005, p. 255) calls it split-intransitive in simple clauses, the split being between different semantic types of verbs. In transitive clauses, there is a set of markings possible on the direct object. However, in the set of examples of questions that I found in Oliveira 2005 the case system is not prominent. The only case marking glossed in these examples is the NOMinative on the subject, although even that gloss is not always given.

In the next two sections, I explain how I specified a fragment of Apinajé capturing the above data, via the Matrix questionnaire. Some choices are straightforward (e.g. including a hierarchy of 1st, 2nd, and 3rd person in the specification) and I do not talk about them; other choices are

[35] It is not obvious from the translation that this is hearsay; I reproduce the translation as given in the book.

explained either because they pertain to questions or because there is something about them which warrants making an explicit mapping to the data.

Ungrammatical examples

There are no ungrammatical examples of questions in Oliveira 2005, so I construct several ungrammatical examples based on the positive statements in Oliveira 2005. For example, the word order is said to be rigidly SOV (p. v), so I can construct an ungrammatical example where the *wh*-object is *in situ*, between the subject and the verb. I construct the following examples based on the positive statements that (i) the order is rigidly SOV; and (ii) question words are fronted.

In (512), the question adverb is not fronted unlike in the real example (513).

(512) *ka tɛ ɲɨ = rĩ a-pa?
2 HAB where = at 2-live
Intended: 'Where do you live?' [apn] (Constructed by me based on Oliveira 2005, p. 169,226)

(513) ɲɨ = rĩ ka tɛ a-pa?
where = at 2 HAB 2-live
'Where do you live?' [apn] (Oliveira, 2005, p. 169)

I construct (514) to illustrate that the *wh*-object must be fronted, and I construct also (515), as there are no examples of questions about the object in Oliveira (2005).

(514) *kaprə̃nrɛ bɔj ba
turtle what hear
Intended: 'What did the turtle hear?' [apn] (Constructed by me based on Oliveira 2005, p. 169,226,254; rigid SOV order)

(515) bɔj kaprə̃nrɛ ba
what turtle hear
'What did the turtle hear?' [apn] (Constructed by me based on Oliveira 2005, p. 169,226,254)

Summary of the final test suite

The original set of question examples from Oliveira 2005 contains 14 items. The set of sentences actually used as the test suite contains 19 items, 2 of them ungrammatical (not vetted). Out of the 17 grammatical items, 1 is constructed by me "from scratch" (515), 2 are the result of splitting a string of sentences into two separate sentences, and 7 include minor modifications unrelated to my analysis of constituent questions, except potentially for modification of type 6 below. The differences can be summarized as follows.

1. Nouns which are marked for plural using particles are written as if the particles were morphemes attached to the word, like in *mɛ=bɔ* in (517).

2. One sentence containing a clausal modifier (516) is included in the test suite also without the clausal modifier (517) (as the clausal modifier causes substantial ambiguity which is unrelated to my analysis of questions).

(516) Mɛ bɔ na a-t-ɔ anẽ ka ri anẽ ?
PL<INDF> what RLS 2-RP-do thus 2 PRT thus
'What happened to you that you are like that right now?'
(Lit.: 'What did you this way...') [apn] (Oliveira, 2005, p. 167)

(517) Mɛ=bɔ na a-t-ɔ?
PL=what RLS 2-RP-do
'What happened to you?' [apn] (Constructed)

3. One sentence which is actually a string of two sentences (518) is split into two (519b).

(518) Dɔ mɛ, ɲĩɨm na mɛ apeč?
where PL LOC-CNTRFG RLS PL end
'Where are they? Where have they gone to?' [apn] (Oliveira, 2005, p. 167)

(519) a. Dɔ mɛ
where PL
'Where are they?' [apn] (Constructed)

b. ɲĩɨ̃m na mɛ apeč
LOC-CNTRFG RLS PL end
'Where have they gone to?' [apn] (Constructed)

4. A greeting is removed from (520) resulting in (521). There is nothing in the Grammar Matrix to correspond to greetings.

(520) pa ɲĩ-ĩm na ka wa mõ
GRT LOC-ALLT RLS 2.NOM DU go
'Hey, where are you going to?' [apn] (Oliveira, 2005, p. 327)

(521) ɲĩ-ĩm na ka wa mõ
LOC-ALLT RLS 2.NOM DU go
'Where are you going to?' [apn] (Constructed)

5. An adverb is removed from (522) resulting in (523). This kind of adverb is not supported by the Matrix (only spatial/temporal and manner adverbs are).

(522) čo kɔt kaj ajtɛ a-tujaro?
Q IRLS 2.IRLS more 2-pregnant?
'Will you get pregnant again?' [apn] (Oliveira, 2005, p. 226)

(523) čo kɔt kaj a-tujaro?
Q IRLS 2.IRLS 2-pregnant?
'Will you get pregnant?' [apn] (Constructed)

6. I treat constructions of multiple *wh*-words which seem rhetorical, like *dɔ pẽr-apu taɲ=mə̃* in (525), as single lexical entries containing spaces. If this particular hypothesis is false (and there is in fact a grammatical structure to these expressions), it would mean that my analysis of constituent questions is insufficient to cover examples like (525). I base my hypothesis on Oliveira's (2005) statement that some "interrogatives are expressions consisting of more than one word", which results in "epistemic semantic nuance" (pp. 168–169), with which she accompanies example (525) and to which she does not add any further information about any possible structure in these phrases.

Question specifications

Constituent questions As illustrated by (509)–(510), constituent questions in Apinajé are characterized by a question word or phrase in the clause-initial position. All 11 sentences I found in Oliveira 2005 which are glossed as constituent questions indeed have this property, except there is one sentence where the question word is preceded by a word glossed as 'but' and one which starts with a greeting word glossed as 'hey'. Oliveira (2005) does not provide any further details about the syntax of constituent questions in Apinajé, and so I specify the language as follows in the Matrix questionnaire (524).

(524)
```
section=wh-q
front-matrix=single
matrix-front-opt=single-oblig
```

This grammar fragment is specified as single obligatory fronting (§6.3), however I do not know anything about multiple questions in Apinajé, and so specifying the language as single fronting is done here for minimally-applicable specification. A larger fragment of Apinajé could be specified differently, depending on the data.

The Apinajé test suite contains several *why*-questions such as (525).

(525) Dɔ pẽr = apu taɲ = mə̃ na ka ri amɲĩ = t-ɔ = anẽ?
but why how RLS 2 PRT RFLX = RP-do = thus
'But why are you acting like this?' [apn] (Oliveira, 2005, p. 169)

I did not implement support for *why*-questions (due to time constraints), only *how*- and *where/when*. This means that none of the parses that my Apinajé grammar might assign to a sentence like (525) will be actually fully correct. But they will be close, and for the purposes of testing, I include adverbs meaning *why* in the specification as "manner" adverbs. This will lead kind of half-way to the correct semantics: there will be an adverbial relation in the MRS connected to the event, but it will not be the right adverbial relation. Such parses are rejected in the treebanking stage.

Polar questions I specify polar questions to feature an optional clause-initial particle *čo*. Filling out the questionnaire yields the following machine-readable specification for polar questions (526).

(526)
```
section=matrix-yes-no
q-part=on
q-part-order=before
q-particle1_orth=čo
q-particle1_wh=imp
```

Non-question specifications

Case system Since case marking is not present in any of the question examples and the word order is said to be rigidly SOV, I simply choose no overt case marking in the questionnaire. The rigid SOV order provides the semantic representations where the semantic roles of verbs' arguments are correctly identified, without the need for overt case marking in the syntax. A larger grammar fragment of Apinajé would need to say more about case marking.

Clitics as auxiliaries In the context of the Grammar Matrix, the concept which can help capture the grammatical contribution of a series of clitics is auxiliary. Auxiliaries in the Grammar Matrix framework (Bender and Flickinger, 2005; Fokkens, 2014) can take verb phrases as complements, including the ones headed by other auxiliaries. Thus, to model (527), I will analyze *na ka ri* as a series of auxiliaries.

(527) Bɔj kačɨw na ka ri amɲĩ = t-ɔ = anẽ?
what PURP RLS 2 PRT RFLX = RP-do = thus
'What did you do that for?' [apn] (Oliveira, 2005, p. 167)

One issue with the current implementation of auxiliaries in the Matrix is that the only auxiliaries which can take VPs headed by other auxiliaries as complements are semantically contentful auxiliaries (intended e.g. for modals, like the English *can, should*). Auxiliaries which do not contribute anything to the semantics are prevented from iterating under the Matrix analysis. This is a limitation with respect to Apinajé, though not one that is associated with my analysis of constituent questions. In this case, I choose to include a specification of auxiliaries which is not ideal as it leads to "dummy" semantic relations included in the MRS; however such a specification allows me to include most of Apinajé example sentences in the test suite "as is" (an alternative would be to pretend that the auxiliaries are morphemes which are attached to the verb).

Grammar performance in the test suite and error analysis

The numeric results for evaluating the Grammar Matrix's analysis of constituent questions on the Apinajé test suite are presented in Table 8.15. The grammar which was obtained automatically by

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
16/17 (94.1)	14/17 (82.3)	0/2 (0)	8.9

Table 8.15: Evaluation results for Apinajé

filling out the questionnaire as described above covered (with some semantic nuances addressed below) all but one of the grammatical sentences included in the test suite. It did not parse either of the two constructed ungrammatical sentences (while it succeeded in lexical analysis for each word in each sentence, i.e. there were no parsing failures due to a missing lexical entry). On average, it assigned 8.9 readings per sentence.

The one sentence the grammar cannot parse is (507) repeated here as (528).

(528) na ka rĩ mẽ kapẽr ja ba
RLS 2.NOM DEM PL talk DEF.ART hear
'Did you hear what she said?' [apn] (Oliveira, 2005, p. 347)

While it is translated as an embedded question and was included in my test suite, structurally it appears to be closer to a relative construction (*Did you hear the things which she said?*'). As such, it was not expected that the grammar would parse it and it is not a problem for my analysis of constituent questions.

Results for two more sentences were rejected in the treebanking stage because they did not have completely correct semantics. As indicated earlier in this section, *why*-adverbs are not fully supported, and I specified them in the questionnaire as "manner" adverbs. The result is that the MRS for (527) looks as in the Figure 8.1. The _reason_n_rel relation is present but there is also the _manner_n_rel relation, which is not ideal and not consistent with what e.g. the ERG

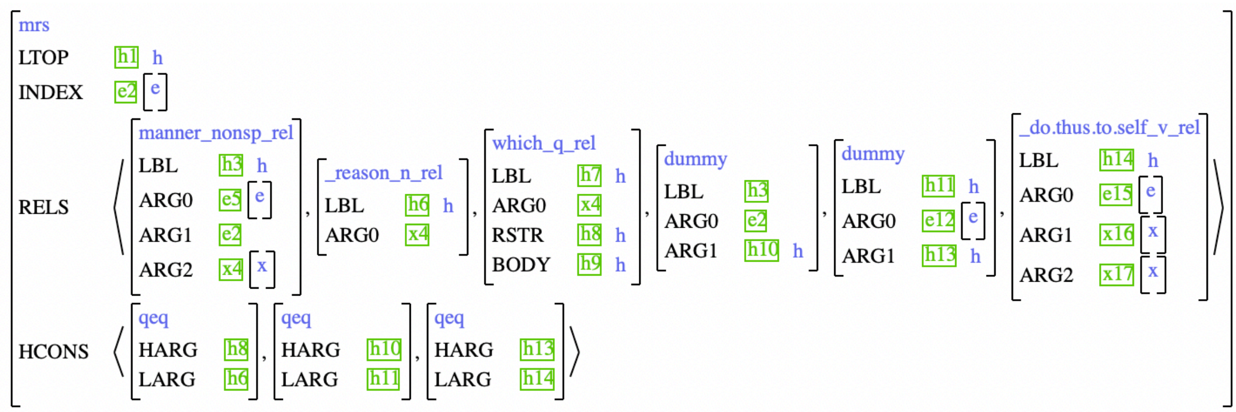


Figure 8.1: The (not ideal) MRS for the Apinajé sentence (527).

(Flickinger, 2000, 2011) will produce for the English sentence *Why did you do this?* (Figure 8.2).

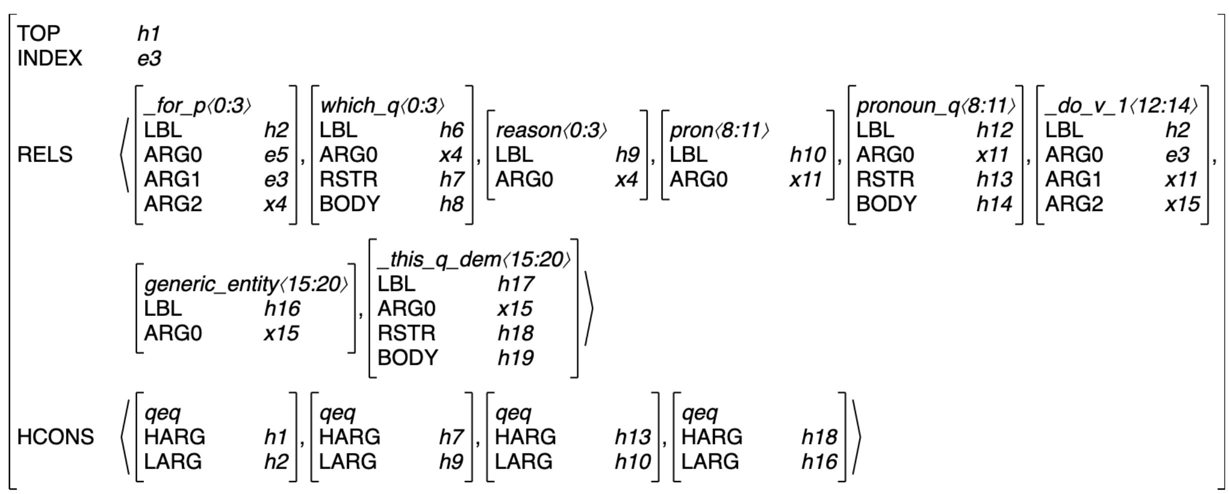


Figure 8.2: The ERG MRS for the English sentence *Why did you do this?*

Because the MRS in Figure 8.1 is not perfect, I rejected such parses in treebanking and they do not count towards validated coverage in Table 8.15. Note that the dummy relations, which are also undesirable, come from the auxiliaries (see §8.5.6). They provide the links from the adverbial relation to the main event (and ultimately to the entire MRS's handle) but they are meaningless and should not ideally be there. However, as they are unrelated to my analysis of questions, they alone would not warrant rejecting the result; it is the manner relation that warrants the rejection.

The average ambiguity is high (8.9 readings per sentence), however it is largely due to one sentence which contains a clausal modifier (516) repeated here as (529).

(529)	Mɛ	bɔ	na	a-t-ɔ	anẽ	ka	ri	anẽ	?
	PL<INDF>	what	RLS	2-RP-do	thus	2	PRT	thus	

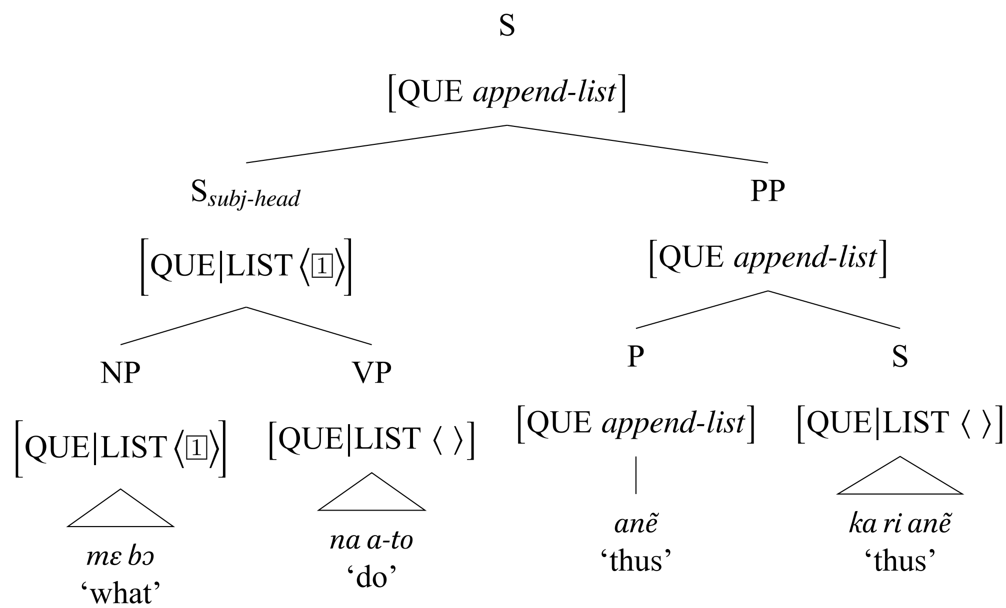
'What happened to you that you are like that right now?'

(Lit.: 'What did you this way...') [apn] (Oliveira, 2005, p. 167)

This sentence gets 82 readings because of certain underspecifications of nonlocal features in the clausal modifiers library (I had addressed a number of similar issues in the clausal modifier library while I was testing my analyses on the illustrative languages, but more such cases were revealed in evaluation). Because nonlocal features remain underspecified in the lexical item for the subordinator (the particle which attaches the modifier clause to the main clause), the subordinator and any elements above it in the tree can show up in places which expect nonempty values for nonlocal features. As a result, the expectation that if an argument or an adjunct was extracted, the gap must be filled, does not hold. All nonlocal features must be specified at the lexical level as either empty or not; the subordinator's should be empty. Because they are actually underspecified, the append list of the SLASH feature becomes broken.[36] This means, for example, that even if no extraction rules are present in a tree, the sentence will still be parsed by the grammar because of the underspecified QUE-list, as illustrated in (530). Since *append-list* unifies with an empty append list, the top S unifies with *root* (75), and the parse is licensed.

[36]It is a requirement and an assumption that nonlocal features not be left underspecified at the lexical level in any grammar. If they are left underspecified, correct behavior cannot be expected with respect to nonlocal features.

(530)



The same issue means multiple extraction rules can be present in a tree with only one question word. In that case, nonlocal constraints on phrasal rules will not be able to do their job because of the aforementioned underspecification bug, and this adds more wrong parses. The combinatorics of three different extraction rules in particular means there can be dozens of parses, as is the case with (529).

To summarize, this is a bug in the overall treatment of nonlocal features in the Grammar Matrix which surfaces in the interaction of the constituent questions library with the clausal modifiers library. The sentence's clausal-modifier-free counterpart (517) only gets one parse, and that parse has the expected semantics. While the bug is physically located in the file associated with the clausal modifiers library, it can be considered a bug related to the addition of the constituent questions library, since prior to adding constituent questions, underspecifying nonlocal features in such cases did not lead to any problems. In principle, it could be thought of as a bug in the clausal modifiers library if there was somehow an expectation that it is possible to foresee every detail of how analyses of different phenomena will interact. But this would not be in the spirit of the method of fragments (§1.2).

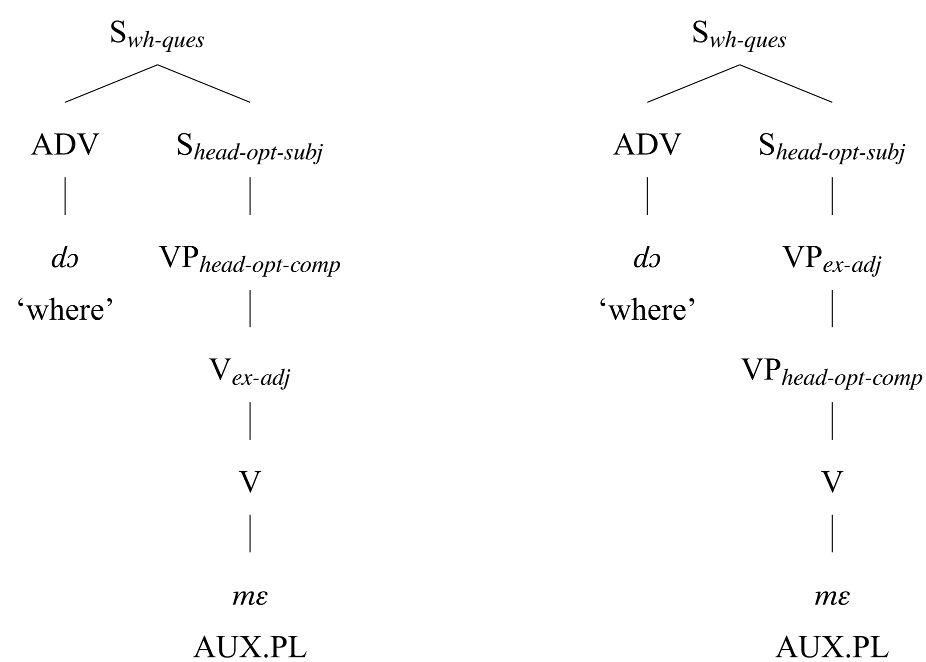
Another sentence which gets many parses, namely 20, is (531).

(531) Taɲ=mɔ̃ na ka tɛ mɛ ∅-ɔ?
how RLS 2 HAB PL 3-do
'How do you guys do this?' [apn] (Oliveira, 2005, p. 168)

This sentence features an extracted adjunct as well as 4 auxiliaries. The extracted adjunct rule (237) is not constrained to not apply to auxiliaries, which means there will be multiple trees corresponding to the adjunct being extracted from each auxiliary (as well as the main verb). In addition, this sentence features a dropped object ('this'). The extracted adjunct rule can apply both below and above the object drop rule, as illustrated by (532a)–(532b) for a short sentence (519a), adding more ambiguity. Both these issues are limitations of my analysis of constituent questions which become evident in interaction with auxiliaries and with argument optionality.

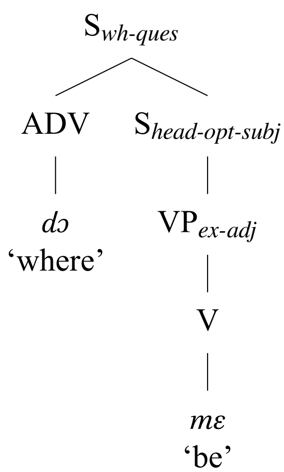
(532)

a. b.



The two trees above (532a)–(532b) illustrate yet another ambiguity problem, namely that the auxiliary *mɛ* can drop its complement. Both of these trees are in fact undesirable and will not have appropriate semantics for (519a). This is a bug in the argument optionality library, unrelated to my analysis of constituent questions. The correct derivation uses another (non-auxiliary and intransitive) lexical entry for *mɛ* and is also present in the results (533).

(533)



Interim summary

The evaluation grammar for Apinajé reveals previously undiscovered issues with specification of nonlocal features in some of the lexical types in the Grammar Matrix, as well as confirms the need for additional adverbial lexical types, such as one for "reason" adverbs. The rest of the issues which the grammar illustrates are unrelated to my analysis of constituent questions. The grammar behaves as expected with respect to modeling single obligatory fronting.

8.5.7 Makah (Wakashan)

Makah [myh] is a Wakashan language which marks polar and constituent questions with clitics ("interrogative mood"). Furthermore, the marking for constituent questions is different from the marking for polar questions (Davidson, 2002, p. 285).

Overview

In Makah, the constituent ('content') interrogative marker attaches to the question word (534)–(547) (Davidson, 2002, p. 285).

(534) ʔačaq = qaːɬ duduˈk
who = CONTENT.3SG sing
'Who is singing?' [myh] (Davidson, 2002, p. 285)

(535) baqiq = qaːɬ tiˈ
what = CONTENT.3SG DEM
'What is this?' [myh] (Davidson, 2002, p. 285)

Examples (534), (536)–(537) have morphemes glossed with verbs (e.g. *sing, have as name* and *going to cook*) as well as question morphemes glossed as *who* and *what*:

(536) ʔačaq-aˈy-quqɬa = qaːɬ = iɬ
who-PL-have.as.name = CONTENT.3SG = 3PL
'What are their names?' [myh] (Davidson, 2002, p. 286)

(537) baqi-ćak-'eːʔis = 'aƛ̓ = qiːk
what-cook-going.to = TEMP = CONTENT
'What are you going to cook?' [myh] (Davidson, 2002, p. 286)

In (538), the morpheme glossed as *which* quantifies an entity *thing for writing* which is written as a separate word, while *waˈscuˈwat* ('which') takes the content interrogative inflection.

(538) waˈscuˈwat = uk = qiːk c̓́at-aˈ-yakʷ
which = POSS = CONTENT write-EPEN-thing.for
'Which pencil is yours?' [myh] (Davidson, 2002, p. 286)

Polar question marking is exemplified in (539). It is a clitic which attaches after the "temporal specifier":

(539) duduˈk = 'aƛ̓ = qaːk = s
sing = TEMP = POLAR = 1SG
'Am I singing?' [myh] (Davidson, 2002, p. 100)

Though Davidson (2002) does not comment on it explicitly, it appears that the interrogative clitic marking is optional in Makah, and the question can be formed simply by using the question word (540) and an indicative mood marker.

(540) baqi-'iˈx̣a = 'aƛ̓ = bu = i
what-die.from = TEMP = PAST = IND.3SG
'What did he die of?' [myh] (Davidson, 2002, p. 189)

Ungrammatical examples

I construct ungrammatical examples for Makah based on the positive statement of Davidson (2002) that the marking for constituent questions is different from the marking for polar questions. Specifically, I construct (541), to illustrate that a polar question cannot be formed using a constituent question marker, and (542) to illustrate the opposite, namely that a polar question marker cannot be used to form a constituent question.

(541) *duduˈk = ’aƛ̓ = qik
sing = TEMP = CONTENT.2SG
Intended: ‘Are you singing?’ [myh] (Constructed based on Davidson 2002, p. 100,285)

(542) *ʔačaq-aˈy quqɬa = qaː = iɬ
what have.as.name = POLAR.3SG = 3PL
Intended: ‘What do they have as their name?’ [myh] (Constructed based on Davidson 2002, p. 286)

In terms of the order, the mood clitics come after the “temporal specifier” clitic and are sometimes fused with or followed by pronominal markers (Davidson, 2002, p. 95). I construct an ungrammatical example (543), to test that my grammar fragment captures the respective order of the interrogative affix and the temporal specifier.

(543) *baqi-ćak-’eːʔis = qiːk = ’aƛ̓
what-cook-going.to = CONTENT = TEMP
Intended: ‘What are you going to cook?’ [myh] (Constructed based on (Davidson, 2002, pp. 95,285)

Question specifications

In the previous section (§8.5.6), I presented an analysis for a fragment of Apinajé where I analyzed clitics as auxiliaries. In particular, it allowed me to use more of the test suite examples exactly as they were given in the reference grammar (clitics written as separate words). For Makah, the same goal (to modify as little as possible in the examples) calls for a morphological marking analysis, though as I explain in more detail below, in general Makah is difficult to model using the current

Grammar Matrix system.

I specify in the questionnaire, on the Morphotactics subpage, position classes for temporal specifier (glossed TEMP in the examples), tense, and mood (fused with pronominal indexing, so, both features included in the same lexical rule). I specify two separate paradigms for constituent and polar interrogative mood.

A straightforward morphological marking analysis accounting for all the examples in the test suite, however, is not possible for Makah in the Grammar Matrix. The Grammar Matrix assumes a rigid distinction between nouns and verbs and furthermore does not currently support serial verb constructions, and so correct semantics for example (534) is only possible to get via the current system by ignoring the morphological analysis and entering *ʔačaq=qa:ɬ* as a full-form entry for a question pronoun like the English *who*, and analyzing *dudu'k* as the main predicate. This clearly goes against the analysis developed by Davidson (2002), and shows that the Matrix system is not well-suited for testing analyses like the one developed in Davidson 2002 for Wakashan languages. Still, a fragment of Makah covering some of the examples is possible to model via the Grammar Matrix. In particular, I can model examples like (534) with correct semantics. Other examples, such as (538), may be syntactically parsed using this full-form lexicon approach but the semantics will be broken, as I discuss below in the error analysis section. I did not count such examples towards treebanked coverage.

In addition to modeling words like *ʔačaq=qa:ɬ* as question pronouns (and not as main predicates), I model examples like (547) as containing an interrogative verb (§6.9). This once again forces me to ignore the morphological component of the analysis; the way I implemented morphological marking of questions (§6.8), I cannot specify an interrogative mood position class as taking as input interrogative verbs (only other kinds of verbs; this is not by design; I simply did not think of such a possibility, and interrogative verbs are added to the lexicon separately from other verbs (§7.8)). This may or may not be wrong, given that my analysis of Makah as having interrogative verbs is not consistent with Davidson's (2002) analysis anyway. If Makah needs a different analysis altogether, then Makah examples are not necessarily evidence that interrogative verbs take interrogative mood inflection.

Non-question specifications

The specification for this grammar fragment of Makah is concentrated in the lexicon and morphotactics. The language being very morphologically rich, specification for e.g. basic word order is less relevant, because in many cases, it is the order of the morphemes and the clitics (which I analyze here as morphemes) that matters. Davidson (2002) does not talk about the language in terms of the basic SVO/SOV, etc., typology. Many of my examples are one-word sentences; only a few, like (534), have a second word. I specify basic word order for this fragment of Makah as "free", simply because I do not know more about it. I specify "None" as the case system, 1st, 2nd, and 3rd person distinction, singular and plural number distinction, past and nonpast tense.

Summary of the final test suite

My test suite for Makah consists of 17 examples, 3 of them ungrammatical (constructed by me) and 1 of the 14 grammatical ones also constructed by me. Of the 13 original grammatical examples, I made the following modifications to 4 of them:

1. I "reanalyzed" example (544), as well as two other one-word sentence examples, as two words (545). In (544), I "reanalyzed" the morpheme glossed as *who* by Davidson (2002) as *what*.

   (544) ʔačaq-aˈy-quqła = qaːɫ = iɫ
   who-PL-have.as.name = CONTENT.3SG = 3PL
   'What are their names?' [myh] (Davidson, 2002, p. 286)

   (545) ʔačaqaˈy quqła = qaːɫ = iɫ
   what have.as.name = CONTENT.3SG = 3PL
   'What do they have as their name?' [myh] (Constructed based on Davidson 2002, p. 286)

   I put "reanalyzed" in scare quotes because I only did this in order to cover a small grammar fragment of Makah; there is no reason to think that it would be possible to reanalyze all of the material that Davidson (2002) has worked with this way. The purpose was to test (and in a way, stretch) the capabilities of the Grammar Matrix, not necessarily to offer an innovative analysis of Makah.

2. I added an example similar to (537), namely (546).

(546) baqi-ćak-’eːʔis = ’aƛ̓ = qaːɬ = iɬ
what-cook-going.to = TEMP = CONTENT
‘What are they going to cook?’ [myh] (Constructed based on (Davidson, 2002, p. 286))

Due to a programming bug in my additions to the customization system, when the user specifies lexical rules for interrogative marking, only one morpheme gets added as an instance of *wh-obj-lex-rule*, which is a rule necessary for sentences like (537) to parse with correct semantics, under the analysis presented in §6.8. In the instance of Makah grammar, the morpheme added as an instance of *wh-obj-lex-rule* happened to be the morpheme *ƛ̓=qaːɬ=i*. This is a programming bug, not an issue with the analysis, so I add a sentence which illustrates a working analysis. I still count (537) as lack of (treebanked) coverage but (546) helps demonstrate that the analysis is in principle possible.

Grammar performance and error analysis

The numeric results for evaluating the Grammar Matrix’s analysis of constituent questions on the Makah test suite are presented in Table 8.16.

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
14/14 (100)	11/14 (78.5)	0/3 (0)	1.93

Table 8.16: Evaluation results for Makah

The full-form lexicon approach, while not ideal in that it ignores much of the structural analysis performed by Davidson (2002), allows me to model Makah examples like (534), and indeed most other examples present in the small test suite, with correct semantics, as illustrated in Figure 8.3.

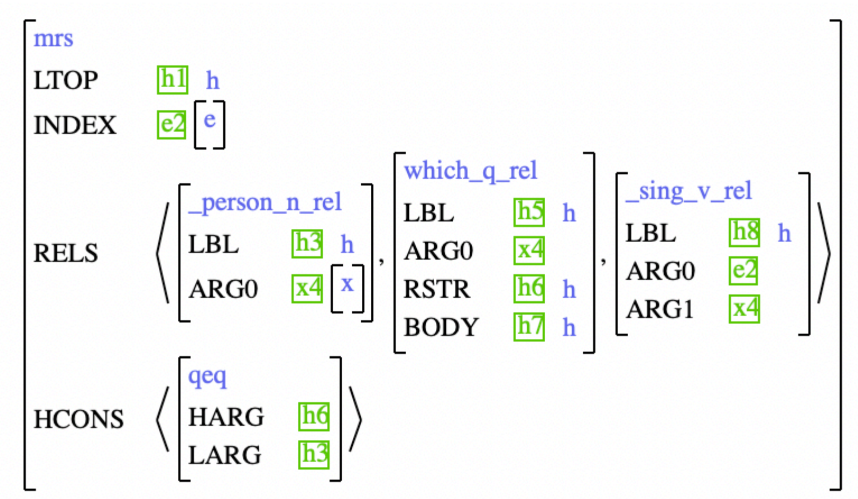


Figure 8.3: A correct MRS for (534)

Some examples cannot be modeled, however, which is expected with this full-form lexicon approach. For example, I can neither model the morphology as analyzed by Davidson (2002) in (538), nor can I just enter *wa'scu'wat=uk=qi:k* as a full-form lexical entry and get a proper semantic representation which would contain a possessive relation (Figure 8.4). There is an adnominal posssession library in the Matrix (Nielsen, 2018), and I use it successfully to model other kinds of possessive strategies (e.g. in §8.5.10), but this Makah strategy is not supported. I did not count such syntactically parsed examples towards treebanked coverage.

The grammar parses (537) in its original form to mean something like “What is going to cook you?” (Figure 8.5). This is due to a programmatic error which leads to only one morpheme ending up as a possible instance of a lexical rule. Due to this error, the sentence can only be analyzed via object drop but not subject drop. I reject this analysis in treebanking.

The main source of ambiguity (apart from the familiar adjunct attachment (§8.3.4)) is revealed by my “re-analysis” of Makah as a language which has interrogative verbs and *in situ* questions. The actual problem here is that my lexical types for interrogative verbs (363) have nonempty QUE values. This is an artifact of the stage of the analysis where I was assuming that QUE is needed on all question words. It is more likely however that QUE is only useful for tracking long-distance

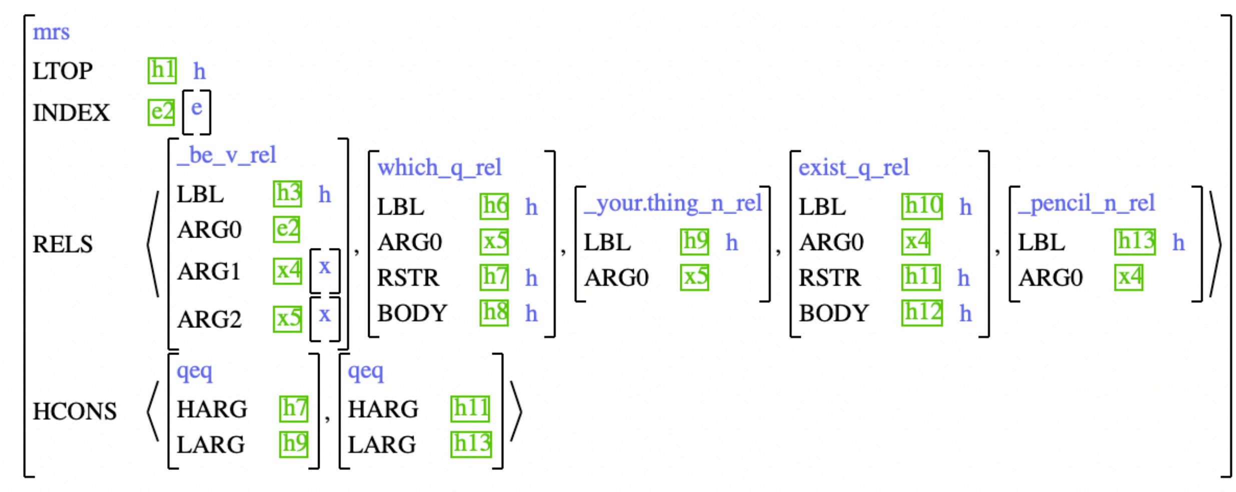


Figure 8.4: An MRS for (538) lacking the appropriate possessive relation

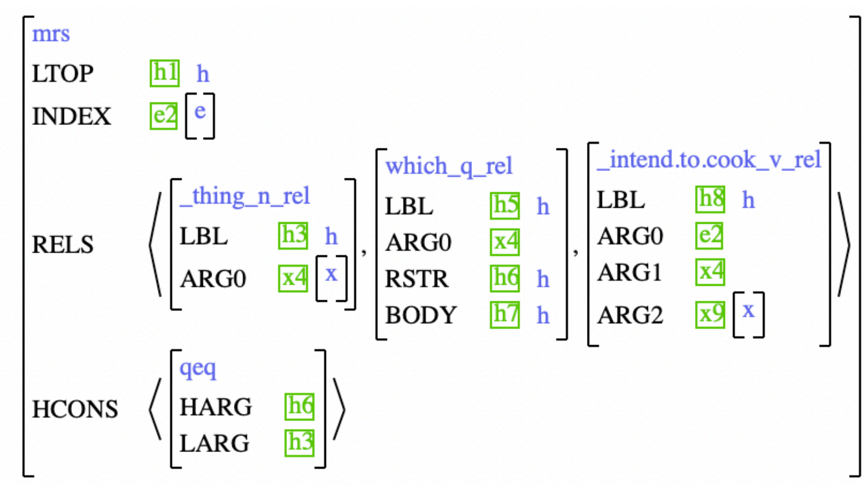


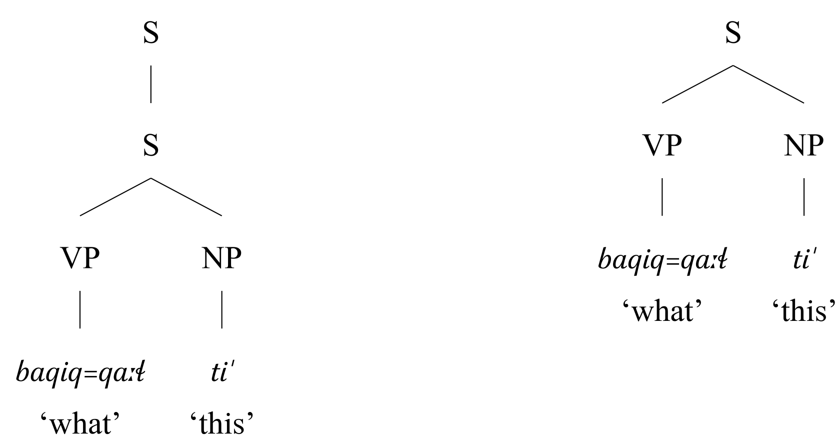
Figure 8.5: An MRS for (537), with 'which thing' corresponding to the entity which is cooking, not the one being cooked

dependencies, and repurposing it for detecting a presence of a question word in a constituent is not a robust strategy (as discussed in §6.6 and in §6.7.3). The interrogative verb is the main predicate and as such it probably does not make sense for it to have a nonempty QUE value (that would mean, it can form a LDD with itself). As is, while I rely on the *in situ* analysis to licence (534) and on interrogative verb analysis to license (547), in many cases, such combination of analyses in one grammar leads to two trees (with the same MRS), as illustrated in (548a) and (548b) for sentence (547).

(547) baqiq = qa:ɬ ti'
what = CONTENT.3SG DEM
'What is this?' [myh] (Davidson, 2002, p. 285)

(548)

a. b.



This shows that while it is possible to obtain correct semantics for some sentences, the analysis is problematic even in such a small fragment (not to mention the completely different take on the language structure developed by Davidson (2002)), where question words are always predicates. Ultimately, the takeaway is that the Grammar Matrix currently is poorly suited for modeling Wakashan languages.

8.5.8 Pacoh (Austroasiatic)

Pacoh [pac] (Austroasiatic) is a Mon-Khmer language spoken in Vietnam. The basic word order is SVO; there is no morphological case marking system; there is a distinction between 1st, 2nd, and 3rd person (Alves et al., 2006, p. 3). In terms of the structure of the noun phrase, some

[37] In Pacoh, it is common to address people in third person instead of second person.

classifiers can precede nouns but generally modifiers follow nouns they modify.

Overview

Constituent questions in Pacoh tend to be formed by fronting the question word (549) but can remain *in situ* (550).[37]

(549) ʔa.məh ʔi.pɛ caː
what 3P do
'What did they (=you all) do?' (Alves et al., 2006, p. 62)

(550) ʔi.pɛ caː ʔa.məh
3P do what
'What did they (=you all) do?' (Alves et al., 2006, p. 62)

In *why*-questions, the question word is always fronted (551)–(552).

(551) viːʔi.mɔ ʔa.caːj pən hɨk lɨː
why SPMY wait much very
'Why are you waiting so long?' (Alves et al., 2006, p. 49)

(552) *ʔa.caːj pən hɨk lɨː viːʔi.mɔ
SPMY wait much very why
Intended: 'Why are you waiting so long?' (Constructed based on Alves et al. 2006, p. 49)

Polar questions are formed with intonation and can also be marked by a particle (553).

(553) maj cɔːm dɔː ʔat tu.mɔː ləjʔ
2S know 3S located where no
'Do you know where he is?' (Alves et al., 2006, p. 62)

The particle occurs in all examples of polar questions that I found in Alves et al. 2006.

In Pacoh, classifiers (e.g. *kən, lam*) and demonstrative pronouns (*ʔn.nɛh*) usually follow nouns (562) but it is not always the case (555)–(556).

(554) ʔi.mɔː ʔi.sər kəm.pɔŋ ʔn.nɛh
how one-climb ladder this
'How does one climb this ladder?' (Alves et al., 2006, p. 49)

(555) ʔa.caːj ʔn.taːŋ li.mɔː kən
SPMY weigh how.many kg
'How many kilos do you weigh?' (Alves et al., 2006, p. 73)

(556) ʔiɲ pləj lam ʔm.mɔː
want buy UNIT which
'Which one will you buy?' (Alves et al., 2006, p. 64)

Ungrammatical examples

Alves et al. (2006) provide some ungrammatical examples as well as some clear statements about what is not possible. I include three ungrammatical examples in the final test suite, one directly from Alves et al. 2006 illustrating that only the animate word meaning *who* can occur in possessive constrictions (557) and two constructed based on the statement that the word meaning *why* is always fronted (559)–(560).

(557) *ʔn.nɛh ʔn.dɔ ʔn.məh
this poss.-of what
Intended: 'What does this belong to?' (Alves et al., 2006, p. 64)

(558) viːʔi.mɔ ʔa.caːj pən hɨk lɨː
why SPMY wait much very
'Why are you waiting so long?' (Alves et al., 2006, p. 49)

(559) *ʔa.caːj pən hɨk lɨː viːʔi.mɔ
SPMY wait much very why
Intended: 'Why are you waiting so long?' (Constructed based on Alves et al. 2006, p. 49)

(560) *hɨk lɨː ʔa.caːj pən viːʔi.mɔ
much very SPMY wait why
Intended: 'Why are you waiting so long?' (Constructed based on Alves et al. 2006, p. 49)

Furthermore, I add an example illustrating the impossibility of the polar question particle in constituent questions, though Alves et al. (2006) do not explicitly say so (but it can be inferred).

(561) *ʔa.məh maj pa.piː ləjʔ
what 2s discuss Q
Intended: 'What are you talking about?' [pac] (Constructed based on Alves et al. 2006, p. 42,86)

Summary of the final test suite

The test suite of Pacoh I use in evaluation consists of 30 examples, 4 of them ungrammatical. Of the 4 ungrammatical examples, 1 comes directly from Alves et al. 2006 and 3 I constructed as explained above. Of the 26 grammatical examples, 25 are in their original form and 1 is constructed as described below.

The only modification to the examples from Alves et al. 2006 is that I add a version of example (562) without the determiner (563). I know (562) will not be parsed as is because I did not specify noun-determiner head-initial order, and I will count (562) towards lack of coverage, but I want to see that the basic pattern without the determiner is covered.

(562) ʔi.mɔː ʔi.sər kəm.pɔŋ ʔn.nɛh
how one-climb ladder this
'How does one climb this ladder?' (Alves et al., 2006, p. 49)

(563) ʔi.mɔː ʔi.sər kəm.pɔŋ
how one-climb ladder
'How does one climb a ladder?' (Constructed based on Alves et al. 2006, p. 49)

Question specifications

In the questionnaire, I specify Pacoh as a language with optional single fronting (as there are no examples of multiple questions in Alves et al. 2006) and obligatory noun pied-piping. I specify the clause-final question particle for polar questions, impossible in constituent questions.

Non-question specifications

I specify SVO word order, no case system, 1,2,3 person distinction, singular and plural number, and animate/inanimate gender distinction. I enter classifiers and demonstrative pronouns as determiners; this is probably not ideal, but serves as a useful approximation in the semantics. Because of that, I cannot model Pacoh's variable order in the noun phrase; the Grammar Matrix forces me to choose either head-initial or head-final order for nouns and determiners (nouns being heads). Because my focus is on constituent questions in the test suite, I choose head-final order for the noun phrase (more of the test suite examples have that order).

In the lexicon, I enter four words in five different examples, e.g. *ho̯ːj ʔn.nɛ* in (564), into the lexicon as one word with a space in it. In the case with (564), I do this because, if I specify two separate entries for *this* (a determiner) and *time* (a noun), while they would form a noun phrase, Matrix-derived grammars cannot yet license noun phrases as adverbial modifiers. So I enter both words with a space as an "adverb".

(564) ho̯ːj ʔn.nɛh ʔi.pɛː tu.mo̯ŋ ʔi.mɔː
time this 2P live how
'How are you living now?' (Alves et al., 2006, p. 49)

In another case, I take *ʔŋ.koh ʔa.ʔaj* to mean something like 'feel pain in...', and analyze it as a transitive verb. It is not that different from the first free translation offered in Alves et al. 2006, but it does require combining two words into one and ignoring the 'that' gloss for *ʔŋ.koh*.

(565) ʔa.ʔɛm ʔŋ.koh ʔa.ʔaj ʔa.məh
3S.SOC that sick what
'Where does it hurt?' ('What is her sickness?') (Alves et al., 2006, p. 65)

One final note is due regarding clausal complements specification. I specify a clausal complementation strategy for embedding questions, as described in §7.4. Pacoh does not use a complementizer, and without the complementizer, this specification in Pacoh helped me discover a bug in the interaction of the clausal complements and the polar questions libraries. If a language specifies VO word order, some clausal complementation strategy which involves either no complementizer or a complementizer which comes before the clausal complement, and at the same time it specifies clause-final question particles, the customization system produces a broken grammar which does not load into the parsing software and cannot parse anything at all. I discuss this issue below in the error analysis section. Meanwhile, it is possible to avoid this bug in the particular grammar of

Pacoh by adding a nonexistent complementizer to it (which will not be in the test suite and will never actually participate in any of the analyses of the Pacoh sentences). This is what I did in order to be able to look at some analyses of Pacoh sentences. For a language which actually does have a complementizer however, if that complementizer comes before clausal complements, such a "hack" would not work, and in order to parse any sentences at all, I would have to forego specifying either the question particle or clausal complements, thus losing the corresponding coverage in the test suite.

Grammar performance and error analysis

The numeric results for evaluating the Grammar Matrix's analysis of constituent questions on the Pacoh test suite are presented in Table 8.17.

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
25/26 (96.2)	21/26 (84.6)	2/4 (50)	1.6

Table 8.17: Evaluation results for Pacoh

The sentence with the determiner following the noun (562) is not parsed, as was expected. Given that the *wh*-determiner usually precedes the noun and is not always fronted (555), it seems like there would need to be a way to model flexible determiner-noun order in the Grammar Matrix to capture these facts, or alternatively to analyze the words I treated as determiners here as adjectives.

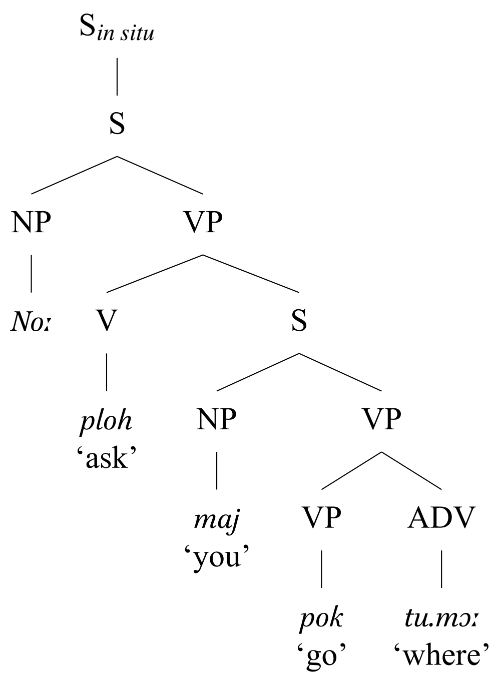
Three more parses are rejected at the treebanking stage. Two are the *why*-questions, for the same reasons as described in §8.5.6 (the MRS for *why* is close to being correct but is not quite). The other parse that I reject is that of (566), and it reflects the problem in the optional fronting analysis which also manifests itself in the Russian grammar.

(566) Noː ploh maj poːk tu.mɔː
NAME ask 2S go where
'Nô asked, "Where are you going?" (Alves et al., 2006, p. 100)

The grammar assigns an analysis to (566) which results in both event variables, one associated with the main verb ‘ask’ and one with the embedded verb ‘go’, to have the sentential force value *ques*. Only the variable associated with the embedded verb should have that value; the one associated with the main verb should be *prop-or-ques*.

This is happening because of the awkward analysis of clause-embedding verbs mentioned in §8.3.2 and described in more detail in Appendix A. One flaw of that experimental analysis is that it attempts to rule out some ambiguity in complex clauses by insisting that the *in situ* rule always attaches high in sentences like (566), as shown in (567).[38]

(567)



The analysis in (567) makes it impossible to model a proposition embedding an *in situ* question in Pacoh and should be revised in the future.[39]

Overgeneration for Pacoh is 50% which means two out of four examples. The ungrammatical

[38]This is done with the WH feature constraint which is + on the question-embedding verb and is, in this grammar, customized − on the mother of the *in situ* phrase. Neither of these things ultimately makes sense; question-embedding verbs should be able to embed polar questions and the *in situ* phrase should probably always just inherit the daughter’s WH value, which means it should always be +. This is a broken analysis of question embedding.

[39]A question embedding a question will in fact have correct semantics, under this analysis (modulo the issue with question parameters which I talk about in §4.2.1 regarding example (138)).

examples admitted by the Pacoh grammar are the ones with the *why*-adverb *in situ* (559). Since the questionnaire does not allow the user to specify fronting obligatoriness on the word level, it was not possible to model this contrast. Ambiguity is due to adverb attachment (§8.3.4).

Finally, as mentioned in the non-question specification section above, Pacoh helped identify a bug in the interaction of question particles and subordinator complementizers analysis. If the specification features a clausal complementation strategy which does not have a complementizer that comes after the complement and at the same time features a clause-final question particle, the system outputs a broken grammar. The grammar is broken because it ends up having conflicting HEAD values on the mother and the head daughter of the complement-head rule. The faulty logic in the customization system was intended to rule out complementizers from attaching after the clausal complement in languages where clause-final particles were possible. The result is that certain specifications which are typologically possible lead to broken grammars. In my Russian grammar, this works out because the question particle there is a modifier, not a complementizer. As a result, the types the customization system puts on the complement-head rule, *+nvjrcdmo* and *+nv*, are compatible with each other (568). But a Pacoh specification (which does not include a "hacky" nonexistent complementizer which would attach the same way as the question particle actually does) reveals the problem in the logic (569).

(568) $\begin{bmatrix} \textit{comp-head-phrase} & \\ \text{SYNSEM|LOCAL|CAT|HEAD} & \textit{+nvjrcdmo} \\ \text{HEAD-DTR|SYNSEM|LOCAL|CAT|HEAD} & \textit{+nv} \end{bmatrix}$

(569) $\begin{bmatrix} \textit{comp-head-phrase} & \\ \text{SYNSEM|LOCAL|CAT|HEAD} & \textit{comp} \\ \text{HEAD-DTR|SYNSEM|LOCAL|CAT|HEAD} & \textit{+nv} \end{bmatrix}$

If question particles are treated as complementizers, then allowing a question particle to attach after the complement while disallowing a subordinator complementizer from doing so is not possible to do via the HEAD value.[40] It should be done by using other features, perhaps along

[40]The fact that the customization system produces the broken type even when no complementizers are specified is a programming bug. That could be easily fixed and does not have anything to do with the analysis. The issue with different attachment still stands though.

the lines of how INIT is used to model different attachment of different complementizers in the clausal complements library (Zamaraeva et al., 2019).

8.5.9 Paresi-Haliti (Arawakan)

Paresi-Haliti is an Arawakan language spoken in Brazil. The reference grammar by Brandão (2014) features a number of long, complex examples which include constituent questions, giving material for testing Grammar Matrix libraries interactions. At the same time, this reference grammar provides an interesting case for testing some hypotheses which are work in progress. For example, many examples are not yet fully glossed; the word order is said to be mostly V-final (the most common order being SOV), yet personal pronouns can clearly occur after the verb, and indeed if they are taken into account, then, according to another source, da Silva 2013, the most frequent word order in the language is SVO. The exact nature of the interaction of information structure with word order is not fully worked out, though there is a section on focus and topic and many examples are glossed for information structure marking.

It is clear from the start that filling out the questionnaire with the basic word order being SOV is not going to lead to perfect coverage over the test suite. But that is exactly what the Grammar Matrix system is about: it allows the user to evaluate a particular set of hypotheses with respect to the test suite and provides some structure for further elicitation (which examples it would be good to have in the test suite which are not yet there). Later, after the overview of the phenomena illustrated by the test suite, I present test results for two alternative specifications of Paresi-Haliti, representing two sets of hypotheses, one associated with SOV word order and another with free word order.

Overview

SOV order is common (570), though other orders are possible, including when the meaning can be disambiguated from semantics or pragmatics (571). SVO order is common with free personal pronouns (572).

(570) ena balazoko waiya
man bottle see
'The man saw the bottle' [pab] (Brandão, 2014, p. 318)

(571) balazoko ena waiya
bottle man see
'The man saw the bottle/*The bottle saw the man' [pab][41] (Brandão, 2014, p. 318) [pab] (Brandão, 2014, p. 318)

(572) zala hayto aza-ita hitso
who that ask-IFV you
'Who was asking you?' (Brandão, 2014, p. 332)

Question words in Paresi-Haliti usually front (573) except in some cases when another constituent is in focus or topicalized (574).

(573) zoana=ite wi=koke wa=moka
INT=FUT 1PL=uncle 1PL=put
'What are we going to do with our uncle?' (Brandão, 2014, p. 339)

(574) kazatarene ala zoare
? FOC what
'kazatarene, what is it?' (Brandão, 2014, p. 333)

Information structure is marked with clitics, and all information-structure-marked constituents tend to occur clause initially.

Polar questions are formed by intonation (575), although occasionally there may be a clause-initial question particle (576). The use of the particle in polar questions is rare (Brandão, 2014, p. 338).

(575) nali kotyoi 0=aitsa-ha
there tapir 3SG=kill-PL
'Did they kill a tapir here?' (Brandão, 2014, p. 338)

(576) zoana Dora 0=zane-heta
INT PN 3SG=go-PERF
'Did Dora go away?' (Brandão, 2014, p. 339)

[41] Brandão (2014) uses the asterisk (*) to mean pragmatically odd here.

I found no multiple questions nor embedded questions, although there is one example where a question is embedded in direct speech (577). There is one example of what looks like at least two coordinated question sentences (578).

(577) kohtse-nae 0=nea-hena zoana kore wi=tsaona
fish-PL 3SG=say-TRS what DUB 1PL=live
'The fish asked themselves "What should we do?".' (Brandão, 2014, p. 157)

(578) wi=hinae-hare-nae 0=zane-ta kala aliyo 0=zane-ta-ha zoana
1PL=relatives-MASC-PL 3SG=go-EMPH DUB where 3SG=go-IFV-PL what
0=ha-h-ita-ha zamani haiya Tangara 0=zane-ta haiya Sapeza
3SG=work-PL-IFV-PL DUB IND2 Tangara 3SG=go-EMPH IND2 Sapeza
0=zane-ta
3SG=go-EMPH
'Our relatives are going, and I do not know where they are going. I do not know whether they are working. Some people go to Tangara, others go to Sapeza.' (Brandão, 2014, p. 103)

How-, *where-* and *why-* questions constitute a large portion of the constituent question examples in the reference grammar. Of the 45 examples I found in the reference grammar, 21 are adverb questions.

Question words can be marked overtly for focus (579).

(579) aliyakere=ta=la hatyohare
how=EMPH=FOC this
'How is this?' (Brandão, 2014, p. 335)

This fact determines which examples I construct in addition to the 45 examples I found in the reference grammar, as explained just below.

When I added adverbs to the Grammar Matrix as part of the support for the constituent questions library (§7.2.1), I did not at the same time extend the functionality of the information structure library so as to allow focus/topic marking on adverbs. So, the library only allows the user to specify such marking on nouns and verbs. Unfortunately, the Paresi-Haliti examples mostly show the information structure marking on adverbs (580).

(580) alyako=atyo=ala Bere zane
where=TOP=FOC PN go
'Where did Pedro go?' (Brandão, 2014, p. 334)

There are five such examples among all of the constituent question examples I found in Brandão 2014, and there is only one example of focus marking on a noun (and another one for which the word marked for focus is not glossed).

To illustrate Brandão's (2014) hypotheses that focus marking occurs on both question and non-question words and that constituents marked as such occur clause-initially, I construct and add to the test suite grammatical examples as follows (581)–(584).

(581) zoare =ala 0=nema-ita
who =FOC 3SG=sleep-IFV
'Who is sleeping?' [pab] (Constructed based on Brandão 2014, p. 334.)

(582) zola koreta 0=iriko-ita
who bamboo 3SG=cut-IFV
'Who is cutting bamboo?' [pab] (Constructed based on Brandão 2014, p. 333.)

(583) zola =ala koreta 0=iriko-ita
who FOC bamboo 3SG=cut-IFV
'Who is cutting bamboo?' [pab] (Constructed based on Brandão 2014, p. 333.)

(584) koreta =ala zola 0=iriko-ita
bamboo FOC who 3SG=cut-IFV
'As for the bamboo, who is cutting it?' [pab] (Constructed based on Brandão 2014, p. 333.)

Ungrammatical examples

One ungrammatical example is given explicitly in Brandão 2014 (585).

(585) *alyako zawati
where axe
Intended: 'Where is my axe?' (Brandão, 2014, p. 334)

It illustrates that the word *akyako* ('where') cannot be used in a sentence which lacks a verb predicate, in contrast to the word *aliyo* which Brandão (2014) glosses like a verb, 'where.is' (recall the interrogative verb gloss ‘be.where’ from Hagège 2008, §6.9) (586).

(586) aliyo zawati
where.is axe
‘Where is my axe?’ (Brandão, 2014, p. 334)

I add two more ungrammatical examples to illustrate that constituents marked for focus must be clause-initial and that otherwise a question word must be fronted (587)–(588).[42]

(587) *zola koreta = ala 0 = iriko-ita
who bamboo 3SG = cut-IFV
Intended: ‘Who is cutting bamboo?’ [pab] (Constructed based on Brandão 2014, p. 333.)

(588) *koreta zola = ala 0 = iriko-ita
bamboo FOC who 3SG = cut-IFV
Intended: ‘Who is cutting bamboo?’ [pab] (Constructed based on Brandão 2014, p. 333.)

Summary of the final test suite

The test suite which I use for evaluation consists of 67 items, 64 of them grammatical. Out of those 64, 45 are directly from Brandão 2014, 22 have modifications or were constructed as described below. Of the 3 ungrammatical examples, 2 are constructed by me and 1 is from Brandão 2014.

The modifications to the original examples are documented below. All of the original examples are also included in the test suite. I did not, at the time of this writing, have these constructed examples vetted by a native speaker, nor by a Paresi-Haliti expert.

1. I added an example based on (615) but with no clausal modifier, to inspect the analysis separately:

   (589) zoare = ite hi = ximarene 0 = tyom-ita
   what = FUT 2SG = youngest.brother 3SG = do-IFV
   ‘What will your brother be doing?’ [pab] (Constructed based on Brandão 2014, p. 290)

[42] Example (588) should be only parsed with the pragmatically strange meaning ‘Whom is the bamboo cutting?’.

2. In two cases, I added corresponding examples without the "connector" *hoka* (a discourse marker, for which there is no analysis in the Grammar Matrix) in e.g. (615).

3. I added several examples without greetings, direct addresses, etc, corresponding to examples like (590)–(591).

(590) zoare ha = maira-ita nozai
what 2SG = fish-IFV my.nephew
'What are you fishing my nephew?' (Brandão, 2014, p. 332)

(591) zoare ha = maira-ita
what 2SG = fish-IFV
'What are you fishing?' (Constructed based on Brandão 2014, p. 332)

4. I added an example similar to (592) but without the causative (593), to separate the valence change phenomenon:

(592) zala nika aikoli aroma-ita
who ? tooth fix-IFV
'Who is having his tooth fixed?' [pab] (Brandão, 2014, p. 332)

(593) zala aikoli aroma-ita
who tooth fix-IFV
'Who is fixing the tooth?' [pab] (Constructed based on Brandão 2014, p. 332)

5. I added a version of example (611) without the (parenthetical?) *say*:

(594) zoare = kakoa kani z = ezoa-ki-heta natyo z = aoka
what = COM ? 2PL = fall-CAUS-PERF 1SG 2PL = say
'With what can you all make me go down again?' (Brandão, 2014, p. 333)

(595) zoare = kakoa kani z = ezoa-ki-heta natyo
what = COM ? 2PL = fall-CAUS-PERF 1SG
'With what can you all make me go down again?' (Brandão, 2014, p. 333)

6. The "dubitative" particle often goes right after the question word (in which case the word can be entered in the lexicon with it) but can occur in other places, where it cannot be

accounted for via the Matrix questionnaire, and it is not a required particle. I added a version of (614) without it (597):

(596) zoare en = eare ka
what 3SG = name DUB
'What is your name?' (Brandão, 2014, p. 333)

(597) zoare en = eare
what 3SG = name
'What is your name?' (Brandão, 2014, p. 333)

7. I split example (598) as (599) and (600):

(598) aliyakere-ta = la hatyo-hare maiha zala 0 = hikoa-re-ha
how-EMPH = FOC that-NMLZ NEG who 3SG = come.out-MNLZ-PL
e = -om-ana aliyakere = ala hatyo-hare 0 = tsema-ha-ti-ye
3SG = -LK-BEN how = FOC that-NMLZ 3SG = HEAR-PL-UNPOSS-NMLZ
'How did they hear that thing? Nobody arrived to (tell) them, how is that?' (Brandão, 2014, p. 96)

(599) aliyakere-ta = la hatyo-hare
how-EMPH = FOC that-NMLZ
'How is that?' (Brandão, 2014, p. 96)

(600) aliyakere = ala hatyo-hare 0 = tsema-ha-ti-ye
how = FOC that-NMLZ 3SG = HEAR-PL-UNPOSS-NMLZ
'How did they hear that thing?' (Brandão, 2014, p. 96)

8. I removed the additional (relative? complex noun modifier?) clause from (601):

(601) zoare halani no = tyonakiri-nae 0 = tiya-ko-tya-ita no = taholo-ni
INT ? 1S = descendant-PL 3SG = cry-LOC-TH-IFV 1S = toy?-POSSED
ni = tyako
1SG = stomach
'What are my descendants, toys crying in my stomach? (Brandão, 2014, p. 277)

(602) zoare halani no = tyonakiri-nae
INT ? 1S = descendant-PL
'What are my descendants? (Brandão, 2014, p. 277)

9. I added two examples based on the coordinated (603):

(603) aliyakere zamani ha = ferakene wi = tyaona-ita zoare zamani wi = tyoma-hena
how DUB 3S = day 1P = live-ITA INT DUB 1P = do-TRS
'[she wants to know] How we live our daily routine, what we do' (Brandão, 2014, p. 310)

(604) aliyakere zamani ha = ferakene
how DUB 3S = day 1P = live-ITA
'How do we live our daily routine' (Constructed based on Brandão 2014, p. 310)

(605) wi = tyaona-ita zoare zamani wi = tyoma-hena
INT DUB 1P = do-TRS
'What do we do' (Constructed based on Brandão 2014, p. 310)

10. I constructed (607) and (608)–(609) based on the quite complex (606).

(606) wi = hinae-hare-nae 0 = zane-ta kala aliyo 0 = zane-ta-ha zoana
1PL = relatives-MASC-PL 3SG = go-EMPH DUB where 3SG = go-IFV-PL what
0 = ha-h-ita-ha zamani haiya Tangara 0 = zane-ta haiya Sapeza
3SG = work-PL-IFV-PL DUB IND2 Tangara 3SG = go-EMPH IND2 Sapeza
0 = zane-ta
3SG = go-EMPH
'Our relatives are going, and I do not know where they are going. I do not know whether they are working. Some people go to Tangara, others go to Sapeza.' (Brandão, 2014, p. 103)

(607) aliyo 0 = zane-ta-ha zoana 0 = ha-h-ita-ha
where 3SG = go-IFV-PL what 3SG = work-PL-IFV-PL
'Where are they going, what do they do for work?' (Constructed based on Brandão 2014, p. 103)

(608) aliyo zane-ta-ha
where go-IFV-PL
'where are they going?' (Constructed based on Brandão 2014, p. 103)

(609) zoana ha-h-ita-ha
what work-PL-IFV-PL
'What do they do for work?' (Constructed based on Brandão 2014, p. 103)

11. I added the direct speech question from (577) separately (610).

(610) zoana kore wi = tsaona
what DUB 1PL = live
'What should we do?' (Constructed based on Brandão 2014, p. 157.)

12. Finally, I added 2 examples illustrating information structure-marked word order, as described above in the Overview section.

Question specifications

I specify Paresi-Haliti as requiring single obligatory fronting of question phrases and as having a clause-initial question particle. Because the Matrix currently does not allow the user to specify information structure marking on adverbs, I enter the adverbs bearing focus marking (580) as full-form, in order to get some kind of structure for the sentences containing them.

In (611), while I could create a (non-contentful) lexical rule to add *=kakoa* as an inflection, it acts more like a postposition (and occurs as a separate word in other examples), so I specify it as such.

(611) zoare = kakoa kani z = ezoa-ki-heta natyo z = aoka
what = COM ? 2PL = fall-CAUS-PERF 1SG 2PL = say
'With what can you all make me go down again?' (Brandão, 2014, p. 333)

Non-question specifications

For the first experiment (see Tables 8.18–8.19), I specify the word order as SOV; for the second, I specify free word order. All other specifications are the same. In particular, I specify clause-initial focus and clitic (modifier) focus markers on the Information Structure questionnaire subpage; in the test suite, the clitics are sometimes written as attached to the word and other times as not. I normalize the test suite so that there is always a space between the word and the clitic.

I specify asyndeton noun and sentence coordination, as an analysis of examples like (612) and (613). (Note that this ultimately adds considerable ambiguity to the grammar.)

(612) zoare 0 = tyaona n = akero koko ityani
what 3SG = be 1SG = aunt uncle child
'What is the child of my aunt and uncle?' (Brandão, 2014, p. 146)

(613) aliyo 0 = zane-ta-ha zoana 0 = ha-h-ita-ha
where 3SG = go-IFV-PL what 3SG = work-PL-IFV-PL
'[I do not know] where they are going, whether they are working.' (Constructed based on Brandão 2014, p. 103)

Paresi-Haliti has NP predicates (614). The Grammar Matrix does not support NP predicates, but I can specify lexical entries for "intransitive verbs".

(614) zoare en = eare are-ka
what 3SG = name ?-DUB
'What is your name?' (Brandão, 2014, p. 333)

Such "verbs" have semantics like _be.one's.name_v_rel. This analysis is not ideal in that it requires an additional lexical entry with awkward semantics, but my goal here is merely to cover examples like (614) to some extent, at least parsing them as constituent questions. The proper analysis of NP predicates is simply not yet included in the Matrix.

There is one example of a clausal modifier in the test suite (615).

(615) zoare = ite hi = ximarene 0 = tyom-ita wa = hikoa-hene-re hoka
what = FUT 2SG = youngest.brother 3SG = do-IFV 1PL = come.out-TRS-NMLZ CON
'What will your brother be doing when we arrive?' [pab] (Brandão, 2014, p. 290)

It is possible to specify a nominalization clausal modification strategy in the Matrix (Howell et al., 2018; Howell and Zamaraeva, 2018), which I do, though this leads to spurious ambiguity and overgeneration in the grammar due to underspecification of nonlocal features in both the nominalization and the subordination rules, which is a result of undertested interactions between the (fairly complex) libraries.

Grammar performance and error analysis

The numeric results for evaluating the Grammar Matrix's analysis of constituent questions on the Paresi-Haliti test suite are presented in Table 8.18, for the SOV word order specification, and in

Table 8.19, for the free word order specification.

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
37/64 (57.8)	23/64 (35.9)	2/3 (66.7)	31.65

Table 8.18: Evaluation results for Paresi-Haliti, SOV word order

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
53/64 (82.8)	36/64 (56)	2/3 (66.7)	36.17

Table 8.19: Evaluation results for Paresi-Haliti, free word order

There is a big difference in coverage between the SOV and the free word order grammar, which is expected. In addition, it can immediately be seen that, on a bigger test suite with more interacting phenomena, problems in the analyses become apparent. In this test suite, it is the interaction of information structure with word order that lacks an appropriate analysis both in the previous analysis of information structure in the Matrix and in my analysis of constituent questions added to it. In addition, the test suite helped uncover a bug in *extracted-adj-phrase* (199), as I specified it in `matrix.tdl`. As for ambiguity and overgeneration, which are severe, they are due mostly to underspecified nonlocal features in several libraries (see (530) for a related example).

Coverage with SOV The SOV grammar does not parse almost half of the examples, and the parses are correct (have correct semantics) in only about one third of the cases. The categories of examples which do not get a correct parse and the corresponding problems are summarized below.

Several of examples (5) simply contain words which are either not glossed or I was otherwise unable to analyze them; I did not enter such words in the lexicon (except in cases where it seemed possible that they could be part of the question phrase, in which case I entered them, with spaces, as a full-form entry for the question word). Such examples are not parsed on the lexical level. In other cases, the word, such as a proper noun, is in the lexicon but if it is used as a greeting, there is no way for the grammar to come up with an analysis for the sentence (3 more examples).

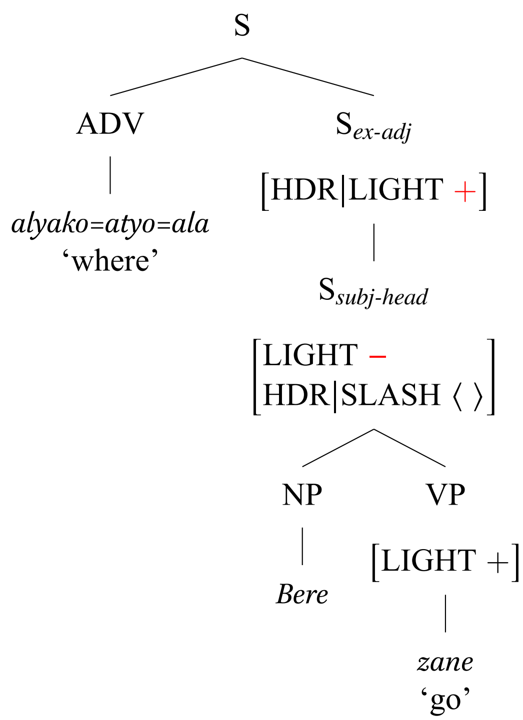
Examples where nouns (612) or personal pronouns (616) occur after the verb are not parsed. Neither the SOV word order nor the additional OSV order which is made possible by the information structure library cover that, so there is nothing unexpected here. Brandão (2014) does not offer an analysis of this word order, though she does clearly say that personal pronouns occur in this position. There are 9 such examples in the test suite.

(616) zala hayto aza-ita hitso
who that ask-IFV you
'Who was asking you?' (Brandão, 2014, p. 332)

As mentioned upfront in this section, specifying SOV plus information structure-marked word order for Paresi-Haliti uncovers two major problems which together block the grammar from parsing many simple constituent question examples, including all where the object or an adjunct is extracted from a transitive clause. The first problem is in my analysis of adjunct extraction and the second is in the interaction of my analysis of question phrase fronting with Song's (2014) analysis of information structure-marked fronting.

First of all, as mentioned in §6.3.1 in a footnote regarding the type *extracted-adj-phrase* (199), there is actually a [LIGHT +] constraint on the head daughter of the adjunct extraction rule that is currently in `matrix.tdl`. Apart from being mentioned in a footnote, that constraint is not shown in (199) because it is an artifact of not a fully developed analysis and, while I added it in order to get better results on some development languages, I did not fully conceptualize it at the time. The constraint did not cause problems with any of the development grammars, which did not include an SOV grammar with obligatory fronting and information structure of any kind (see §9.4 for related discussion). With SOV word order, however, because of that constraint, the adjunct extraction rule cannot apply to a constituent formed by e.g. a word and its overt subject. The situation is illustrated in (617).

(617)



The problem illustrated in (617) does not arise in languages where the subject-head rules can take SLASH-ed head daughters, because then the adjunct extraction rule can apply lower (in this case, at the VP level). However, in this grammar, the information structure library constrained the head daughter of the subject-head rule to have an empty SLASH list (presumably to rule out some ambiguity associated with additional word orders which the library provides to grammars in which this constraint is included, though I have to leave the investigation to future work). This interaction of the two libraries was not anticipated before the evaluation stage. As a result, even simple examples like (580) are not parsed. The Paresi-Haliti test suite has lots of examples with question adverbs, and this problem in my analysis costs significant coverage to the SOV grammar.

The same empty SLASH constraint added to this grammar by the information structure library causes more than just the problem illustrated in (617). It prevents many sentences, e.g. (589), from parsing under my analysis of fronting which requires, for an SOV word order, that the complement be extracted first and then the subject-head apply higher in the tree, taking a SLASH-ed head daughter. Working on the interaction of the information structure and the constituent questions library is an important, complex, and interesting task which I hope will be undertaken separately in the future.

To account for the contrast between (586) and (585), I specified *aliyo* as a question verb ('be.where'), however such examples feature V-initial word order, and that order is ruled out by the Matrix-generated grammar which only allows SOV (as basic word order) and OSV (as information structure-marked word order).

The SOV grammar does not parse example (584) correctly. It assigns it a structure where the subject is extracted and fronted, not the complement, because of the aforementioned problem with the subject-head phrase not allowing head daughters from which a complement was extracted.

Coverage with free word order Beyond the same items that cannot be parsed because one or more words in the sentence do not get any analysis (e.g. greetings, discourse markers), the free word order grammar cannot parse only 2 sentences (which the SOV grammar also does not cover). Both seem to be special kinds of utterances which do not have a verb, one presented here as (618).

(618) zoane-re koho
INT-NMLZ basket
'How much is the basket?' (Brandão, 2014, p. 336)

On the surface, the free word order grammar covers a lot more compared to SOV, which is expected, as it admits more orders. Treebanked coverage is another matter, however. Many of the parses do not correspond to the right semantics, and so the validated coverage of the grammar, while still greater than that of the SOV grammar, is more modest.

Examples with determiner meaning *whose* (619) do not have possessive relations in the MRS; only a predication _whose_q_rel (compare Figure 8.6 to Figure 8.7).

(619) zala ityani eze
who son this
'Whose son is he?' (Brandão, 2014, p. 332)

---

[43]Note that the system can in fact model *whose* questions, as I discovered by accident at a later stage, while working with the Jalkunan grammar (§8.5.10). It was not possible for me to make any changes to the Paresi-Haliti grammar presented here at that stage, due to time constraints.

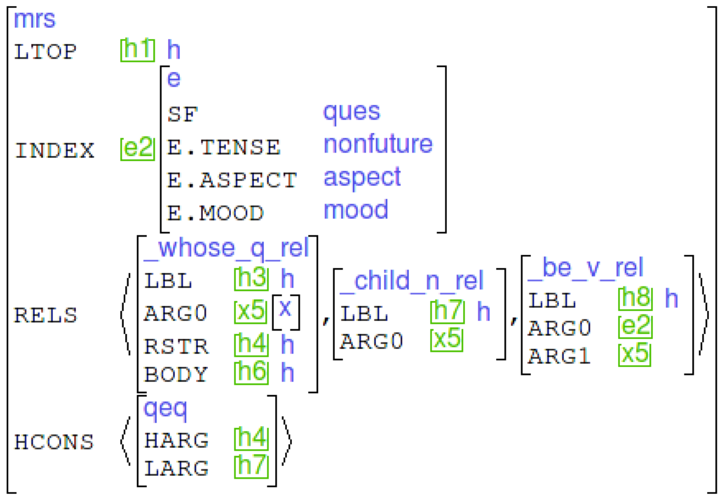


Figure 8.6: An MRS given by the Matrix grammar for sentence (619).

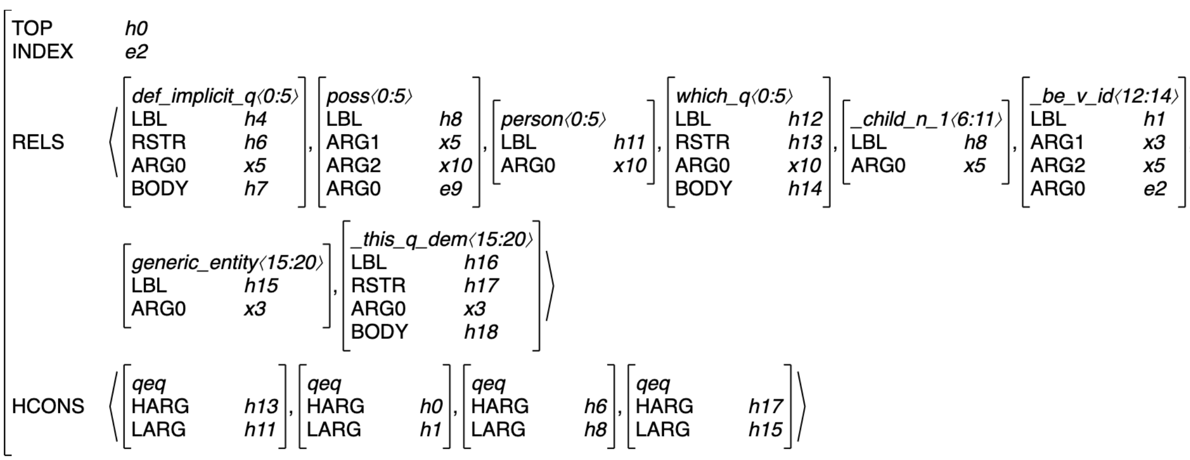


Figure 8.7: An MRS given my the ERG for sentence *Whose child is this?*.

There is also the not-quite-correct semantics for the main predicate, but that is not related to the analysis of questions. I reject such parses as not really yielding the semantics associated with the Matrix analysis of adnominal possession, which is like the ERG in that it must include a _poss_rel.[43]

Similarly (and like all the grammars described here), the *why*-question semantics is not quite right (3 examples in the test suite). These examples represent areas where I did not implement an analysis of a phenomenon related to constituent questions not because I was not aware of it but mostly for time constraints.

On the other hand, there are many broken structures due to underspecified nonlocal features, like example (530) which I included to illustrate the problem in the Apinajé section. In the Paresi-Haliti results, there are parses where the top node is an extraction rule (and no other types of parses, because the sentence is e.g. ditransitive and so a questionnaire-specified Matrix grammar could not currently be expected to parse it). Of course such parses cannot have correct semantics and I do not include them in validated coverage.

The parse for the sentence with a clausal modifier (615) does happen to correspond to the right semantics but it is an otherwise buggy parse: due to a combination of issues, the structure is only possible with an extracted adjunct, the information about which is then lost due to nonlocal feature underspecification. Normally, such a structure would not satisfy the root condition (75).

Finally, this grammar's analysis for the sentence (584) is still incorrect, even though the free word order grammar does not have the problem with not allowing complement extraction. The free word order grammar again only admits a reading that the bamboo is the subject of the clause, not the object. The subject-head rule in this grammar can take head daughters from which the complement was extracted, however the information structure library was never fully implemented to interact with free word order, and so an appropriate filler-head rule which is separate from the *wh-ques-phrase* and which would license the word meaning *bamboo* as a fronted, topicalized object, is not included in this grammar by the customization system (this is by mistake, or due to this work being left unfinished, rather than by design). Furthermore, the structure is only possible because of the broken nonlocal features in the grammar which come from the various underconstrained rules associated with clausal modifiers and nominalization; otherwise the question word would not be allowed in a non-fronted position with no other fronted word at the left periphery.

Overgeneration is the same in both grammars in terms of the test suite. The information library structure seems to allow the user to specify strictly clause-initial focus marking in the questionnaire, but the result is that the focus marker can appear anywhere in the sentence (this is orthogonal to the constituent questions library and its interactions with the information structure library). For this reason, ungrammatical examples such as (588) are parsed. More importantly, because of the underspecified nonlocal features in various types associated with adnominal possession, nominalization, and clausal modifier libraries, various structures, including ones with question words in all positions, are licensed despite the specification of single obligatory fronting of question phrases. Both grammars probably overgenerate massively in this respect, by licensing all sorts of impossible structures with underspecified nonlocal lists. This, however, is very trivially fixed at the level of lexical types (as part of future Matrix development or in the context of individual grammar development).

Ambiguity Coordination and clausal modifier rules account for most of the ambiguity in the grammars, which is a known situation in the Matrix. In the SOV grammar, there is also ambiguity due to both the *w*h-ques-phrase and the information structure's filler-gap rule present in the grammar.

Interim summary

To summarize, the free word order grammar does have higher treebanked coverage than the SOV grammar for Paresi-Haliti, however it overgenerates because of the combination of more possible orders and broken nonlocal features. With the bugs associated with the LIGHT feature in adjunct extraction and with the SLASH constraint on the head-subject rule imposed by the information structure library fixed, the SOV hypothesis seems to have a greater potential.

The experiment with a Paresi-Haliti grammar mainly uncovers severe issues in the interaction of the current version of the constituent questions library and the information structure library, as well as severe issues associated with types which still remain in various Matrix libraries which have underspecified nonlocal features. In addition, it shows limitations of the current capacities for modeling morphological structure of question phrases, particularly ones which are used to ask *how, why-* and *whose*-questions (but see how *whose* questions in fact can be modeled correctly using the same system, in §8.5.10).

8.5.10 Jalkunan (Mande)

Jalkunan is a Mande language spoken in Burkina Faso. I used a reference grammar by Heath (2017) which features a particularly consistent and clear glossing in examples, including some information which is not morphologically overt ("zero" markings, "zero" copula).

Overview

In Jalkunan, SOV and SVO constituent orders are found. The order seems to depend on the verb, e.g. there are 'OV'-verbs and 'VO'-verbs. OV is more common (Heath, 2017, p. 10).

For polar questions, there is a clause-final particle *yà* (620).

(620) dí sɛ̆ yà
child come.PFV Q
'Did the child come out?' [bxl] (Heath, 2017, p. 270)

Polar questions can be embedded with a complementizer *wà* (621).

(621) mùʔú = ∅ sà ɲìí nàà wà mā ní sɔ̀ = rɛ̄ʔ
1PL = IPFV FUT spend.night.IPFV here whether 1SG 3SGNONHOBJ know.PFV = NEG
'Whether we will spend the night here, I don't know.' (Heath, 2017, p. 277)

Constituent questions are marked by low tone. In (622), the clause ends with a low tone, so there is no additional marking. In (623), the final vowel is reduplicated with a low tone.

(622) māʔā-nĭ = ∅-ì = ∅
who-INDEP = be = it.is = Q
'Who is it?' [bxl] (Heath, 2017, p. 272)

(623) māʔā sɛ́ = ɛ̀
who come.PFV = Q
'Who came out?' (Heath, 2017, p. 272)

Question phrases are *in situ* (636).

(624) wō = ∅ sà kpɛ́ kùnò
2SG = IPFV FUT what eat.IPFV
'What will you eat?' (Heath, 2017, p. 274)

Question adverbs and PPs usually occur clause-finally (625).

(625) wó = ∅ mì
2SG = be where?
'Where are you?' (Heath, 2017, p. 274)

In *why*-questions, the question phrase can optionally be in the clause-initial position (626).

(626) kpɛ́ kùdù wō sà
what for 2SG come
'Why did you come?' (Heath, 2017, p. 268,274)

Embedded constituent questions are expressed with relative clauses (627).

(627) mɛ̀ʔɛ́ mì = ∅ sí = ì wàà mā ní sɔ̀ = rɛʔ
person REL = IPFV FUT = 3SGNONH go.IPFV 1SG 3SGNONHOBJ know.PFV = NEG
'The person who will go, I do not know (= I don't know who will go)' (Heath, 2017, p. 277)

Ungrammatical examples

To illustrate that some adverbs can only occur clause-finally, I construct (628).

(628) *mì wó = ∅
where 2SG = be
Intended: 'Where are you?' (Constructed based on Heath 2017, p. 274

To illustrate the question particles distribution, namely that the tone particle occurs only in constituent questions and the =*yà* particle occurs only in polar questions, I construct (629) and (630).

(629) *dí š = V
child come.PFV = Q
Intended: 'Did the child come out?' [bxl] (Constructed based on Heath 2017, p. 270.)

(630) *kpɛ́ mɛ̀ɛ́ = yà
what be.done.PFV = Q
Intended: 'What happened?' (Constructed based on Heath 2017, p. 273)

I am not attempting to model or test the phonological contrast, and so I do not add examples illustrating the different specific tone markings. I add one example with no particle, to illustrate that the clitic is required (631).

(631) *kpɛ́ mɛ̀ɛ́
what happen
Intended: 'What happened?' [bxl] (Constructed based on (Heath, 2017, p. 273).)

To illustrate that question words are *in situ*, I construct the following example, which is not ungrammatical but it should only have one reading, the one which corresponds to the question word being *in situ* (632).

(632) kpɛ́ = ∅ sà wō kùnò = V
what = IPFV FUT 2SG eat.IPFV
'What will eat you?'/*'What will you eat?' (Heath, 2017, p. 274)

Summary of final test suite

The final test suite consists of 38 examples, 33 of them grammatical, modified as described below. Only minimal modifications were needed, mainly related to morphophonology (a component not included in the Grammar Matrix as a result of a principled decision to treat morphosyntax as independent of morphononology (Bender and Good, 2005)). The only syntactic modification of note is separating some clitics with a space. Additional 5 ungrammatical examples were constructed as explained above.

Modifications:

1. Added the silent clitic where it was apparently skipped. Compare (625) to (633). In (633), there is the silent low tone marking at the end of the word, but in (625) there is none, although both examples represent constituent questions ending in low tone. Heath (2017) clearly states that the low tone marking is "inaudible if the final word already ends in an

L-tone" (p. 272). I normalized the test suite so that all examples look like (633).

(633) māʔā-nǐ = ∅-ì = ∅
who-INDEP = be = it.is = Q
'Who is it?' [bxl] (Heath, 2017, p. 272)

2. Replaced each specific vowel clitic marking (included the silent one) with a symbolic =V, separated by a space (to represent a reduplicated vowel with low tone, or generally a clitic whose phonological content depends on the preceding vowel).

3. Added the clause-final tone marking =ɔ̀ in (635) (compare to (634); I assume it was just accidentally forgotten in (635), as Heath (2017) does not mention any cases where this marking would be optional.)

(634) wó = ∅ sàá ɲɔ̀ tɔ́ = ɔ̀
2SG = be house which in = Q
'Which house are you in?' (Heath, 2017, p. 276)

(635) wō sàà-rá = ∅ làʔá ɲɔ̀ tɔ́
2SG house-NOM = be place which in
'Where is your house?' (Heath, 2017, p. 276)

4. Separated aspect-marking auxiliaries (636) with a space, adding (637) to the test suite instead of the original (636) (and the same in all such cases).

(636) wō = ∅ sà kpɛ́ kùnò
2SG = IPFV FUT what eat.IPFV
'What will you eat?' (Heath, 2017, p. 274)

(637) wō = ∅ sà kpɛ́ kùnò
2SG = IPFV FUT what eat.IPFV
'What will you eat?' (constructed based on Heath 2017, p. 274.)

5. Separated the clitic glossed as *be* (638) with a space, adding (639) to the test suite instead of (638), and the same in all such cases.

(638) kpɛ́ = ∅ nɛ̀
what = be there
'What's there?' (Heath, 2017, p. 273)

(639) kpɛ́ = ∅ nɛ̀
what = be there
'What's there?' (Heath, 2017, p. 273)

Question specifications

I specify the constituent questions strategy as *in situ*, and furthermore add two particles on the Yes/No subpage, one for polar questions (impossible in constituent questions) and one obligatory in constituent questions. I enter most question words in the lexicon as they are presented in the examples. I add noun constructions like *wáʔátí ɲɔ̀-nɔ̀* from (640) as "adverbs", in addition to having the determiner and the noun entries in the lexicon.

(640) wó = ∅ sáá wáʔátí ɲɔ̀-nɔ̀
2SG = IPFV come.IPFV time which-NOM
'When do you come?' (Heath, 2017, p. 277)

Where there is no overt adposition (cf. (641)), the Matrix-derived grammar will not have a chance to parse such a construction as an adjunct, unless the whole thing is entered as an adverb.

(641) wó = ∅ sàá ɲɔ̀ tɔ́ = ɔ̀
2SG = be house which in = Q
'Which house are you in?' (Heath, 2017, p. 276)

I add an interrogative verb to account for (642).

(642) àà dóò
3PL.HUM be.where
'Where are they?' (Heath, 2017, p. 275)

Non-question specifications

Most of the examples I have in the test suite are SOV (and SOV is more common than SVO), so I specify SOV word order. There is no overt case marking (apart from an occasional NOM which does not appear to participate directly in the word order or case frames); there is 1-2-3-person distinction and singular and plural number, which I specify straightforwardly as usual, as well as there being future tense and perfective and imperfective aspect. I add auxiliaries marking tense and aspect and specify them as taking VP complements. I enter the clitic glossed *be* as an intransitive verb (although that is not semantically fully accurate, but this issue is orthogonal to my analysis of questions). Finally, I do not specify a clausal modification strategy in this grammar. There is one example in the test suite with a clausal modifier, however I already know about the problems associated with the interaction of the clausal modifiers library and the constituent questions library from looking at other evaluation grammars. I use the Jalkunan grammar to inspect other issues without the noise that the underspecified nonlocal features introduce in all grammars which have clausal modifiers.

Grammar performance and error analysis

The numeric results for evaluating the Grammar Matrix's analysis of constituent questions on the Jalkunan test suite are presented in Table 8.20.

coverage (%)	validated cov. (%)	overgeneration (%)	readings per sentence
28/33 (84.8)	26/33 (78.8)	2/5 (33.3)	3.25

Table 8.20: Evaluation results for Jalkunan

Coverage The sentence with the clausal modifier is not parsed, as I did not specify a clausal modification strategy, to avoid the noise associated with including it. The "embedded constituent question" is not parsed, as it contains a relative clause. The embedded polar question is not parsed because the clausal complements library does not support the Jalkunan strategy with a "dummy" pronoun which occurs in addition to the clausal complement (621).

In example (643), the word meaning *how much* is only found in the lexicon as a determiner, but there is then no analysis for such a sentence. If there was a noun there, such as one meaning *money*, then I would expect to get an analysis, but as is, this is not the kind of construction I expect the grammar to handle.

(643) sòló = ∅ = è
how.much = be = it.is
'How much is it?' (Heath, 2017, p. 275)

In the current version of the system, adpositions (and PPs) cannot modify clauses headed by auxiliaries. That is clearly incorrect and is an artifact of an unfinished analysis of English subject-auxiliary inversion (not presented as part of this work). This issue costs valid coverage of sentences like (644) in Jalkunan:[44]

(644) wō = ∅ mùú màá kpɛ́ dɛ̀
2SG = IPFV field cultivate.IPFV what with
'With what do you do farm work?' (Heath, 2017, p. 274)

In the sentence above, the PP cannot attach low either due to the incompatibility of the *clist* constraint on the subject of the clause imposed by the constituent questions library via the *head-adjunct-phrase* (the purpose of *clist* is described in §6.5.2) and the *olist* constraint put on the same subject of the clause by the auxiliary lexical type. In other words, the interaction between auxiliaries and constituent questions is broken in this aspect.

The sentence (645) is parsed incorrectly, meaning something like *how many sheep own you?*, because a fronted object is not anticipated by this *in situ* SOV grammar.

(645) tàgà sóló = ∅ wō ká = à
sheep how.many = IPFV 2SG poss = Q
'How many sheep do you have?' (Heath, 2017, p. 276)

The Jalkunan grammar, where I specify an adnominal possession strategy to account for (646), uses the same strategy to account for (647), which was a welcome surprise. The grammar provides an analysis presented in (648). I am not sure whether it is expected that the unary rule labeled D in (648) can apply to the question pronoun which was not entered as part of the adnominal

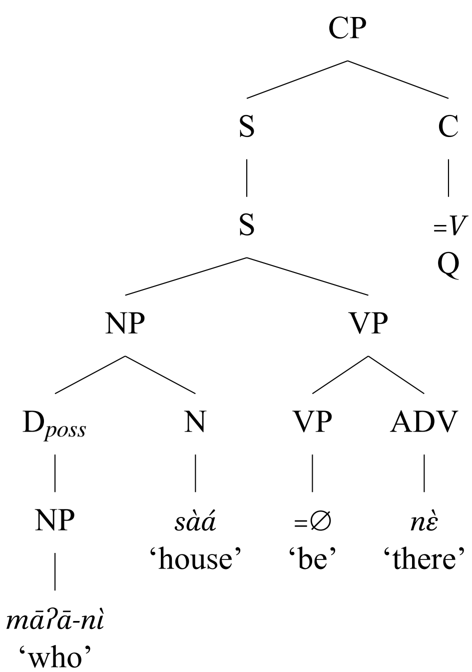
[44]The sentence is parsed by the grammar but incorrectly, due to underspecified nonlocal features in the adnominal possession library which result in a possessive lexical rule applying where it should not (there are no possessive

possession marking strategy, but even if this is by accident, the result is absolutely correct (Figure 8.8). This is an example of how an implemented grammar can make correct predictions which a human may not think about or overlook.

(646) wō sàà-rá = ∅ làʔá ɲɔ̀ tɔ́
2SG house-NOM = be place which in
'Where is your house?' (Heath, 2017, p. 276)

(647) māʔā-nǐ sàá = ∅ nὲ = ὲ
who-INDEP house = be there = Q
'Whose house is that?' (Heath, 2017, p. 273)

(648)



markers in the sentence).

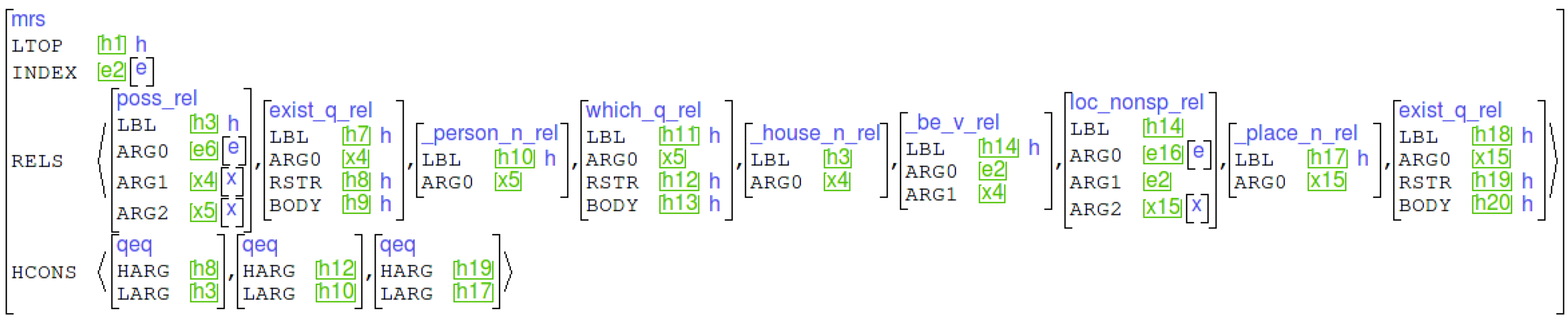


Figure 8.8: MRS for sentence (647). ARG1 of the possession relation is the possessum. The meaning is: *Which person possesses the house there?'*

Overgeneration Per the analysis presented in §7.6, all particles are optional in polar questions. There is no way currently to specify a particle as impossible in a polar question. So the example that illustrates the impossibility of the tone marking in polar questions is parsed by the grammar. There is also currently no way to specify adverb attachment, so the example illustrating the impossibility of the *where*-adverb occurring clause initially, is also parsed. The example illustrating that questions must be *in situ* is parsed but with the appropriate meaning that the *wh*-word signifies the subject of the clause. So, this last example is not counted towards overgeneration.

Ambiguity The ambiguity in the grammar is due mostly to adverbial attachment. Some is also due to the adnominal possession pronoun which is added to the grammar as an additional lexical entry that has the same orthography as a personal pronoun.

8.5.11 Interim summary

Evaluation of my additions to the Grammar Matrix system on five held out languages from five different, held-out language families is summarized below in Table 8.21 with respect to treebanked (validated) coverage. In the rightmost column, I list the phenomena the interaction with which is handled well in the sense that a correct parse can be obtained.

Language	ISO-639-3	Family	Gram. items	Coverage	Handled phenomena
Apinajé	[apn]	Macro-Jê	17	82.3	evidentials, arg. drop, clausal modifiers
Makah	[myh]	Wakashan	14	78.5	clausal complements, arg. drop
Pacoh	[pac]	Austroasiatic	26	84.6	arg. drop
Paresi-Haliti	[pab]	Arawakan	64	56.0	adnom. poss, coordination
Jalkunan	[bxl]	Mande	33	78.8	adnom. poss.

Table 8.21: Evaluation (held-out) languages. Treebanked coverage

While there are various shortcomings revealed by this evaluation, in many cases the analysis of constituent questions works as expected, including in interaction with other phenomena, such as adnominal possession, evidentials, and clausal modifiers. Even when, due to underspecified nonlocal features in some lexical types, the grammars produce lots of incorrect parses, they also produce the correct one (and in the case with nonlocal underspecification at least, the incorrect parses can be eliminated trivially). A particular highlight is the correct parse of the Jalkunan sentence (647) which I was not even consciously targeting when I was putting together the specification of the language, and yet the grammar knew exactly what to do with it. This shows that the analysis of adnominal possession (Nielsen, 2018) generalizes to constituent questions, even though constituent questions were not part of the Grammar Matrix when the analysis was developed and tested. It shows also that the analysis of question pronouns that I present here works well with the adnominal possession analysis. Crucially, this example demonstrates how implemented grammars are capable of making correct predictions which a human may overlook.

Error analysis reveals some general methodological issues in the work presented here as well as a number of specific issues in the analyses presented in Chapters 6 and 7. I will discuss the methodological takeaways in §9.4. As for the specific issues, the most severe problems were identified in the interaction of my constituent questions analyses with information structure. The analyses in that area should be significantly revised and the work of the two libraries with regard to fronting consolidated. The unfinished analysis of subject-auxiliary inversion which is *de facto* part of my constituent questions library also caused issues, particularly where the interaction with auxiliaries is concerned. Finally, a simple-to-fix, analytically trivial, but severe problem is that nonlocal features are currently underspecified in many places in the Grammar Matrix system. The combination of that underspecification with the addition of extraction and filler gap rules by the constituent questions library leads to overgeneration.

The Grammar Matrix system with the new constituent questions library did best on the Mande and Austroasiatic languages, and also well on the Macro Jê language. The previously unseen combination of interrogative verbs and particles worked without an issue, so did the interaction of question words and the adnominal possession strategy (this observation is separate from the nonlocal underspecification issue). All in all, the presense in the library of interrogative verbs helped improve validated coverage on most of the evaluation languages, which may support Hagège's

(2008) opinion that they are more common than is often assumed by typologists.

The worst results were achieved for the Wakashan and the Arawakan families. This is perhaps not surprising given that languages of the Americas tend to be somewhat underrepresented in typological literature, and that has been affecting Matrix development. The Grammar Matrix is better suited for modeling analytic, concatenative morphology, and assumes a clear distinction between nouns and verbs as well as a robust notion of verb case frame. Another clear takeaway is that the level of complexity of the examples and the number and diversity of the examples makes a lot of difference for the evaluation methodology utilized here. High coverage can be expected for small test suites, but the Paresi-Haliti (Arawakan) test suite is big and diverse, featuring complex examples from fluent speech. The Grammar Matrix in its present form does significantly more poorly on such test suites, compared to the ones consisting mainly from simple, elicited examples illustrating mainly one phenomenon. At the same time, including realistic examples in the process of Matrix development such as described here is a good way to map out future directions. My work with the evaluation languages summarized above points to non-verbal predicates as one direction which would advance the system.

8.6 Summary

This chapter presented the results of testing and evaluating the new constituent questions library for the Grammar Matrix. I presented coverage, overgeneration, and ambiguity metrics for five development and five evaluation (held-out) languages. The takeaways are summarized in the next chapter.

Chapter 9
DISCUSSION AND CONCLUSION

This dissertation presented a new library for the Grammar Matrix system, a meta-grammar engineering framework featuring both typological breadth and formal-syntactic depth. The library covers several strategies for forming constituent questions, including question phrase fronting, morphological marking, question particles, and the less well-known interrogative verbs. The user of the system can now fill out the web questionnaire specifying these strategies, add question words to the lexicon, detail lexical rules in the Morphotactics section, and then obtain automatically an implemented HPSG grammar-program which, when loaded into DELPH-IN parsing software, can parse and generate sentences from the specified language. This final chapter discusses the takeaways from the process of developing and evaluating the library as well as what I see as the most important directions for future work.

I start from analytical issues and directions for future work, first discussing the issues arising from the simple view on sentential force adopted in DELPH-IN (§9.1). Then I talk about information structure and question phrase fronting (§9.2), since without a well-modeled interaction between the two, an analysis of interrogative constructions is more cumbersome than it needs to be. Then I revisit "lexical threading" and its role in simplifying analyses while at the same time paradoxically making the system more complex (§9.3).

The second part of the chapter is dedicated to questions related to the overall methodology that I used here (§9.4). I discuss the size of the test suites and grammars and how that affects the results, and what that means for Matrix development as a whole (§9.4.1). I proceed with a related discussion about the quality of the test suites and grammaticality judgments and of the use of corpora, or lack thereof (§9.4.2). Finally, I discuss the issue of the overall complexity of the system and express hope that future methodological advancements will support future development of the Grammar Matrix and similar systems (§9.5).

9.1 Question semantics in DELPH-IN

In §6.2, I described a very limited analysis of embedded questions which does not account for the contrast between e.g. verbs that embed only questions (like the English *wonder*) and verbs that embed only propositions (the English *think*), resulting in admitting sentences like **I think whether Kim arrived*. Earlier in §4.1.3, I talked also about how desirable semantic representations for complex sentences containing several questions ((138) repeated here as (649)) should link question words to the right parameters of events.

(649) Does Kim know who seems to have arrived? [eng]

My analysis does not achieve either of these goals, and, to reiterate, that has to do with (i) there not being semantic features representing interrogative content other than the SF feature; and (ii) the SF feature being underspecified between *ques* and *prop* on the mother of head-subject and head-complement clauses.

Ginzburg and Sag's (2000) approach to semantics allowed them to model more nuanced semantics compared to DELPH-IN. There are however reasons for DELPH-IN semantics being simpler, and these reasons have to do with implementation and scalability. DELPH-IN researchers have tried maintaining more nuanced semantics using a hierarchy of *message* types, where each type encoded a particular kind of semantic content (§4.2.1), however they have collectively decided that such an approach was not scalable in the context of implemented grammars. It was not clear which items in the grammar should have semantic *messages* and which should not, and furthermore, what the complete set of these messages should be (a discussion somewhat similar to the discussion of semantic roles in syntax). In other words, Ginzburg and Sag's (2000) treatment of question semantics was not ignored; it was tried and ultimately rejected. At the same time, the SF feature is clearly not sufficient to construct a properly precise semantic representation for (649).

As for capturing the contrast between the embedding properties of *think* and *wonder*, this requires a more nuanced approach to modeling intonation questions, although unlike linking question parameters to events, the issue at hand is not necessarily semantic in nature. Intonation questions are currently modeled in the Grammar Matrix by the underspecified SF on all head-subject and head-complement constructions. This makes it not straightforward to model what seems to be a universal (or a very common) distinction between verbs which embed only questions and verbs which embed only propositions, because clauses will be underspecified between the two unless they are licensed by a e.g. question-forming phrase.

An alternative analysis of sentential force is necessary, which is both scalable and nuanced enough. It seems like the problem with clause embedding verbs could be addressed with prosody. Prosody has been modeled in HPSG (Alahverdzhieva and Lascarides, 2010) and including prosodic features into the Grammar Matrix would make it possible to not necessarily underspecify SF at the level of head-subject and head-complement phrase. At the end of the day, even something as simple as punctuation (accounting for question marks) could ameliorate the problem of not being able to distinguish between an intonation question and a declarative clause (which is something that the ERG can do (Flickinger, 2000, 2011) but the Grammar Matrix cannot yet). The problem with linking question phrases to the correct parameters of events requires handling at the level of the CONTent features, potentially along the lines of ICONS, as was suggested to me by several members of DELPH-IN.[1]

9.2 *Information structure and interrogative syntax*

Information structure and the syntax of interrogative constructions are clearly very tightly connected. This is evident both from syntactic and from typological literature, where the discussion of focus is often inseparable from the discussion of constituent questions. After all, constituent questions ask after new information.

Having undertaken the task of modeling constituent questions for the Grammar Matrix, I wish that I had developed it from within the information structure library, at least the parts which have

[1]This was some subset of: Guy Emerson, Woodley Packard, Dan Flickinger, Berthold Crysmann, Emily M. Bender, Sanghoun Song, Ann Copestake.

to do with question phrase fronting. I believe it would have resulted in a more robust analysis which would have fewer bugs in it (for example, it would be harder to miss the problem with SOV grammars which I discuss in §8.5.9) and would be easier to generalize and to develop further. It has long been observed that Grammar Matrix libraries are not modules (Bender et al., 2010b), in that it is not possible to fully separate them from each other in the work they are doing. Still, they are usually developed separately, and my constituent questions library was originally conceptualized as something that starts out fresh, as its own subsystem. In contrast, the adjectives library (Trimble, 2014) was developed entirely within the existing lexicon library (originally added by Drellishak (2009b)). Of course it makes sense to develop support for adjectives from within the lexicon; but it seems like a similar project design can be appropriate not only in the context of the lexicon.

In the context of this work, the analysis of information structure is most relevant in relation to the analysis of question phrase fronting, as well as where it comes to focus marking on question words. Both the information structure library and the constituent questions library concern themselves with dislocated constituents; both use the extracted subject rule and (different versions of)

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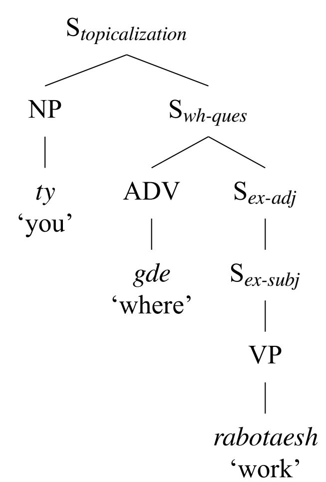
[2]The analysis of (20b), repeated here as (i), would look something like (ii). The question word is fronted.

(i) Ты где работаешь?
Ty *gde* rabotaesh?
2SG where work.2SG
'Where do you work?' [rus]

(ii)



the filler-gap rule. It is worth noting especially that an information-structure based analysis of seemingly optional question phrase fronting, such as in Russian, would be both in line with the mainstream syntax tradition (which rejects the notion of optional fronting) and might eliminate the need for additional features and types I introduced in this work (L-QUE, *clist*, §6.5.2).[2] In the context of this work, I did not have enough time to ensure proper interaction between the two libraries or to reanalyze optional fronting as obligatory, with whatever material preceedes the question phrase being fronted as well, but it definitely seems like a lot of the work currently done by both of them can be consolidated. This should now be easier to undertake with the simpler, lexical threading-free, system which allows for easier reasoning about extraction and for using fewer extraction rules.

9.3 Lexical threading

Lexical threading (§4.1.2), which I took out of the Grammar Matrix as part of this work, presents an interesting case of trade-off between simplicity and complexity of different kinds. In the Grammar Matrix, the mechanism was originally included because it was part of the ERG (Flickinger, 2000, 2011). In the ERG, it serves the analysis of *easy* adjectives. However, specifying the order of elements on the nonlocal lists at the lexical level necessitates multiple extraction or multiple filler-gap rules for languages with multiple fronting and flexible word order (§6.5.1). Furthermore, there was a consensus among Matrix developers that lexical threading somewhat severely affects the developers' (human) ability to reason about grammars and their behavior (which is still necessary, even in computationally aided research). Using lexical threading in practice means more mistakes are made, and they may take much longer to identify and fix. In particular, having to keep in mind that, even if a verb's nonlocal list seems underspecified at some point in the tree, in reality its length and the order of elements are already strictly set, is hard, and having to do so sort of defeats the purpose of being able to inspect trees in the software (decreases computational aid). For these reasons, it was decided to take lexical threading out, which I did. However, *easy* adjectives are not the only phenomenon which is made easier to analyze by having lexical threading at one's disposal; Bouma et al. (2001a) talk about some in their work, and I present here the case of morphological marking of questions (§6.8). It is remarkable how much simpler an analysis is with lexical threading than without it. In a sense, this situation is probing into the very notion of having one core grammar for all languages. I still think this is a very attractive idea, but flexibility is important. Part of the problem with lexical threading is not lexical threading itself but the nature of the DELPH-IN JRF (specifically, that the number and the order of daughters is fixed in constructions). This relates to the problem of *essential* and *incidental* complexity which I discuss last, in §9.5.

9.4 Methodology

I was lucky to have an established methodology to work with when undertaking this project. Bender et al. (2010b) developed a series of steps which Matrix developers are expected to follow (see also Chapter 5). Here, I would like to discuss some of the tensions and trade-offs which the methodology includes, particularly as the overall complexity of the system increases over the years.

9.4.1 Breadth vs. depth

The main tension is between the breadth and the depth of the analyses, reflected in test suites (in the spirit of test-driven development (§5.7)). The established methodology for Matrix development assumes that the scope of the data that the analyses cover is informed by typological surveys. Such surveys by definition prioritize breadth and usually only give a few examples of each phenomenon. At the same time, developing a formal analysis for a phenomenon often calls for studying data from specific languages in depth, which requires in turn native speaker judgments on a variety of constructions. In this dissertation, I attempt to do both. I speak Russian natively and so I was able to work with Russian in more depth, compiling a much larger test suite compared to other languages which are part of this study. The result is that I present an analysis here which clearly does not have 100% coverage over Russian, as shown in §8.3.2, and while the rest of the development grammars do have 100% coverage over their respective test suites, those test suites are small compared to the Russian one. The unsurprising takeaway here is that in-depth work on one language is likely to uncover issues in analyses which would otherwise go unnoticed. For example, there were no examples of multiple or long-distance questions in any of the reference grammars I worked with, and yet the analysis of multiple fronting is one of the more challenging ones, and long-distance questions are a phenomenon which bears great importance in the study of syntax. If I were not working with Russian and English, I would not have touched on these issues. But phenomena like English long-distance questions and Slavic multiple fronting get so much attention in the syntactic literature that I had been assuming at first that modeling them is about the most important thing for my analysis. Come the evaluation stage, I did not see a single long-distance question or a sentence which would contain multiple question phrases in one clause, let alone multiple fronting. Perhaps, even if syntacticians focus so much on e.g. long-distance questions, from the Grammar Matrix's perspective, it means they may be an interesting puzzle, but a system which models a broader range of phenomena robustly but does not cover long-distance questions might ultimately be of more use for future work. On the other hand, I was close to not including interrogative verbs (§6.9) into development because they did not get much attention in the literature, and yet I ended up using them in three out of five evaluation grammars (perhaps adding evidence to Hagège's (2008) opinion that interrogative verbs are common, they just are not always mentioned).

The larger each test suite, the fewer test suites can be compiled and used for development. The principal question here is: While diving deeper into one development grammar predictably takes away from the typological breadth of the test-driven development, does it in fact take away from the robustness and generalizability of the solution itself? (Recall also the discussion about "syntactic idealism" vs. "syntactic materialism" which I started in §1.2, and the debate on how much it is possible to learn about human language by looking only at one language). Some of the issues which surfaced in evaluation indicate that the answer to this question is: Unless the test suite is compiled in a very principled way, a deeper analysis of one language is likely to be severely biased and to generalize worse than a simpler analysis which lacks coverage but is robust enough to be directly extended. My analysis, influenced deeply by the larger Russian test suite and focused on (typologically rare) multiple fronting, introduced into the system some severe issues associated with undertested interactions between libraries which could be done with more diverse test suites from more different languages (such as a language with SOV order and single fronting; see §8.5.9). The issues can be fixed, but methodologically this means that the risks of sacrificing typological breadth do not seem to be easily outweighed by looking more into one language. (I discuss the related issue of the methodology of building the test suites later in §9.4.2.)

In the future, perhaps the Grammar Matrix or similar systems could grow by both types of contributions organized separately: analyses which were shown to work broadly cross-linguistically (classic Matrix development) and analyses which were shown to cover larger sets of sentences from one language.[3] The missing bit, I believe, is the methodology of combining the two. Having tried working with a large test suite as part of this dissertation, I would advise future Matrix developers to avoid that[4] but to rather undertake separate projects integrating large grammars into the Matrix as part of deepening and extending the analysis for an already supported phenomenon.[5]

9.4.2 *Compiling test suites*

It is crucial for the results of projects such as this one how the test suites are compiled. Test suites consist of grammatical and ungrammatical sentences. With grammatical sentences from evaluation languages (that the developer does not speak, and the purpose of which is to test what the experience would be of a researcher that has this particular set of hypotheses and examples), grammatical sentences can be selected in a fully principled manner in that it can be the entire set of sentences in the reference grammar which contain a particular phenomenon (for example, all constituent questions found in the reference grammar). But even with evaluation languages, con-

[3]Drellishak (2009b) tested his analysis of direct-inverse systems for the Grammar Matrix on a Sahaptin test suite that consists of thousands of sentences; however, those were computer generated. I am talking about natively vetted test suites or test suites which come from corpora, or at any rate about a setting where a language expert is actively involved.

[4]Emily M. Bender usually does warn people (and she did warn me) about working with a language they know well as a development language, perhaps for reasons similar to the ones I summarized here.

[5]As a thought, perhaps just like classic Matrix development projects culminate in held-out evaluation, perhaps theses which focus on one language could include, as a final stage, integration of (parts of) the analysis into the Matrix.

structing additional examples, including ungrammatical, requires a method. As for development languages, which the developer may speak, choosing grammatical examples requires a method, as it is not possible to collect "all examples" of a phenomenon in a language one speaks or knows well. Literature can be of help but there is no guarantee that a principled method was used in choosing examples for literature either.[6] But without a method, it is easy to end up with a test suite biased in such a way so as to fail to test for some important aspects of the analysis.

Development test suites drive the analysis (§5.7). In that sense, it is possible to start simply with some sentences (illustrating the phenomenon being modeled) which come to mind, however the test suite should then grow in a methodical manner. Ideally, the test suite should be tied directly to the analysis, i.e. with each addition to the basic analysis (after it is initially sketched), the developer should consider all possible ways in which the addition may be tested, and add examples to the test suite accordingly, grammatical and ungrammatical. As an example, in §8.5.10, I document an issue with the lexical type for adpositions. In my system as I evaluate it, that type cannot modify auxiliaries — a clearly incorrect assumption and an artifact of an unfinished analysis of English subject-auxiliary inversion.[7] What could have prevented that is, after the AUX constraint was put in the adposition lexical type, I could have considered what the range of (at least English) structures affected by this change is, whether they are grammatical or not, and add them all to the test suite.[8] Of course such a methodical approach means fewer subphenomena will be considered and covered, but hopefully the analysis will be more robust. There is no discovery in this call for method, but there are reasons why I did not myself observe it, and they have to do with the overall complexity of the system (see §9.5) as well as with the fact that compiling a test suite methodically is a special skill which takes time to train.

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[6]For development languages, if some of them are high resource, test suites can be compiled from corpora, except that brings us right back to the problem of possibly sacrificing too much breadth in the analysis. Unless one subscribes to the view that all languages' structure can be evinced by a single language, working with a corpus perhaps remains more appropriate for Matrix "integration" projects which I suggest above in §9.4.1 rather than for typologically informed Matrix library development.

[7]Consider how this once again speaks in favor of not overly focusing on phenomena which get a lot of attention in syntactic literature, in the Grammar Matrix context at least.

[8]One feature of DELPH-IN grammars and software that is useful here is generation. The functionality provides a complete list of strings licensed by a given grammar, given a semantic representation. Looking at such a list helps

In such projects, there will invariably be some development data that is hard to judge (§8.3.2). I wish I had time to conduct a speaker experiment with respect to some of the Russian data, particularly long-distance questions. Once again, this activity probably belongs to a different kind of project, such as integrating large grammars into the Matrix. For classic Matrix development, such data perhaps is best left out of scope.

Finally, there is the issue of vetting any modified or constructed examples (including ungrammatical ones), during both the development and the evaluation stages, whenever the developer does not know the language they work with. Ideally, all examples should be vetted, however with languages for which there may be a single expert in the world and no accessible speakers, this is often not possible to do. I would like to note two separate takeaways regarding this, based on my experience with this dissertation. First, the necessity to modify examples from reference grammars has reduced dramatically since I was last working on the clausal complements library a few years ago. Thanks to the additions to the Matrix made by all the project participants (including Haeger (2017), Nielsen (2018), Howell and Zamaraeva (2018), and Zamaraeva et al. (2019)) there is almost no need to modify examples anymore, because most of the phenomena found in examples are now supported. Of course there are still phenomena to be added, including noun predicates, noun modifiers, relative clauses, ditransitive verbs, and direct speech, but the days when examples could be used in their original form only if they were simple intransitive or transitive clauses, are gone. This however addresses only the issue of modifying original examples; the issue of vetting any constructed examples still remains. Constructing examples is necessary primarily to illustrate ungrammaticality, since reference grammars rarely include those. But it can also be needed to illustrate a clear positive statement from a reference grammar for which an example is missing. In any case, vetting by an expert is highly desirable but usually cannot be obtained. So the second thing I would like to note here is that the only way to mitigate this issue I can imagine is allocating more time to evaluation. I myself spent several weeks on the evaluation part of Chapter 8, and that was certainly not enough to establish any contacts. I think that ideally,

to make test suite compilation more methodical (Bender et al., 2010a), although it does not necessarily provide a complete list of structures affected by a particular change in the grammar.

evaluation should take several months. This means that the scope of the project will be narrower, but the quality in the end will undoubtedly be higher.

9.5 Essential and incidental complexity

Grammar Matrix is a complex system. At the time of this writing, there are 17 libraries (see also §3.4), and they can add a substantial number of types and custom feature constraints to a grammar. The Matrix core (`matrix.tdl`) itself is also fairly large and has a number of complex types. Types are implemented in DELPH-IN JRF which has a fairly complex treatment of e.g. lists; the customization logic is implemented in python, and the questionnaire interface is implemented in JavaScript. All of this put together creates a space which is not easy to reason about. What is more, some of this complexity is not really about the complexity of human language; it is merely a result of technical choices and more generally, of the nature of implementation.

In software engineering, *essential complexity* of a solution is understood as inevitable, dictated by the nature of the problem itself. *Incidental complexity*, on the other hand, is due to factors unrelated to the problem but rather related to e.g. the choice of the framework (Sangwan and Neill, 2009). It is important to note that incidental complexity may be just as necessary and unavoidable as essential complexity, particularly in the context of any implementation.

The notions of essential and incidental complexity applies to formal grammars, implemented or not. A desideratum for any language theory, for example, has always been that it be "elegant"; however the nature of human language may be highly complex and not necessarily and not always expressible in simple and "elegant" terms (e.g. Fokkens, 2014, p. 10). In this sense, the presence of multiple types which interact with each other in a large combinatoric space in Matrix-derived grammars could be hypothesized to represent essential complexity. At the same time, making lists fixed-length in DELPH-IN JRF is clearly just a technical choice, and there is no reason to assume that it is related to the nature of human language (though there could be discussions related to processing constraints in humans). What is furthermore interesting here is that making this technical choice makes certain things (e.g. implementing parsers) simpler while making other things (e.g. writing extraction rules) more difficult. Unless we discover that humans store information in fixed-length lists, this is perhaps an example of incidental complexity.

With respect to the work presented here, examples of incidental complexity are numerous. Ultimately, given that DELPH-IN HPSG does not claim to be the one true theory of language, almost any specific analysis can be described in terms of incidental complexity. But I would hypothesize that the methodological tensions described above (size of test suites; the trade-off between depth and breadth of the analysis) are due to the essential complexity of the object of study. In this sense, so is the imperfect shape of the grammar artifacts. So long as they can be built on, these artifacts have scientific value, even when they do not make correct predictions. If in the future we cultivate more principled ways of reasoning about the nature of complexity we are dealing with, we may be able to better balance project requirements which are in tension, and projects like the Grammar Matrix could be taken to the next level.

9.6 Conclusion

I presented an analysis of a number of typologically attested ways to form constituent questions, integrated into the Grammar Matrix system, tested on 5 languages from 3 language families and evaluated on a further 5 "held-out" language families. Evaluation showed that the current Grammar Matrix system, with the analysis of constituent questions integrated into it, is well suited for modeling a range of question-related phenomena, especially in analytic languages. Results for a Macro-Jê, an Austroasiatic, and a Mande language demonstrated that the questionnaire can be filled out relatively straghtforwardly and correct semantic representations can be obtained for most sentences. Several issues found in the interaction with e.g. auxiliaries are accidental artifacts which can be easily removed. Filling out the questionnaire for a Wakashan and an Arawakan language was challenging, although the analysis of separate morphological marking for polar and constituent interrogatives that I presented in this dissertation proved useful for Wakashan. For future work, I identify consolidating this analysis with an analysis of information structure as perhaps the biggest priority for advancing our understanding of the structure of constituent questions via the lens of HPSG. The discussion I offer both in Chapter 8 and here focuses mostly on the shortcomings of the analyses and on methodological problems. However, this work, paired with the archived open-source system, presents a demonstrably functioning, broad system of HPSG analyses. These analyses not being perfect is not really bad news; as argued by Bierwisch (1963), Müller (1999), and Bender (2008), unless the analysis was rigorously tested, it cannot claim a concrete area of applicability. In this sense, while the analyses presented here need to be improved along some dimensions, what is important is that (i) the issues in the analyses are simply overt (compared to possibly hidden imperfections of purely theoretical analyses); (ii) my work builds on previous work in a literal way. Analyses developed for the Grammar Matrix previously are included in the same machine-readable grammars in which my analysis of constituent questions is included, and then entire grammars are tested on sentences, so there is an empirical guarantee that my analysis does not interact with previous work in unexpected ways (to the extent that can be made apparent by the existing test suites); (iii) finally and by the same token, my analysis can be built upon literally and directly from where I leave off.

APPENDIX A: A PARTICULARLY LIMITED ANALYSIS

This appendix discusses the last three rows of Table 8.7 which summarizes the Russian development grammar's coverage issues (repeated below as Table 9.1, with the last three rows in question separated with a horizontal line). The last three rows in the table have to do with complex

Phenomenon	tot.	of them, '?'	ex.
сколько ('how many ... of X') scrambling	2	0	(470)
в каком ('in which ... X') scrambling	5	0	(471)
Embedded *li*	8	0	(472b)
Focus particle modifying determiner	1	0	(473)
Coordination of different arguments	1	0	(474)
Coordination of argument and adjunct	2	0	(475)
Coordination of extracted and clause-final adjunct	1	0	(476)
Questions embedded by *что* ('that')	7	4	(652)
LD questions with *спрашивать* ('ask')	15	9	(653)
Clauses with *wh*-words embedded by *думать* ('think')	4	0	(654)

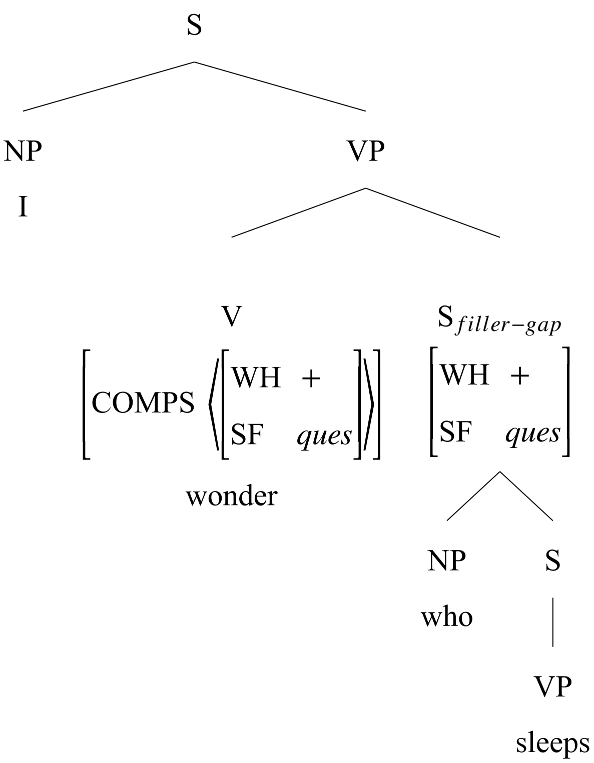
Table 9.1: Russian development grammar: Coverage issues

sentences, in which verbs meaning *think* and *ask* embed propositions and questions. This part of the grammar involves and experimental analysis which is in the process of being revised and for that reason was not presented in Chapter 6. I briefly sketch the analysis below.

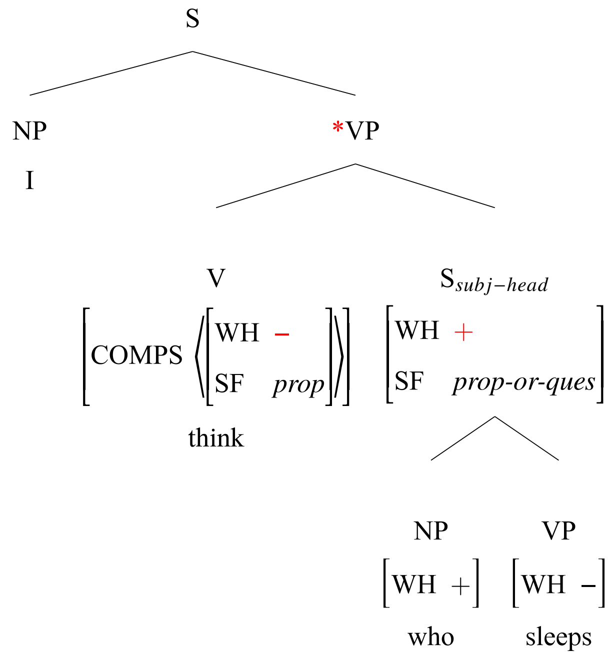
Recall from §6.6 that all *wh*-words added by the customization system are [WH|BOOL +]; all non-*wh*-words are [WH|BOOL −]. Recall also that basic head-subject and head-complement rules set their mother's WH value to the logical OR of the daughters and so the information about whether or not a *wh*- word is present in any of the constituents is always tracked in the tree unless a question phrase structure rule has been used and reset that value. Unary rules like the bare NP rule simply copy up the sole daughter's value.

Examples (650) and (651) show how this works in fronting languages, in particular that (651) is blocked because the verb *think* requires [WH|BOOL −] on its complement but the *wh-question-phrase* subject-head rule has propagated its non-head daughter's WH|BOOL + value to the embedded S node via the logical OR.

(650)



(651)



The clear limitations of this analysis involve the fact that polar questions will still be embedded by a *think*-verb specified like this. Below I review further issues which are revealed by the Russian test suite.

The first issue involves clauses which have question words in them but are at the same time embedded by a propositional complementizer *chto* (*that*). The issue is illustrated here as (652).

(652) ?(A) ты думаешь, что кто идет?
?(A) ty dumaesh, chto kto idet?
(and) 2SG think.PRES.2SG that who.NOM go.PAST
'And who do you think arrived?' [rus]

In (652), the question is about what the person thinks, so it is a matrix question, except the question word is not fronted. This sentence is predicted to be ungrammatical by my Russian grammar because the complementizer *chto* ('that') does not allow clausal complements which have question words in them, as shown in (651).

The second issue has to do with sentences where a question word is fronted and at the same time belongs to a clause embedded by a verb like *спрашивать* ('ask') (653). These most likely involve parenthetical reading of *ask* and so are rhetorical questions, not actual constituent questions, though I am not absolutely sure at this point (an additional speaker study is required). This is the largest category in terms of the number of examples in the test suite gotten wrong, because complex sentences allow for more combinations of e.g. word order and because absolutely all such sentences are predicted ungrammatical by the grammar.

(653)	Кто,	я	спрашиваю,	приехал?
	Kto,	ya	sprashivayu,	priehal?
	who.NOM	1SG	ask.PRES.1SG	arrive.PAST

‘I ask, who arrived./Or maybe: Who (I ask) arrived?’

The grammar does not license sentences like (653) because the embedded clause (which is just the verb *приехал*) is [WH|BOOL −] and *спрашивать* (‘ask’) insists on that feature being + on the complement (in contrast to *думать* (‘think’) and *что* (‘that’), which insist otherwise). This is another clear fault of the experiment of using the WH feature to model the contrast between *think* and *ask*.

Perhaps more problematic (compared to sentences involving *спрашивать* (‘ask’)) is the grammar’s inability to license sentences like (654)), because these definitely have a non-parenthetical, direct constituent question reading.

(654)	Кто	ты	думаешь	что	видел?
	Kto	ty	dumaesh	chto	videl?
	who.NOM	2SG.NOM	think.PRES.2SG	what.ACC	see.PAST.2SG

‘Who do you think saw what?’ [rus]

Such sentences are clearly possible in Russian as they are in English, and yet they are ruled out by the assumption that the verb *think* insists on [WH|BOOL −] clausal complements. This part of the analysis requires further work, perhaps along the lines of Ginzburg and Sag’s (2000) idea that there are duplicate lexical entries for *wh*-words, some [WH|BOOL +], which always front, and some [WH|BOOL −], which never front (see also §9.2).

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