

©Copyright 2017

Michael Haeger

# An Evidentiality Library for the LinGO Grammar Matrix

Michael Haeger

A thesis  
submitted in partial fulfillment of the  
requirements for the degree of

Master of Science

University of Washington

2017

Committee:

Emily M. Bender

Fei Xia

Program Authorized to Offer Degree:  
Linguistics

University of Washington

**Abstract**

An Evidentiality Library for the LinGO Grammar Matrix

Michael Haeger

Chair of the Supervisory Committee:

Professor Emily M. Bender

Department of Linguistics

This thesis describes a library extending the LinGO Grammar Matrix to support evidentiality. Evidentiality refers to the linguistic phenomenon where elements of a language's grammar express the source of information for a speaker's statement. This thesis reviews linguistic literature dealing with evidentiality, proposes an analysis within the Minimal Recursion Semantics (MRS) framework for modeling the semantics of evidentials, and describes the implementation and evaluation of a software library meant to extend the LinGO Grammar Matrix, a software system for the rapid prototyping of grammars, to cover evidentials.

# TABLE OF CONTENTS

	Page
List of Figures . . . . .	iii
List of Tables . . . . .	v
Chapter 1: Introduction . . . . .	1
Chapter 2: The LinGO Grammar Matrix . . . . .	3
2.1 Head-driven Phrase Structure Grammar . . . . .	3
2.2 Minimal Recursion Semantics . . . . .	7
2.3 The Grammar Matrix . . . . .	15
2.4 Summary . . . . .	17
Chapter 3: Evidentiality in the World's Languages . . . . .	18
3.1 Term Systems . . . . .	18
3.2 Expression of Evidentiality . . . . .	24
3.3 Complexities of Marking Evidentiality . . . . .	25
3.4 Semantic Complexities . . . . .	28
3.5 Summary . . . . .	37
Chapter 4: Analysis . . . . .	39
4.1 Semantic Representation . . . . .	40
4.2 Syntactic Means of Expressing Evidentiality . . . . .	46
4.3 Summary . . . . .	51
Chapter 5: Implementation . . . . .	53
5.1 Questionnaire . . . . .	53
5.2 Grammar-producing Code . . . . .	57
5.3 Summary . . . . .	60

Chapter 6:	Evaluation . . . . .	61
6.1	Pseudo-language Tests . . . . .	62
6.2	Illustrative Language Tests . . . . .	64
6.3	Held-Out Language Tests . . . . .	71
6.4	Summary . . . . .	77
Chapter 7:	Conclusion . . . . .	78

## LIST OF FIGURES

Figure Number	Page
2.1 Example of a basic feature structure representing a word . . . . .	4
2.2 Feature structure of lexical item <i>bark</i> (syntax) . . . . .	6
2.3 Feature structure of 3sg lexical rule (syntax) . . . . .	7
2.4 Feature structure of Subj-Head Phrase Rule (syntax) . . . . .	8
2.5 First interpretation of <i>Every hungry child eats some sandwich</i> . . . . .	9
2.6 Second interpretation of <i>Every hungry child eats some sandwich</i> . . . . .	9
2.7 Underspecified representation of <i>Every hungry child eats some sandwich</i> . . .	10
2.8 Feature structure of lexical item <i>bark</i> (semantics) . . . . .	11
2.9 Feature structure of 3sg lexical rule (semantics) . . . . .	13
2.10 Feature structure of Subj-Head Phrase Rule (semantics) . . . . .	14
2.11 Definition of the 3rd Singular Lexical Rule in TDL . . . . .	16
4.1 The general semantic model for an evidential . . . . .	41
4.2 Evidential semantics of <i>The fish must be getting poisoned</i> . . . . .	43
4.3 Evidential semantics of <i>He must have left his daughter-in-law there, they say.</i>	45
4.4 The evidential semantic template used in this library . . . . .	45
4.5 Evidential semantics of <i>He/she/it evidently fell.</i> . . . . .	46
4.6 The evidential-lex-rule supertype . . . . .	47
4.7 The inferential-evidential-lex-rule type . . . . .	48
4.8 Example of auxiliary verb types that take VP complements and appear after the verb . . . . .	49
4.9 The trans-first-arg-raising-lex-item-1 type . . . . .	50
4.10 An example lexical entry for an inferential auxiliary verb . . . . .	50
5.1 Evidentials Questionnaire Page . . . . .	54
5.2 Evidentiality on the Morphology Page . . . . .	55
5.3 The evidentials and morphology sections of a choices file . . . . .	56
5.4 Production of inflectional supertypes . . . . .	58

5.5	Addition of evidential predicates for auxiliary verbs . . . . .	59
6.1	Pseudo-language test sentence MRS . . . . .	63
6.2	Geographic distribution of the illustrative languages . . . . .	66
6.3	Test suite for Kazakh . . . . .	67
6.4	Kazakh sentence and MRS . . . . .	68
6.5	Qiang sentence and semantics . . . . .	68
6.6	Geographic distribution of the held-out languages . . . . .	73
6.7	Ladakhi sentence and MRS . . . . .	74

## LIST OF TABLES

Table Number	Page
3.1 Summary of evidentiality-related linguistic phenomena . . . . .	38
4.1 Coverage of evidentiality-related phenomena in the present library . . . . .	52
6.1 Pseudo-language test results . . . . .	65
6.2 Illustrative language test results . . . . .	72
6.3 Held-out language test results . . . . .	77



## Chapter 1

# INTRODUCTION

In this thesis I describe the research, implementation, and evaluation involved in developing a library for the LinGO Grammar Matrix to support evidentiality. The LinGO Grammar Matrix is a software system that produces grammar fragments based on input from user-linguists through a graphical web interface. The functionality of the Grammar Matrix is generally extended through the development of libraries that focus on supporting some linguistic phenomenon. Libraries for negation, argument optionality, adjectives, and several other phenomena have been developed in the past.

The grammars produced by the Grammar Matrix can be used for both parsing and generation tasks. One of the benefits of Grammar Matrix-style grammars is that they provide a semantic representation of a sentence’s meaning in addition to capturing syntactic structure. Besides NLP applications, these grammars can also be useful in linguistic research by facilitating the formal description of grammatical rules and the testing of linguistic hypotheses.

The linguistic phenomenon this library seeks to support is evidentiality, the grammatical encoding of the speaker’s information source. According to a typological study by Aikhenvald (2006), evidentiality is a phenomenon found in approximately a quarter of the world’s languages. In Aikhenvald’s terminology, the term *evidentiality* refers to a semantic category whose primary meaning is information source. Evidential systems vary significantly across languages that possess the category. Aikhenvald notes that languages that possess this feature are not well represented in Indo-European, and since it is these languages that have had the longest history of study in modern linguistics, scholarship on evidentiality has been relatively sparse until recently.

As an example of an evidential system, a language may have two categories: reported and

everything else, where information gained from hearsay must be marked, similarly to how an English speaker may say *it is said that* . . . . Alternatively, a more developed evidential system may have separate categories for information perceived visually by the speaker, information perceived through the other senses, information received through hearsay, and information inferred from evidence. Evidential meanings can be expressed by bound morphemes, clitics, and independent words and phrases. Evidential meanings in a single language need not be limited to a single morphological or syntactic slot within the language’s grammar. Further, evidential meanings may be split across two layers that interact to create specific evidential semantics from different combinations of forms.

An overview of the Grammar Matrix project, as well as its theoretical foundations, Head-driven Phrase Structure Grammar (HPSG) and Minimal Recursion Semantics (MRS), is provided in Chapter 2. Chapter 3 is a review of the typological literature dealing with evidentiality. The first step in developing a library is defining the phenomenon based on this literature review. The second step is to determine the theoretical analysis in HPSG and MRS that the library is aiming for. An account of my analysis of evidentiality in these frameworks is found in Chapter 4. Chapter 5 describes the changes this library makes to the Grammar Matrix’s code to implement the analysis described in Chapter 4, while Chapter 6 explains how I evaluated the coverage and performance of this library. Chapter 7 concludes the thesis, including thoughts on directions for future work.

## Chapter 2

# THE LINGO GRAMMAR MATRIX

The LinGO Grammar Matrix (Bender et al., 2002, 2010) is an ongoing project aiming to provide tools for the rapid development of grammars for computational applications. A number of applications in computational linguistics require the ability to parse sentences in a given language. This requires a grammatical model of the language, a “grammar”, which defines the possible combinations of words and phrases in the language. The Grammar Matrix’s theoretical groundings are in the Head-driven Phrase Structure Grammar (HPSG) (Pollard and Sag, 1994) approach to syntax, a phrase-structure grammar approach that uses complex feature structures to encode properties of words and phrases, such as tense of verbs, or unfulfilled argument requirements. The HPSG grammars produced by the Grammar Matrix further encode semantic information in a scheme called Minimal Recursion Semantics (MRS), as described by Copestake et al. (2005). In this chapter, I will provide an overview of HPSG, MRS, and the Grammar Matrix project itself.

### 2.1 *Head-driven Phrase Structure Grammar*

Head-driven Phrase Structure Grammar (HPSG), originally developed by Pollard and Sag (1994), is an approach to syntax that relies on constraints and unification to model linguistic phenomena.

#### 2.1.1 *Feature Structures*

Linguistic entities, such as words and phrases, are represented in HPSG as typed feature structures (Carpenter, 2005), data structures composed of feature-value pairs, where the value itself may be another feature structure. The type of a feature structure defines which

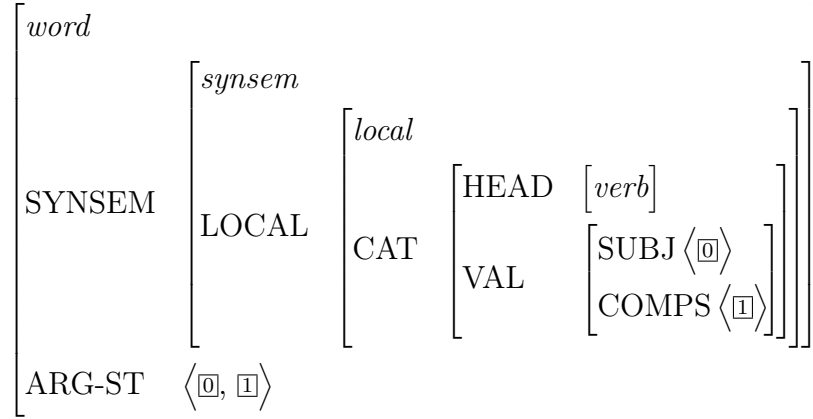


Figure 2.1: Example of a basic feature structure representing a word

features are appropriate for the feature structure and defines constraints on the feature structure's values. Further, types are organized in a hierarchy that limits which feature structures can unify with each other. As an example, an HPSG grammar of English could represent transitive verbs with a *tr-verb* type that constrains feature structures instantiating the type to have a COMPS (complements) list with a length of one, indicating that it must be provided with one complement. It is possible in this formalism to require two or more features to refer to the same feature structure; this is called reentrancy or structure sharing.

These feature structures are often represented as attribute-value matrices. As an example, Figure 2.1 shows an attribute-value matrix that could be produced by a grammar developed in HPSG. Each feature structure is represented between square brackets; the feature structure's type is in italics at the top, its features are in capital letters to the left, and the values are located to the right of their features. Reentrancy/structure sharing is shown by a small box with a number inside, a tag that represents feature structure identity.

The feature structure types are organized in a hierarchy, allowing for multiple inheritance. So, for example, the type *basic-head-subj-phrase* inherits from *head-valence-phrase* and *head-compositional* in the Grammar Matrix. Inheritance means that the child type must impose all constraints of all its parents. If there are any conflicting constraints between the parent types and/or the child type, the child is an invalid type.

### 2.1.2 Applying Rules with Unification

The way that a lexical or phrase structure rule is applied is that the feature structure of the components of the phrase or the stem of the lexical rule are identified with the appropriate features in the rule's feature structure. This is done through an operation called unification (Shieber, 2003), which harmonizes the constraints of all feature structures that are being identified. If any of these constraints are inconsistent with those contributed by the other feature structures, unification fails, and the combination is invalid. This is how the sentence *Three dogs barks* would be labeled ungrammatical: *barks* constrains its subject to be singular, and the rule constrains *Three dogs* to be the subject of *barks*. Since *Three dogs* is plural, violating the constraint contributed by *dogs*, unification fails.

### 2.1.3 Definition of a Grammar

There are three main categories of types in an HPSG grammar, 1) lexical types, 2) construction types, and 3) miscellaneous types. Lexical types, like the *tr-verb* type proposed above, are types instantiated by entries in the lexicon. Construction types describe phrase structure rules, such as the head-complement rule, and lexical rules. Finally, the miscellaneous types define other useful properties, like the different values for CASE or TENSE.

In this section I'll explain how various lexical and phrase structure rules apply to the sentence *The dog barks*. The syntactic analysis given here is taken from a simplified grammar of English produced by the Grammar Matrix and used in the course LING 567<sup>1</sup> at the University of Washington. An abridged feature structure representing the syntactic properties of the lexical item *bark* can be written as in Figure 2.2. Here, the lexical type of the word is expressed in the feature structure's type, *itr-verb-lex*, the supertype of all intransitive verbs. The intransitive constraint is shown by the empty COMPS list (which refers to the complements of the word). The SUBJ (subject) list contains one element, with constraints that that element be a noun in the nominative case. Further, the element of the SUBJ list

---

<sup>1</sup><http://courses.washington.edu/ling567/>

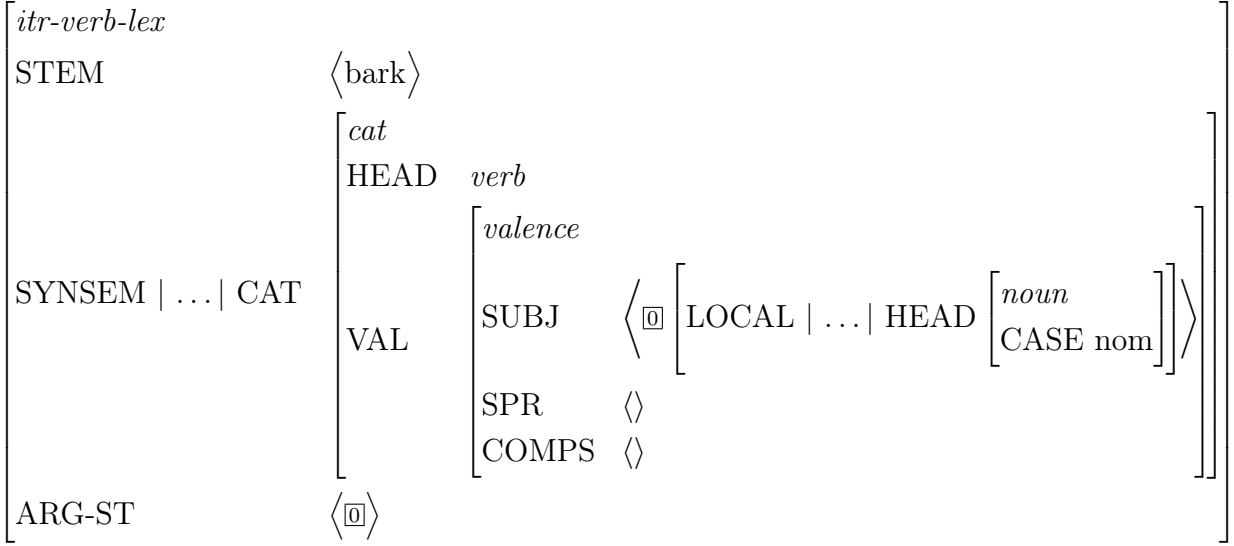


Figure 2.2: Feature structure of lexical item *bark* (syntax)

is identified with the single element on the ARG-ST list (ARG-ST is the concatenation of the SUBJ, SPR, and COMPS lists). The SYNSEM feature refers to the combination of syntactic and semantic information (more on semantic information in the next section), LOCAL refers to the local properties of the word (NON-LOCAL deals with long-distance dependencies), and CAT contains the syntactic properties of the word.

By contrast, the lexical entry of *dog* would have an empty SUBJ list, since nouns don't need subjects, but an SPR list of one element, since English nouns (usually) require a specifier of some sort (additional rules exist to account for plural and mass nouns).

In order to account for the form *barks*, a lexical rule is applied to *bark*, the *3sg-lex-rule*. In Figure 2.3 I show an abridged feature structure demonstrating how this rule applies to the word *bark*. Here, the ARGS list to the rule consists of a single argument, the daughter (DTR), that is, the lexical item *bark*. The application of a lexical rule consists of identifying a lexical item (or the feature structure of a different lexical rule) with the DTR feature. Here, the CAT feature of this feature structure is identified with that of the daughter, maintaining the basic syntactic information from the daughter. The major change is that the PERNUMTENSE-

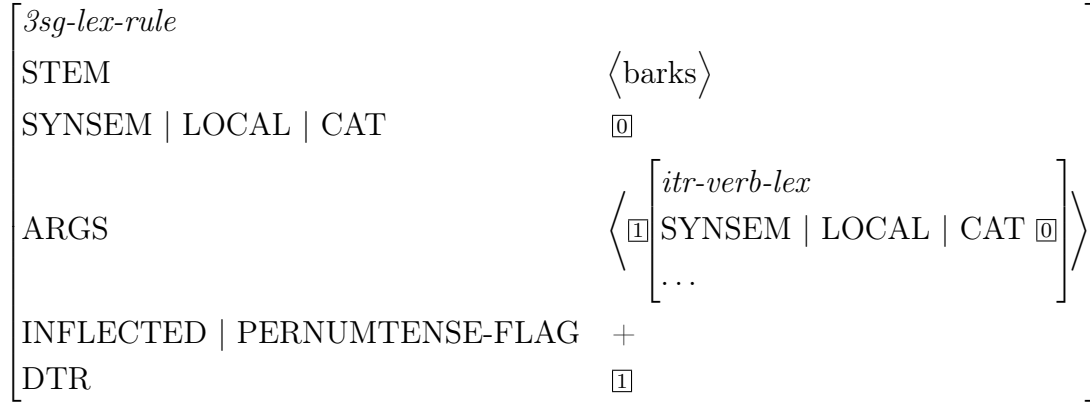


Figure 2.3: Feature structure of 3sg lexical rule (syntax)

FLAG in INFLECTED is satisfied. (Also, the subject of the verb is constrained to be 3rd person singular, but this is handled in the semantics, not shown in this figure.) The flag features inside INFLECTED represent the requirements for a word to be considered fully inflected; specifically, all flags in INFLECTED must be *na-or-+*, that is, non-applicable or true, for the word to be used in a sentence.

In Figure 2.4 there is an example of an abridged feature structure representing the application of the Subj-Head Phrase Rule to this sentence, which combines the subject phrase (*the dog*) with the head, *barks*. Its head daughter must have a SUBJ list with one element, which must unify with the SYNSEM of the non-head daughter. The rule’s feature structure in turn has an empty SUBJ list, meaning it requires no further subject. Since the HEAD type is *verb*, and the VAL lists are all empty, the feature structure unifies with the initial symbol and thus represents a complete sentence.

## 2.2 Minimal Recursion Semantics

The foregoing section discussed how the syntax of a sentence is represented in the Grammar Matrix’s HPSG-based framework, but it did not discuss one of the Grammar Matrix’s main benefits: the ability to produce a formal representation of a parsed sentence’s semantics (or, in reverse, to generate a sentence from that semantic representation). The Grammar

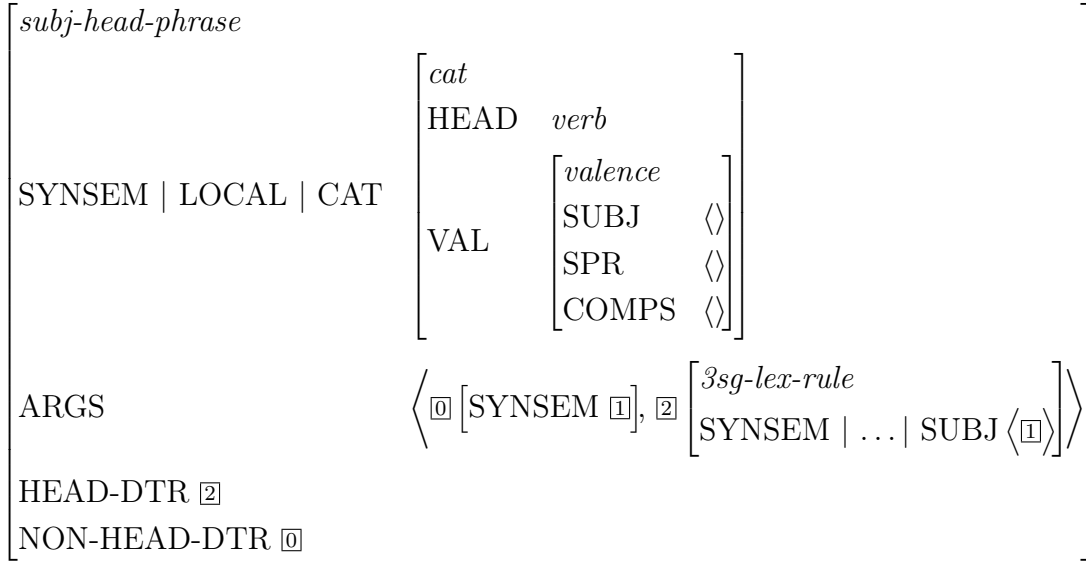


Figure 2.4: Feature structure of Subj-Head Phrase Rule (syntax)

Matrix makes use of Minimal Recursion Semantics (MRS) (Copestake et al., 2005). An MRS structure formally represents the meaning of a word, phrase, or sentence. An MRS structure consists of a bag of *elementary predications* (EPs), each EP consisting of a *predicate* and the predicate’s *arguments*.

One of the primary benefits of MRS is that it is able to represent both fully disambiguated scopal semantics as well underspecified scopal semantics. This is useful for representing such scopally ambiguous sentences as *Every hungry child eats some sandwich*, which has two interpretations: 1) for every hungry child, there is some sandwich that that hungry child eats, and 2) there is some sandwich, and every hungry child eats that one sandwich. The way this is accomplished is through *handles*: every EP has a *label*, whose value is one of the handles in the MRS structure; EPs that are scopally conjoined (like *hungry* and *child* in the preceding example) share the same handle. Each EP, in addition to variable arguments that refer to individuals, can also contain scopal arguments that refer to handles. A label is *equal modulo quantifiers* (qeq) to a another label if the two labels point to the same handle, or if there is a chain of quantifier EPs in between the first and second label.



$$\langle h_1, \left[ \begin{array}{l} h_1:\text{every}(\text{ARG0 } x, \text{RSTR } h_2, \text{BODY } h_3), \\ h_2:\text{hungry}(\text{ARG0 } x), h_2:\text{child}(\text{ARG0 } x), \\ h_3:\text{some}(\text{ARG0 } y, \text{RSTR } h_4, \text{BODY } h_5), \\ h_4:\text{sandwich}(\text{ARG0 } y), \\ h_5:\text{eat}(\text{ARG1 } x, \text{ARG2 } y) \end{array} \right] \{ \} \rangle$$

Figure 2.5: First interpretation of *Every hungry child eats some sandwich*

$$\langle h_3, \left[ \begin{array}{l} h_1:\text{every}(\text{ARG0 } x, \text{RSTR } h_2, \text{BODY } h_5), \\ h_2:\text{hungry}(\text{ARG0 } x), h_2:\text{child}(\text{ARG0 } x), \\ h_3:\text{some}(\text{ARG0 } y, \text{RSTR } h_4, \text{BODY } h_1), \\ h_4:\text{sandwich}(\text{ARG0 } y), \\ h_5:\text{eat}(\text{ARG1 } x, \text{ARG2 } y) \end{array} \right] \{ \} \rangle$$

Figure 2.6: Second interpretation of *Every hungry child eats some sandwich*

In addition to this bag of EPs, an MRS structure further contains a *top handle*, identified with the handle of the root EP or conjunction of EPs in the structure, as well as a list of *handle constraints*, or HCONS. These handle constraints usually take the form of qeq relation requirements. The MRS structure shown in Figure 2.5 represents the first meaning of the sentence *Every hungry child eats some sandwich*. Conversely, the second interpretation of this sentence would be represented with the MRS structure in Figure 2.6.

The differences between these two MRS structures are the values of the *body* arguments of the two quantifiers. In the first case, the body of the *some* quantifier is the situation *x fights y*, and the body of the *every* quantifier is the *some* quantifier. In the second situation, this is reversed. The MRS structure shown in Figure 2.7 represents the semantics of the

$$\langle h_0, \left[ \begin{array}{l} h_1:\text{every}(\text{ARG0 } x, \text{RSTR } h_2, \text{BODY } h_7), \\ h_3:\text{hungry}(\text{ARG0 } x), h_3:\text{child}(\text{ARG0 } x), \\ h_4:\text{some}(\text{ARG0 } y, \text{RSTR } h_5, \text{BODY } h_8), \\ h_6:\text{sandwich}(\text{ARG0 } y), \\ h_9:\text{eat}(\text{ARG1 } x, \text{ARG2 } y) \\ \{ h_2 =_q h_3, h_5 =_q h_6 \} \end{array} \right] \rangle$$

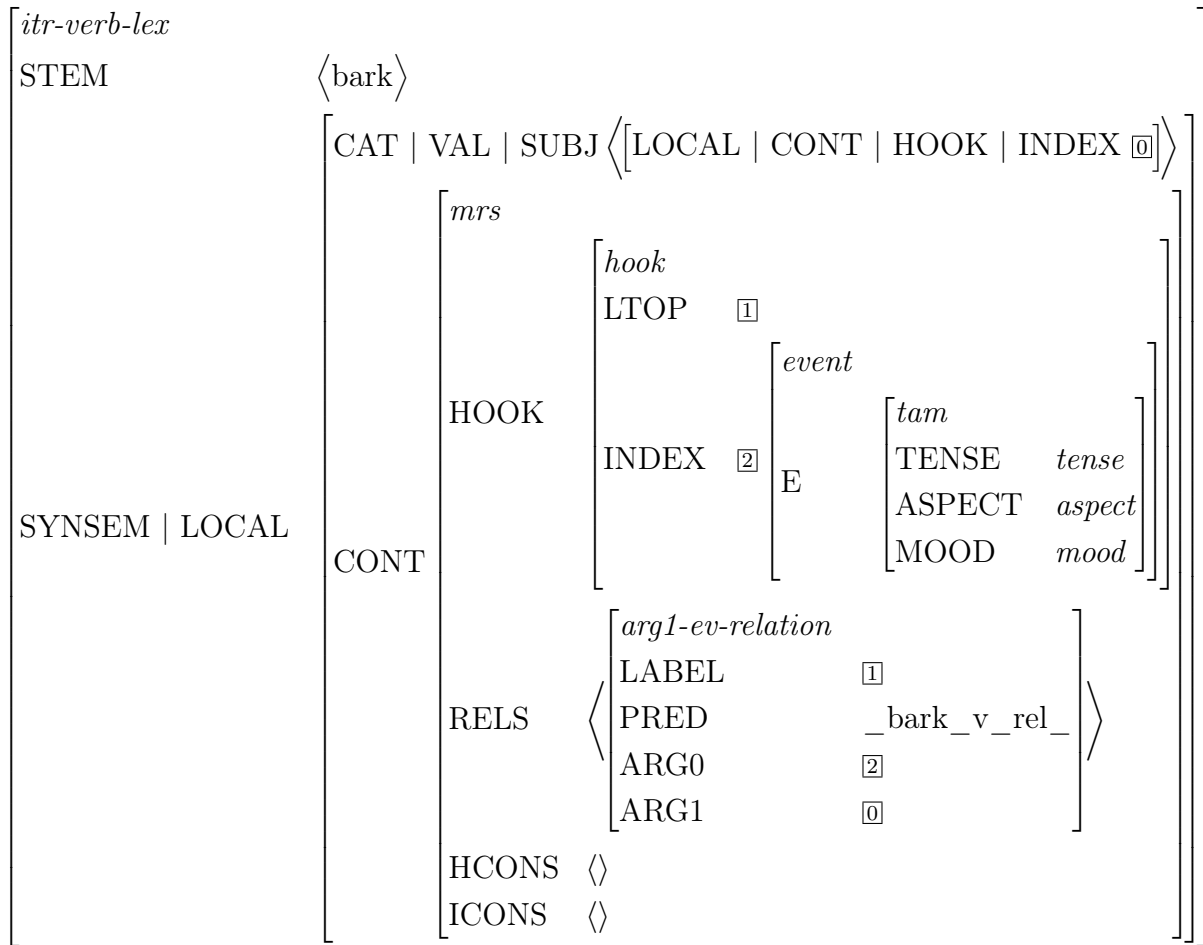
Figure 2.7: Underspecified representation of *Every hungry child eats some sandwich*

sentence in a way that allows either interpretation. Here, the body arguments of the two quantifiers are left unspecified, but the handle constraints require that the restrictions of both quantifiers are qeq to the nominal associated with that quantifier. So, the restriction of *every* is qeq to *hungry child* and the restriction of *some* is qeq to *sandwich*.

An important feature of MRS is that it is strictly compositional, meaning that the semantics of the daughters of the rules are all present in the semantics of the result of the rule. That is to say, semantics are never deleted in MRS; they are only combined and potentially added to.

To illustrate how MRS applies to the Grammar Matrix, I return to the sentence *The dog barks*, this time looking at the semantic features that were omitted earlier. Note that I separate syntactic and semantic feature structures only for presentational reasons; in a Grammar Matrix-style grammar, the semantic and syntactic information are contained in a single feature structure. Again, the feature structures are abridged, to focus on the most important features.

Figure 2.8 illustrates the abridged feature structure of *bark*, this time focusing on the most important semantic features. The CONT feature stands for *content*, and is the main place semantic information appears. The HOOK feature represents the information that is “visible” to other feature structures and subject to their constraints. HOOK contains the LTOP feature, pointing to the local top handle of the MRS structure. The INDEX feature points

Figure 2.8: Feature structure of lexical item *bark* (semantics)

to the individual represented by this word itself; that is, the event of barking. This event contains the feature E, which in turn contains the semantic information of tense, aspect, and mood. The fact that these features currently only constrain their values to their types indicates that they are *underspecified*; that is, they can be unified with another feature structure irrespective of that other feature structure’s tense-aspect-mood values.

The RELS feature of CONT represents the bag of EPs in an MRS structure, each element corresponding to a single EP. The semantic relation of the EP is represented by the PRED feature. The ARG0 feature is the argument which represents the event of barking itself; this is identified with HOOK | INDEX value. On the other hand, ARG1, which in this case represents the agent, that is, the barker, is identified with the INDEX value of the verb’s subject’s INDEX. This constraint is what will tie together the semantics of *the dog* and *barks* when the Subj-Head Phrase Rule is applied to the two phrases.

In Figure 2.9, there is an abridged feature structure for the application of the *3sg-lex-rule* to the verb *bark*. The primary difference between this view of the feature structure, on the one hand, and the syntactic view and lexical item feature structure given in Figure 2.2. on the other, is twofold. First, the TENSE of the *barking* event is constrained to be *nonpast*. The semantics would not be right if it was underspecified for tense, since *The dog barks* could then be considered semantically equivalent to *The dog barked*. There is a semantic difference between the two sentences, which is captured in a feature of the event’s feature structure. This is an important observation that merits an explicit statement: not all semantic content is represented by EPs; some semantic content may be represented by features instead. This is an important point in the analysis of evidentiality in this thesis.

The second important semantic difference is that the person of the subject is specified to be *3rd*, and the number of the subject is specified to be *sg* (singular). This is how agreement works in HPSG: the feature structure of one element of the sentence places constraints on an element on one of its valence lists. This way, unification with a non-third-singular noun phrase, like the first person singular pronoun, will fail, preventing the grammar from accepting the ungrammatical sentence *\*I barks*.

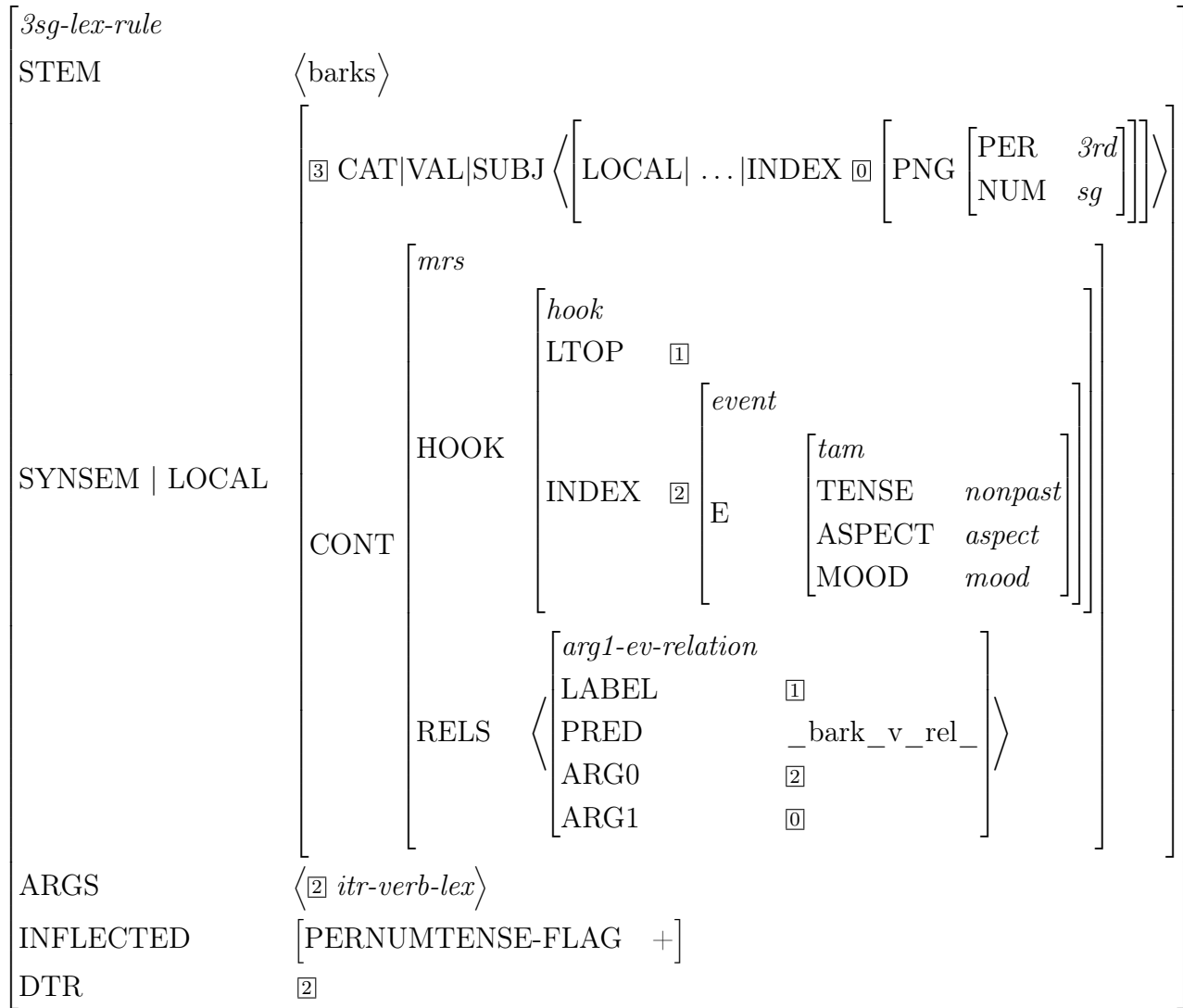


Figure 2.9: Feature structure of 3sg lexical rule (semantics)

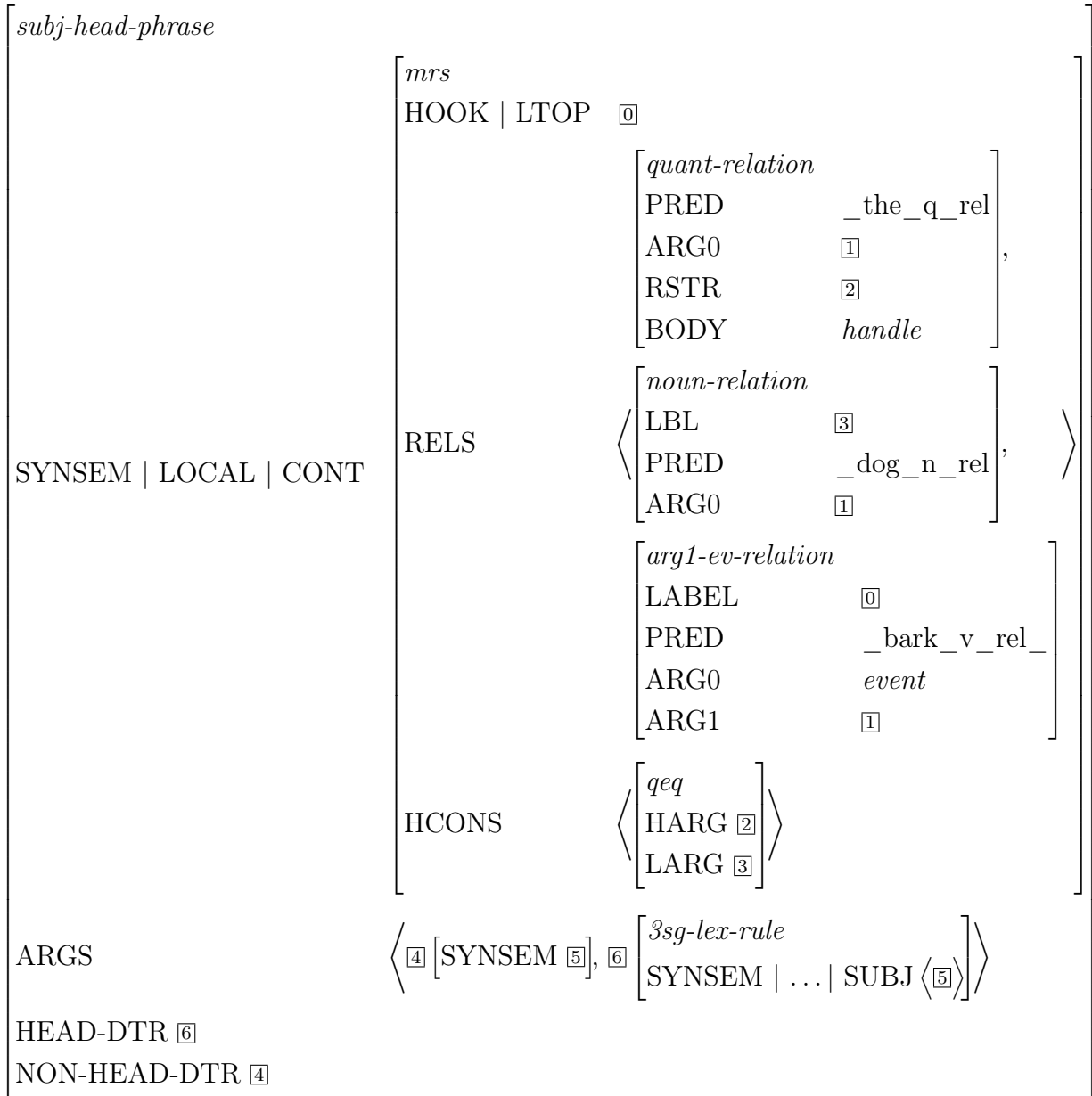


Figure 2.10: Feature structure of Subj-Head Phrase Rule (semantics)

Finally, I present the Subj-Head phrase structure rule applied to the sentence *The dog barks*. Figure 2.10 displays some of its more important features in a feature structure. This feature structure shows the result of semantic composition in MRS: the two EPs from the phrase *the dog* are both included in the RELS list. As required by constraints we’ve seen previously, the ARG1 of the *barking* predication (that is, the barker), is identified with the ARG0 of the *dog* predication (and also with the ARG0 of the *the* predication).

This example also demonstrates how quantifiers are represented in MRS. The RESTR field, or restriction, of the *the* quantifier is *qeq* to the label of the *dog* EP. This equality modulo quantifiers is represented by the *qeq* feature structure in the HCONS list.

Finally, this shows that the LTOP (local top label) of the whole sentence is identified with the label of the *barking* predication. This is standard for basic sentences in MRS: the top label of the sentence is the label of the main event being communicated. That said, if a scopal modifier is introduced, then the top label would be the label of the modifier.

The examples in this section cover the main semantic features of MRS as they relate to grammars developed with the Grammar Matrix. The formal representation of semantics in the MRS framework will be a fundamental part of the library I develop for this thesis.

### 2.3 The Grammar Matrix

The LinGO Grammar Matrix itself is a piece of software that allows users to quickly prototype grammatical models of the kind described above. It consists of a core of grammatical type declarations (Bender et al., 2002) and two major modules for customizing grammars (Bender et al., 2010). The first module is the questionnaire, a web application that allows a user-linguist to answer typological questions about a language, as well as enter specifics of its lexicon and morpheme inventory. The web application produces as output a *choices file*, which stores the content of the answers to the questionnaire in a standard, human-readable format. The second module, which can be invoked from the web application but can also be run separately, takes a choices file as input and produces as output a collection of files that store the grammatical model as a collection of TDL files representing the type hierarchy and

```

3sg-lex-rule := infl-lex-rule & prenumtense-lex-rule-super &
  [ SYNSEM.LOCAL [ CAT.VAL.SUBJ.FIRST.LOCAL.CONT.HOOK.INDEX.PNG [ PER 3rd,
                                                                    NUM sg ],
                                                                    CONT.HOOK.INDEX.E.TENSE nonpast ] ] .

```

Figure 2.11: Definition of the 3rd Singular Lexical Rule in TDL

feature structures of the grammar in the DELPH-IN Joint Reference Formalism.

As an example, the code for the *3sg-lex-rule* in the grammar of English used for the previous examples is shown in Figure 2.11. The first line indicates the name of this type and the types from which it inherits. The remaining lines declare any further constraints the type being defined imposes.

In the format of the Grammar Matrix, feature structures are expressed using the DELPH-IN Joint Reference Formalism (Copestake, 2002a) in TDL-type files. A grammar is composed primarily of definitions of types and the definitions of grammar entities, such as entries in the lexicon, lexical rules, and phrase structure rules.

The files that are produced by the Grammar Matrix can be used with other tools, including a number of DELPH-IN tools, including the Lexical Knowledge Builder (LKB)<sup>2</sup> (Copestake, 2002c) and the Pet<sup>3</sup> (Callmeier, 2000), ACE<sup>4</sup>, and Agree<sup>5</sup> (Slayden, 2012) parsers. The heart of a grammar is composed of a series of TDL files, such as <name of language>.tdl, irules.tdl, lexicon.tdl, and rules.tdl, that are produced according to the user-linguist’s input to the questionnaire. There is also a file called matrix.tdl, which contains general definitions of basic types and is the same for all grammars output by the Grammar Matrix. The customized TDL files expand on matrix.tdl types and define new types that often inherit from those in matrix.tdl.

---

<sup>2</sup><http://moin.delph-in.net/LkbTop>

<sup>3</sup><http://moin.delph-in.net/PetTop>

<sup>4</sup><http://moin.delph-in.net/AceTop>

<sup>5</sup><http://moin.delph-in.net/AgreeTop>



A common workflow is for a user-linguist to produce a prototype grammar using the Grammar Matrix, then subsequently directly edit to TDL to add features and constraints not yet supported by the Grammar Matrix. This process allows linguists to skip the large amount of boilerplate code involved in setting up a basic grammar, and to focus on the more difficult or obscure syntactic/semantic issues in representing the language.

## **2.4 *Summary***

This chapter has outlined the theoretical framework under which the LinGO Grammar Matrix operates, as well as its technical details. This has been a necessarily quick overview, and there are many particulars that have been omitted. However, this chapter has hopefully provided readers with enough of an understanding of these frameworks to assist an understanding of the issues developed in this thesis.

## Chapter 3

# EVIDENTIALITY IN THE WORLD'S LANGUAGES

This chapter consists of a review of the typological literature on evidentiality. The goal of this review is to ground the library in cross-linguistically valid analysis of evidentiality. Since the goal of the Grammar Matrix is to provide a useful tool to linguists working on any language, it is important for libraries to account for the diversity within a linguistic phenomenon across the world's languages.

I'll begin with an overview of the most common types of evidential inventories, followed by a discussion of how evidentials are most commonly expressed. Then I will discuss some of the ways evidentials interact with other grammatical categories and with each other.

### 3.1 *Term Systems*

Aikhenvald (2006) develops a typology of evidentials in languages based on 1) the number of *terms*, or evidential values, that the language contains, and 2) language's specific inventory of terms. To provide the reader with a sense of the range of evidential systems in the world's languages, a short summary of this typology is given here. I will begin with four-term systems, to give readers a sense of the most common evidential terms, then I will discuss three- and two-term systems. Finally, I'll briefly mention systems with five or more terms, which tend to be more idiosyncratic than the simpler systems.

Aikhenvald includes a recurring label *everything else*. In two-term systems this term is an evidentially neutral form. Aikhenvald notes that "Strictly speaking, systems of this kind have only one evidential 'term'. They have been included on a par with two-term systems because of the semantic similarities and tendencies towards historical development"

(Aikhenvald, 2006, 23). This label also shows up in three-term B5<sup>1</sup> systems, which are analogous to two-term A3 systems. These are the only systems Aikhenvald applies the term to; she does not apply the term to systems with four or more terms; in these, the lack of evidential marking is not considered part of the evidential system. To be consistent with Aikhenvald's typology, I also use the term *everything else*, but it should be clearly understood that these *everything else* terms do not provide evidential semantics.

### 3.1.1 Four-term systems

C1. *Visual, Non-visual sensory, Inferred, Reported*. Here, the visual evidential indicates that the speaker saw the event that is being stated. The non-visual sensory term indicates that the speaker perceived it through another sense, such as hearing or touch. The inferential term means that the speaker's statement is an inference based on evidence, while the reported evidential indicates that the speaker was told about the event by someone else. These terms are common in simpler systems, where two or more terms may be combined into a single term, as discussed below.

C2. *Direct (or Visual), Inferred, Assumed, Reported*. Here, the direct (or visual) term can refer either to any sensory information source or strictly vision. The distinction between inferred and assumed is that "the inferred evidential typically refers to inference based on visible or tangible results, or direct physical evidence. The assumed evidential is to do with assumption, or general knowledge" (Aikhenvald, 2006, 54).

C3. *Direct, Inferred, Reported, Quotative (or a second Reported)*. Here, the visual and non-visual sensory terms of C1 are combined into the direct term. Aikhenvald says that the reported and quotative can mean slightly different things in different languages. In Cora (crn),<sup>2</sup> the reported evidential means the same thing as in the previous two types, while the

---

<sup>1</sup>In Aikhenvald's typology, A refers to a two-term system, B refers to a three-term system, and C refers to a four-term system.

<sup>2</sup>This is an ISO-639-3 language code. These codes are always three letters long, and they exist to provide a standard way of identifying languages, considering that there may be more than one name for a single language. A list of these codes can be found at <http://www-01.sil.org/iso639-3/codes.asp>.

quotative term indicates that the speaker’s speech is a verbatim quote from another person, either real or a character in a story. On the other hand, in Southeastern Tepehuan (stp), which Aikhenvald includes in this category, there are two reported evidentials: the first is when the reported information was not previously known to the speaker, the second when the speaker did previously know the information (Aikhenvald, 2006, 58).

### 3.1.2 *Three-term systems*

B1. *Direct (or Visual), Inferred, Reported.* The first term, depending on the language, can refer only to visually-acquired information, or it can refer to any information acquired through the senses. When the direct evidential is explicitly visual, as in Qiang (cng), there may be the option to not mark evidentiality, which would be required for non-visual sensory information sources (Aikhenvald, 2006, 45).

B2. *Visual, Non-visual sensory, Inferred.* In this type of system, information acquired through hearsay appears to be combined with the inferential term, as is the case with Siona (snm) (Aikhenvald, 2006, 46).

B3. *Visual, Non-visual sensory, Reported.* The example that Aikhenvald cites for this category is a language isolate in Papua New Guinea, Oksapmin (opm). She cites Lawrence (1987) for her description of the language’s evidential system. Lawrence notes that the firsthand terms (under which he includes both the visual and non-visual sensory terms) deal with “information about things which [the speaker] has experienced, observed, or thought out” (Lawrence, 1987, 54). This inclusion of information that the speaker has “thought out” seems to indicate that inferential meanings would be included under the category for the source of evidence on which the inference is formed.

B4. *Non-visual sensory, Inferred, Reported.* In these systems, there is also the option to not mark the sentence for evidentiality. In this evidentially ambiguous case, there are multiple possible readings. If the information is obtained visually, the sentence would be unmarked for evidentiality; however the unmarked form could also be used in other cases, when the speaker feels it is unnecessary to mark information source (Aikhenvald, 2006, 49-50).

B5: *Reported, Quotative, ‘everything else’*. Aikhenvald draws a comparison to A3 systems, discussed below, which distinguish between a hearsay evidential and everything else (Aikhenvald, 2006, 50). The difference in B5 is that a reported evidential indicating that the information source is hearsay is contrasted to a quotative evidential that indicates that the statement is a direct quote.

### 3.1.3 Two-term systems

A1: *Firsthand and Non-firsthand*. In this system *firsthand* refers to information acquired through the senses of the speaker (a combination of visual and non-visual sensory meanings), and *non-firsthand* refers to information from all other sources (mostly, this is a combination of inferential and hearsay meanings).

A2: *Non-firsthand and everything else*. At first glance, this category appears to be the same as A1, except with the orders reversed. However, in these languages, the *everything else* form is evidentially ambiguous; it can be used for both situations where the information is firsthand and situations where it is not. The *non-firsthand* term explicitly means that the information was not gained firsthand through the speaker’s senses. Aikhenvald includes in this category languages like the Turkic languages that traditionally have been said to have “directive” (*everything else*) and “indirective” (*non-firsthand*) evidentials.

A3: *Reported and everything else*. In this system, the *reported* term indicates that the information was told to the speaker by someone else; all other cases are covered under *everything else*. The *reported* term often takes on an additional meaning that the speaker is unsure of or questions the information, as in Estonian (est), Latvian (lav), and Warlpiri (wbp), but this is not necessary, and in languages like the Kham languages (kif, kgj, kip, kjl) and Lezgian (lez), the reported evidential does not imply anything about whether the speaker is uncertain (Aikhenvald, 2006, 33).

A4: *Sensory and Reported*. This category is similar to A1, with the main difference being that the inferential meaning is categorized under sensory evidence instead of being grouped together with reported.

A5: *Auditory and everything else*. Here, the distinction is between information directly perceived through hearing and information acquire through any other means. This is a rare category—Aikhenvald found only one such language, Euchee (yuc). Aikhenvald conjectures that “Euchee is a dying language. So, could it be the case that such an unusual system is simply the result of the drastic reduction so frequently observed in the situations of language obsolescence?” (Aikhenvald, 2006, 37).

### 3.1.4 *Systems with five terms or more*

There are fewer thorough analyses of evidential systems with more than four terms than of systems with four and fewer terms, so Aikhenvald doesn’t bother creating a sub-typology as she did with the other systems. I’ll give here two examples to show how evidential systems may extend past the types we’ve seen so far.

One example of a language with five terms is Traditional Wintu (wnw), which has 1) Visual, 2) Non-visual sensory, 3) Inferred, 4) Assumed, and 5) Reported evidentials. The meanings of most of these are similar to those found in the simpler systems. As an example of the difference between inferred and assumed, take the situation where the speaker is communicating the main event *He is chopping wood*. The inferred evidential would be used when “I have gone to his cabin, find him absent and his axe is gone” (Aikhenvald, 2006, 60). On the other hand, the assumed evidential would be used when “I know that he has a job chopping wood every day at this hour, that he is a dependable employee, and, perhaps that he is not in his cabin” (Aikhenvald, 2006, 60).

Aikhenvald cites a language in Papua New Guinea, Foe (foi), as an example of a language with a six-term evidential system. Its terms are: 1) Participatory, 2) Visual, 3) Non-visual sensory, 4) Mental deduction, 5) Visible evidence, 6) Previous evidence. Aikhenvald states that “‘Participatory’ or factual evidential implies that the speaker is participating in the action, or is making a statement of a generally known fact . . . Visual implies that the action was seen . . . Non-visual (‘sense perception’) indicates that the action was perceived by hearing, smelling, feeling, or understanding . . . Mental deduction implies an inference based on

something for which the speaker has evidence perceived with his senses ... Visible evidence implies inference base on the visible results ... Previous evidence describes, for instance, an event the evidence for which the speaker had seen, but cannot see at the moment of speech” (Aikhenvald, 2006, 63).

These two examples demonstrate how more complex systems can differ, as well as how the semantic distinctions between evidentials tend to become more nuanced in systems with more terms. Considering this, a system for modeling evidentiality should allow flexibility in defining new evidentials, as it would be unnecessary, difficult, and most likely impossible to produce a universal inventory of evidential terms that could apply to every language. That said, having a default inventory of the most common terms could be useful, since there is regularity in the simpler evidential systems.

### *3.1.5 Variation within a type*

One important thing to note is that even within a type, the meanings of the terms may not perfectly match. For example, Qiang (cng) and Shasta (sht) are classed as B1 (Direct, Inferred, and Reported terms) systems. However, the direct term means different things in the two languages. In Shasta, the direct term can refer to any information acquired through the senses, whereas in Qiang, the term refers strictly to information acquired visually. If the speaker can sense something through another sense without seeing it, they would use the inferential term. This difference could motivate splitting this type into two distinct types, though Aikhenvald does not do so, and it would lead to a less compact typology.

This observation is not very important when working on an implementation of the grammar of a single language, but it is worth keeping in mind when it comes to multilingual applications, such as machine translation. Also, when specifying an inventory of commonly used evidentials, this distinction will be important to keep in mind.

### 3.2 *Expression of Evidentiality*

There is significant variation to the morphological, syntactic, and lexical means by which evidentiality is expressed across the world's languages. Evidentials can be inflectional affixes, as in Yukaghir (ykg), or Qiang (cng), as demonstrated in this example with the visual evidential (VIS), an affix on the verb:

- (1) the: zdzyta:            fia-qə-(w)u.  
3SG Chengdu+LOC OR-go-VIS

‘He went to Chengdu.’ (used in a situation where the speaker saw the person leave and that person has not yet returned) [cng] (LaPolla, 2003, 65)

They can be clitics, such as the second-position clitics found in Shipibo-Konibo (shp) and Quechua (que), the latter shown by this example:

- (2) huk=si    ka-sqa huk machucha-piwan payacha.  
once=REP be-SD one old.man-WITH woman

‘Once there were an old man and an old woman.’ [que] (Aikhenvald, 2006, 68)

In Quechua, the clitics can also occur on a focused element of the sentence:

- (3) Pidru kunan=**mi**    wasi-ta    tuwa-sha-n.  
Pedro now=**DIR.EV** house-ACC build-PROG-3SG

‘It is now that Pedro is building the house.’ [que] (Aikhenvald, 2006, 69)

Evidentials can be expressed as independent words, as in Western Apache, where the non-visual experiential evidential is an independent particle:

- (4) Train hilwoł            hiłts’ad.  
train 3SG.PROG.run NVEXP

‘I hear the train (running).’ (noise heard) [apw] (de Reuse, 2003, 80)



Or, as in the hearsay evidential of Japanese (jpn), they may be expressed with a combination of a nominalizing evidential particle plus the copula:

- (5) Kaza ga cuyo-katta **-soo** da.  
 wind S.M. strong-PAST **HEARSAY** COP

‘They say the wind was strong.’ [jpn] (Aoki, 1986, 230)

It’s fairly common to see the evidential system of a language combined with the tense system of a language, especially with past tenses. This is common in the Turkic languages, like Kazakh (kaz), where two past tenses exist, *-DI*, which is evidentially ambiguous, and *-IptI*, which indicates that the information source is non-firsthand, as shown in these examples:

- (6) tūs-**ipti**.  
 fall-**PAST.INDIR**

‘[He/she/it] has evidently fallen, evidently fell.’ [kaz] (Johanson, 2003, 279)

- (7) qara-**dï**.  
 see-**PAST.DIR**

‘S/he saw.’ [kaz] (Muhamedowa, 2015, 175)

### 3.3 Complexities of Marking Evidentiality

#### 3.3.1 Scattered Systems

In some evidential systems, the evidentials form a single grammatical category, all occupying a single position in the phrase, or a single slot in a verb’s morphology, for example. However, it’s not uncommon for the evidential system to span multiple separate slots or parts of speech. For example, in Japanese (jpn), the evidential system contains terms expressing 1) hearsay, 2) inference based on “visible, tangible, or audible evidence collected through [one’s] own

senses,” 3) inference “when the evidence is circumstantial or gathered through sources other than one’s own senses’, and 4) inference when “the speaker believes in what he is making an inference about” (Aoki, 1986, 231-233). Due to the three inferential terms, this system does not fit neatly in Aikhenvald’s typology described in the previous section. The way Evidential 1 is marked is by the phrase *soo da*, where *soo* is a noun and *da* is a copula, preceded by a verb, predicate adjective, or predicate noun phrase:

- (8) Kaza ga cuyo-katta **-soo** da.  
 wind SUBJ strong-PAST **HEARSAY** COP

‘They say the wind was strong.’ [jpn] (Aoki, 1986, 230)

- (9) Kare wa daigakusei da-tta **-soo** da.  
 he TOP university.student be-PAST **HEARSAY** COP

‘They say he is a university student.’ [jpn] (Aoki, 1986, 231)

Evidential 2 is marked with *yoo da*, where *yoo* is a noun, and *da* is again the copula. Evidential 3 is expressed with *rasii*, where *rasi* is an adjective. These are shown in the following examples:

- (10) Kono kusuri wa yoku kiku **yoo** da.  
 this medicine TOP well work **INF.EXP** COP

‘I infer from my own experience that this medicine works well.’ [jpn] (Aoki, 1986, 232)

- (11) Kono kusuri wa yoku kiku **rasii**.  
 this medicine TOP well work **INF.CIRCUM**

‘I infer from what I heard that this medicine works well.’ [jpn] (Aoki, 1986, 232)

Evidential 4, like Evidential 1, is expressed with *soo da*, though Evidential 4 can only appear with infinitive verbals; it therefore cannot occur with predicate nominal phrases:

- (12) Ame ga huri **soo** da.  
rain SUBJ fall **INF.IMMINENT** COP

‘It looks like it is going to rain (any minute).’ [jpn] (Aoki, 1986, 233)

Another example of a scattered system is Kazakh. In Kazakh, as noted above, there is the non-firsthand (indirective) past tense *-IptI*. There is also an indirective copula particle *eken*. Take, for example, the two following sentences:

- (13) kel-e-di **eken**.  
come-PRESENT-3S **INDIR.COP**

‘He/she/it is/was evidently coming.’ [kaz] (Johanson, 2003, 279)

- (14) kel-**ipti**.  
come-**INDIR.PAST**

‘He/she/it has evidently come, evidently came.’ [kaz] (author)

Here, the indirective past tense is expressed by a suffix on the verb, while the indirective can also be expressed by another word.

### 3.3.2 Multiple Subsystems

Evidential subsystems may co-occur with each other, potentially with some constraints. Here, a subsystem refers to an inventory of evidential terms like one of the types identified by Aikhenvald in her typology; however, this subsystem may be combined with another inventory that belongs to a different type. Often, the subsystems will occur in different positions or contexts. For example, in Jarawara (anq), in the past tenses of main clauses,

there is a two-way distinction between firsthand and non-firsthand. These suffixes also encode the gender of the subject. For example, the immediate past firsthand masculine suffix is *-(ha)re*, whereas the immediate past non-firsthand masculine suffix is *-(hi)no*.

It is grammatical to have this firsthand/non-firsthand distinction be the only one in a sentence. However, Jarawara contains two further optional evidential terms: one for hearsay and one for inference. The hearsay term is marked by a suffix in the tense/modal system, while the inferential term is expressed in a secondary verb. These can combine with a non-firsthand past but not with a firsthand past. For example, the far past non-firsthand and reported evidentials are combined in the following sentence:

(15) hi-we-**himata-mona**-ka.

Oc-see-**FP.N.M-REP.M**-DECL.M

‘[She] saw him.’ [anq] (Dixon, 2003, 173)

Multiple subsystems may appear in a language when different syntactic contexts select different systems. For example, in Tucano (tuo), a declarative clause allows a system with four terms: visual, non-visual sensory, inferred, reported, an interrogative clause allows a three-term system: visual, non-visual sensory, inferred, and an imperative clause allows a two-term system that distinguishes between hearsay and everything else (Aikhenvald, 2006, 85). The meaning of evidentials in non-declarative clauses varies across languages. For example, the hearsay/imperative combination mentioned above could range from being a simple politeness marking, to indicating that the order came from someone other than the speaker.

### 3.4 *Semantic Complexities*

In addition to the simplest cases of evidentiality, which involve applying one evidential term to a sentence, there are a number of more complex cases that arise. This section will deal with these more complex cases, in which evidentials may interact idiosyncratically with other evidentials, tense marking, and negation.

### 3.4.1 Multiple Evidential Marking

Evidentiality can be marked more than once in a single clause, but this multiple marking is never redundant (Aikhenvald, 2006, 88). Instead, there can be multiple simultaneous subsystems in a language that interact within a clause to produce nuances in the evidential semantics. Aikhenvald (2006) identifies four semantic effects of evidential collocations:

- (i) The different evidentials apply to different constituents of the clause
- (ii) The different evidentials mark different information sources for the same event that corroborate or complement one another
- (iii) The different evidentials mark both that the information was reported to the speaker as well as the reporter’s information source
- (iv) In narratives, one evidential marks the information source of the narrator, and the other evidential marks the information source of a character

An example of the first example is the following sentence from Jarawara (anq):

- (16) Banawaa batori-tee-**mone**    jaa faja    otaa            ka-waha-**ro**  
 Banawa    mouth-CUST-**REP.f** AT then 1nsg.EXC.S APPL-become.dawn-**REM.P.FIRSTH.f**  
           otaa-ke.  
           1nsg-DECL.f

‘Then the day dawned on us (FIRSTHAND) at the place REPORTED to be (customarily) the mouth of the Banawa river.’ [anq] (Aikhenvald, 2006, 88)

This is an interesting example because it shows an evidential applying to a noun phrase, rather than a verb phrase, semantically applying to an instance instead of an event.

Qiang (cng) and Shipibo-Konibo (shp) demonstrate two different ways in which the second approach can apply. In Qiang, the visual and inferred evidentials can be used together in the case where visual evidence confirmed or supported a previously formed inference. LaPolla provides an example, to which Aikhenvald adds the following real-world context: “the speaker first guessed that someone was playing drums next door, and then went next

door and saw the person holding a drum or drumsticks" (Aikhenvald, 2006, 89).

- (17) oh, the: *zəbə zete-k-u*.  
oh 3SG drum beat-**INFR-VIS**

‘Oh, he WAS playing a drum!’ [cng] (LaPolla, 2003, 70)

In Shipibo-Konibo, on the other hand, when the inferential evidential is combined with either the reported or firsthand evidential, the reported/firsthand evidential indicates the source of the evidence on which the inference is based. Take, as an example, the following sentence:

- (18) *Ka-ment-tan-we koka-baon-ra jawe-bira miin-ke*,  
go-quickly-go.do-IMP maternal.uncle-PL:ERG-**DIR.EV** what:ABS-**INFR** bury-COMPL  
bake-**ra** sion i-t-ai.  
child:ABS-**DIR.EV** ONMO do.INTR-PROG-INC

‘Go quickly and see! What could your uncles have buried, a child is crying.’ [shp]  
(Valenzuela, 2003, 44)

In the first clause *Ka-ment-tan-we koka-baon-ra jawe-bira miin-ke*, the direct evidential *-ra* and the inferential evidential *-bira* are both present, indicating that the clause (a question) involves an inference based on direct evidence, in this case the inference being that the uncles buried something, based on the direct evidence of the sound of a child crying underground.

The third semantic interaction is demonstrated by the following example from Bora (boa):

- (19) *Hotsée=βá=?há-p<sup>he</sup> umiβá khuruβá-ʔóó-ha-tu*.  
Joseph=**REP**=**NONWITNESSED**-PAST escaped dark-room-house-from

‘Joseph escaped from jail a while back.’ [boa] (Aikhenvald, 2006, 91)

Here, the reported and non-firsthand evidentials are both present, indicating that the speaker learned of the event from a reporter, and the reporter learned of the event from a non-firsthand source.

Tsafiki provides another example of this type of relationship between two evidentials, where both the inferential and the reported are marked. In this sentence, it is reported that the reporter inferred that the canoe was grabbed and turned over:

- (20) kanowa=ka dilan=tala ka-to ke ere-ka jo-**nu-ti**-e  
 canoe-ACC turn.over=DIR get-S throw send-PERF AUX.BE-**INFR-REP**-DECL  
 ti-e.  
 say-DECL

‘The canoe must have been grabbed and turned over it is said.’ [cof] (Aikhenvald, 2006, 91)

Aikhenvald notes that in this mode of combining evidentials, the order of evidentials is language-specific. As can be seen, Bora places the reported evidential closer to the stem than the non-firsthand evidential, but in other languages the reported evidential can be preceded by the reporter’s information source, as in Tsafiki. However, it is worth noting that Thiesen and Weber analyze the evidentials in Bora not as affixes, but as clitics (Thiesen and Weber, 2012, 306-310). Thus, the arbitrariness of ordering that Aikhenvald notes may not apply to affixes on a verb.

In order to demonstrate the fourth approach to evidential combination, Aikhenvald cites Eastern Pomo (peb). Two hearsay markers appear in this sentence, one an affix and one a clitic in the second position. It is common, though not required, for both markers to appear in Eastern Pomo sentences. In an example from a myth, the hero of the myth leaves the dwelling of the old, blind villain of the story:

- (21) bá=**xa**=khí xówaqa-**nk’e**-e.  
 then=**HS**=3.AGENT outwards.move-**SENSORY.EV-HS**

‘Then he started to walk out, it is said.’ [peb] (McLendon, 2003, 110)

Here, the hearsay marker indicates that the narrative was reported to the speaker, as is the norm with traditional tales, while the non-visual sensory evidential refers to how the blind villain learned that the hero was leaving (since he is blind, presumably by hearing the hero's footsteps). It's worth noting that the hearsay marker cannot combine with the direct knowledge evidential in the same way, as "the direct knowledge evidential  $-(y)a$  cannot combine with any of the three other suffixes" (McLendon, 2003, 109).

A feature of Eastern Pomo is that whether it uses the third or fourth modes of combination depend on the specific evidentials used. When the reported evidential co-occurs with the non-visual sensory, as is seen here, the meaning is constructed according to approach (iv). However, when the reported evidential co-occurs with the inferential, the effect is the same as in approach (iii), as seen in the following example:

- (22) kalél=**xa**=k<sup>h</sup>í                      maʔór-al                      q'á-**ne-e**.  
 simply=**HS**=3.AGENT daughter.in.law-PATIENT leave-**INFR-REP**

'He must have simply left his daughter-in-law there, they say.' [peb] (McLendon, 2003, 112)

Here, the speaker is making an inference from the report he heard. McLendon notes that this combination "seems always to be interpreted as reflecting the narrator's inferences, and suggests perhaps that the narrator is not quite certain as to what happened at this point in the narrative, perhaps because he/she didn't recall exactly what was said by the person from whom he/she had heard the narrative" (McLendon, 2003, 111).

These four ways that evidentials can interact with each other demonstrate that evidential semantics can involve multiple roles, such as the source of information and the receiver of information, in addition to the relationship between the evidential event and the main event.



### 3.4.2 Evidentiality and Negation

The ways that evidentiality applies to a negated sentence vary by language. “An evidential usually has the whole clause within its scope” (Aikhenvald, 2006, 96). Aikhenvald cites the following example from Maricopa (mrc) to illustrate this:

(23) waly-marsh-ma-’-yuu.

NEG=win+DUAL-NEG-1SG-**VISUAL**

‘They didn’t win (i.e. they lost), I saw it.’ [mrc] (Aikhenvald, 2006, 96)

In this case, when an evidential co-occurs with negation, the evidential takes the whole negated clause as its sentential argument. In other systems, the evidential can fall under the scope of negation, as in the following example from Akha (ahk):

(24) é náa, hə à, àdjé ə mímjò djáj ə mà  
then this noun.part what noun.part thing make verb.part not

ɲá é, hə bə.

**EV:NONPAST.VIS.PERCEPTION** FINAL.PART this one

‘Then, as (for this photo), what kind of things they are making (I don’t know: negated visual experience), this one.’ [ahk] (Aikhenvald, 2006, 97)

In some languages, such as Japanese (jpn), it is possible to specify the scopal relationship between negation and evidentiality by the ordering of the evidential and the negation words. Take, for example, the following two sentences<sup>3</sup>:

(25) ame ga furi **sou** ja nai.

rain NOM fall **EVID.SEEM** COP NEG

‘It doesn’t look like it’s going to rain.’ [jpn]

---

<sup>3</sup>These example sentences and their translations were produced by Emily M. Bender and verified by a native speaker of Japanese.

- (26) ame ga fura nasa **sou** da.  
 rain NOM fall NEG **EVID.SEEM** COP

‘It looks like it’s not going to rain.’ [jpn]

In the first sentence, the evidential is within the scope of the negation, as the whole clause *It looks like it’s going to rain* is negated. In the second example the scopal relationship is reversed: the negated clause *It’s not going to rain* is within the scope of the evidential.

Considering these examples, especially the Japanese sentences, it seems likely that evidentiality behaves like an independent predication, rather than as a property of the main event’s predication. This is a conclusion that Aikhenvald agrees with, saying, “In all these cases evidentials behave similarly to predications in their own right, unlike most other grammatical categories. In this way, evidentials resemble negation” (Aikhenvald, 2006, 100).

### 3.4.3 Tense of Evidentials

Sometimes the tense of an evidentially marked clause refers to the event being reported, and sometimes to the evidential event, that is, the event of the speaker gaining knowledge of the main event. For example, in Tariana (tae), tense indicates the time of the main event when combined with the evidentials for visual, non-visual sensory, and inferential information sources. This is illustrated in the following example:

- (27) kya di-nu-ka-**naka**.  
 rain 3SGNF-come-DECL-**PRES.VIS**

‘The rain is coming.’ (It is coming now and I see it now) [tae] (Aikhenvald, 2006, 100)

On the other hand, when a hearsay evidential is used, the tense indicates the time when the speaker heard the main event reported, as in the following example:

(28) Tiago di-ñami-**pida**.

Tiago 3SGNF-die-**PRES.REP**

‘Tiago has died.’ (I’m hearing about it right now.) [tae] (Aikhenvald, 2003, 148)

The context of this statement is that the speaker just heard a report of Tiago’s death on the radio, hence the present tense marker, even though Tiago had died a few days before the statement.

Evidentials in Tariana are not distinguished in the future tense except for a reported evidential. When the main event is in the future and a reported evidential is used, the verb will be marked with both a purposive marker and the appropriately tensed evidential marker, as seen here:

(29) du-ñami-karu-**pidaka**.

3SGF-die-FUT.NOM-**REC.P.REP**

‘She was said (a short time ago) to be going to die (in the future).’ [tae] (Aikhenvald, 2003, 148)

Further, in Western Apache (apw), whether or not the past tense marker *ni*’ includes the evidential or not depends on the evidential used. This marker indicates what de Reuse calls an “asserted past tense”; that is, it is used when “the speaker emphasizes that something happened in the past, and that s/he is quite certain that it happened” (de Reuse, 2003, 91). There are four evidential particles that can combine with *ni*’: *hiłts’ad* (non-eyewitness experiential), *ch’iñu* (quotative), *łek’eh* (quotative), and *lāq̄* (mirative inferential).

If *ni*’ appears before the evidential, then the evidential event is not within the scope of *ni*’. If *ni*’ appears after the evidential, the evidential event is within the scope of *ni*’ (along with the main event) when the evidential is *hiłts’ad* or *ch’iñu*. This distinction based on the ordering of *ni*’ can be seen in the following two examples:



### 3.5 *Summary*

In this chapter I have attempted to provide a typological overview that is brief but nevertheless covers the issues most relevant to the project of this thesis. The summary of Aikhenvald's scheme for the classification of evidential systems shows the most common inventories of evidentials across the world's languages as well as the forms by which these evidentials may be expressed. The subsequent sections dealt with the complexities involved in the expression of evidential systems across languages. These considerations will be important in making design decisions, such as in choosing whether to model evidentiality as a property of the main event or an independent event predication. This question will be addressed in more detail in the next chapter. A number of linguistic phenomena have been addressed in this chapter. For easy reference, in Table 3.1 I provide a table summarizing those phenomena.

Table 3.1: Summary of evidentiality-related linguistic phenomena

<b>Phenomenon</b>	<b>Relevant Section</b>
Evidentials as verbal inflection	3.2
Evidentials as (second-position) clitics	3.2
Evidentials as clitics appearing on focused element	3.2
Evidentials as sentence-final particles	3.2
Evidentials as nominalizer + copula	3.2
Combination of evidentiality and tense	3.2
Evidentials scattered across multiple position classes, word types, etc.	3.3.1
Co-occurrence of semi-redundant evidentials (e.g., Jarawara)	3.3.2
Constraints on evidentials based on clause type	3.3.2
Multiple non-redundant evidentials present in one clause (e.g., Qiang, Bora)	3.4.1
Scopal relationship between evidentiality and negation following phrase structure (e.g., Japanese)	3.4.2
Evidentials with their own time reference (e.g., Tariana)	3.4.3
Complex interaction between tense and evidentiality (e.g. Western Apache)	3.4.3

## Chapter 4

### ANALYSIS

In order to support evidentiality, the Grammar Matrix needs 1) a general semantic analysis of evidentiality in the Minimal Recursion Semantics (MRS) framework and 2) an implementation that could accurately produce semantics based on this analysis for all the syntactic and morphological means by which evidentiality is expressed. In this chapter, I will develop a semantic analysis of evidentiality; the implementation will be discussed in the next chapter.

The primary goal of the present library is to support the development of grammars with the most common type of evidential marking, which is a single evidential applying to a single clause. However, as noted in Chapter 3, there are many ways that evidentials can interact with other phenomena, such as when evidential events possess their own tense, the interaction of multiple evidentials, and particular interactions of evidentiality and negation. Many of these interactions are idiosyncratic to particular languages, and I consider them out of the scope of this library. Nonetheless, grammars created using this library will provide a starting point in the development of a more complete grammar when necessary.

This chapter discusses how to model evidential semantics in MRS, as well as how to analyze lexical and phrase structure rules to produce the correct semantics. I will begin by developing a general model of evidentiality in MRS that I expect will be able to cover all evidential semantics found in natural language. Then, I will propose a more compact model that will be used in the present library that will be sufficient for modeling its functionality, and which could be extended by grammar engineers as necessary for particular languages.

## 4.1 *Semantic Representation*

In this section I will develop a generally applicable semantic model for evidentials in the MRS framework. I will then propose a reduced model that covers the basic functionality that the library requires. Even though it is not implemented in this library, the general model is still explored to provide grammar engineers working on extending grammars produced by the Grammar Matrix with a standard way of analyzing evidential phenomena found in the languages under study.

### 4.1.1 *Evidentials: Predicates or Features?*

The first thing to determine is the best way to represent the semantics of evidentials in the Grammar Matrix. Two options are available: 1) as an elementary predication (EP) and 2) as a feature on *event*-type feature structures. Analyzing evidential semantics as EPs would facilitate modeling scopal interactions between evidential EPs and other EPs; also, it allows evidentials to carry their own tense information. Modeling evidentials as features on the event would follow the established model for representing such semantic categories as tense, aspect, and mood. Further, this would allow for multiple exponence of evidentiality, as occurs with other phenomena such as tense and aspect.

A number of the examples in the typological review chapter suggest that at least some languages treat evidentiality as a separate EP that scopes over the main EP. The fact that evidentials can have their own time reference, for example, suggests an EP interpretation, as do the interactions between negation and evidentiality observed in Japanese. In addition, notes that “Marking evidentiality more than once is different from the multiple expression of any other category: it is never semantically redundant. Having several evidentiality markers in one clause allows speakers to express subtle nuances relating to types of evidence and information source” (Aikhenvald, 2006, 88). Thus, it appears that support for multiple exponence of evidentiality is not needed, removing one of the major motivators for a feature, rather than EP, analysis.



PRED	"ev_⟨evidentialterm⟩_rel"
ARG0	<i>event</i>
ARG1	<i>handle</i>
ARG2	<i>individual</i>
ARG3	<i>semarg</i>

Figure 4.1: The general semantic model for an evidential

In this thesis, then, I will analyze evidentials as EPs. This analysis agrees with the approach of Murray (2017). Murray recognizes four major pieces of an evidential predicate. First is the *evidential proposition* itself, which is related to the *scope proposition*, the main proposition that the speaker is communicating. In addition to these propositions, there is also the *evidence holder*, usually the speaker, the person who gained knowledge of the scope proposition through the means expressed by the evidential proposition. Finally, there is the *evidence base*, or source of the information. For example, if a hearsay evidential is expressed along with an identification of the reporter, the reporter would be the evidence base of the evidential (Murray, 2017, 10).

I adapt this terminology to the MRS framework by proposing a general template for an evidential predicate, where each of the four pieces posited by Murray is an argument of the predicate. The ARG0 refers to an *event*, representing the evidential event itself (roughly corresponding to Murray’s evidential proposition). The ARG1 is handle-valued, representing what I call the main EP, Murray’s scope proposition. The evidence holder and evidence base are represented by ARG2 and ARG3 respectively. The evidential base is of type *semarg* since an evidential EP can be the evidence base for another evidential EP, though it also needs to support individuals being the source of information; *semarg* is an underspecified type appropriate to both individuals and handles. The PRED value would specify the particular evidential term. A graphical representation of this can be found in Figure 4.1.

#### 4.1.2 *The Descriptive Adequacy of this Model*

In this section, I will look at some examples that involve interactions between evidentials and other phenomena of language. These examples should illustrate that this generalized model can handle many, if not all, of the complexities found in the evidential systems of natural languages.

This analysis supports the interaction between evidentials and negation in Japanese: either the negation or the evidential may scope over the other, depending on the phrase structure of the sentence. This analysis also allows separate tenses to be specified for the main proposition and the gathering of the evidence, as required in Tariana (page 34) and Western Apache (page 35), since the evidential predication is associated with its own event through its ARG0.

To illustrate how this predicate analysis can handle combinations of evidentials, I turn now to a few examples of more complicated interactions of evidentials identified in the typological review chapter. First of all, take the following example from Shipibo-Konibo (shp). The context is that the speaker and his family have put some *barbasco*, a plant used to poison fish for the purpose of fishing, into the river. Some time has passed since they placed the *barbasco*.

- (33) ...moa=**ra**      i=**bira**-[a]i      yapa      paen-i      oin-non      bo-kan-we!  
 already=DIR.EV do.I=INFR-INC fish:ABS become.dizzy-SSSI see-PROSP go.PL-PL-IMP  
 ‘...the fish must be getting poisoned already, let’s go see (them)! [shp] (Valenzuela, 2003, 44)

Here, some direct evidence (the fact that a good deal of time has passed since they put the poison in the river) informs the inference (that the fish must be poisoned already). The semantics of *the fish must be getting poisoned already* could be expressed using the proposed model like this in Figure 4.2. In this example, the direct evidential serves as the information base of the inferential evidential. The direct evidential’s ARG1 is underspecified because in

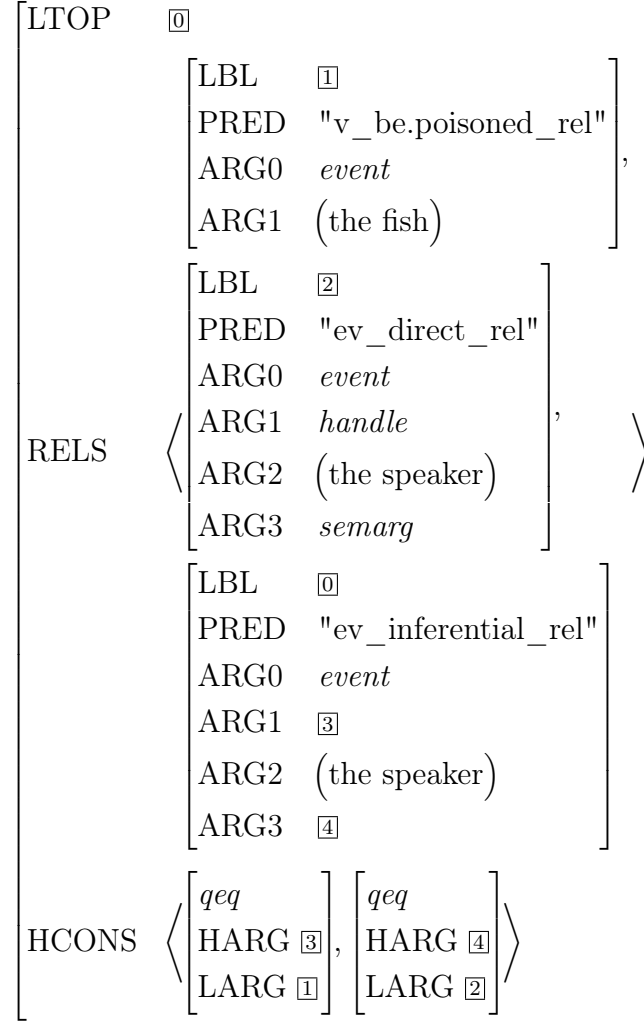


Figure 4.2: Evidential semantics of *The fish must be getting poisoned*

this situation the direct evidence that informs the inference is not explicitly stated. The direct evidential is still included since it serves as the evidential base for the inferential evidential.

In the case of Eastern Pomo (peb), the proposed approach can model the evidential semantics of this sentence:

- (34) kalél=xa=k<sup>h</sup>í                      maʔór-al                      q'á-**ne-e**.  
 simply=HS=3.AGENT daughter.in.law-PATIENT leave-**INFR-REP**

‘He must have simply left his daughter-in-law there, they say.’ [peb] (McLendon, 2003, 112)

In the proposed model, this would be represented as in Figure 4.3. Here the information receiver of one evidential is identified with the information source of another evidential.

In this section I have demonstrated how this general semantic analysis can be used to cover some of the more complex situations that appear cross-linguistically with evidentials, specifically the identification of information source in hearsay evidentials and the use of one evidential as the information base of another.

#### 4.1.3 *The Representation in this Library*

Recall that the purpose of this library is to model the basic cases of evidentiality where there are no complex, idiosyncratic interactions between evidentials and tense, negation, or other evidentials. In this basic case, the evidence holder is almost always the speaker. Since MRS has no mechanism to identify any argument with the speaker, the presence of this argument is superfluous for the library. Likewise, in the basic case, the evidence base often is not explicitly stated in a way that is grammaticized, so this this argument is also omitted. This yields a semantic representation as shown in Figure 4.4. Here, The ARG0 points to the evidential event and the ARG1 points to the main EP. As an example, in Figure 4.5 I show the analysis in this framework of the following sentence (Example 35) from Kazakh (kaz):

- (35) tūs-**ipti**.  
 fall-**PAST.INDIR**

‘[He/she/it] has evidently fallen, evidently fell.’ [kaz] (Johanson, 2003, 279)

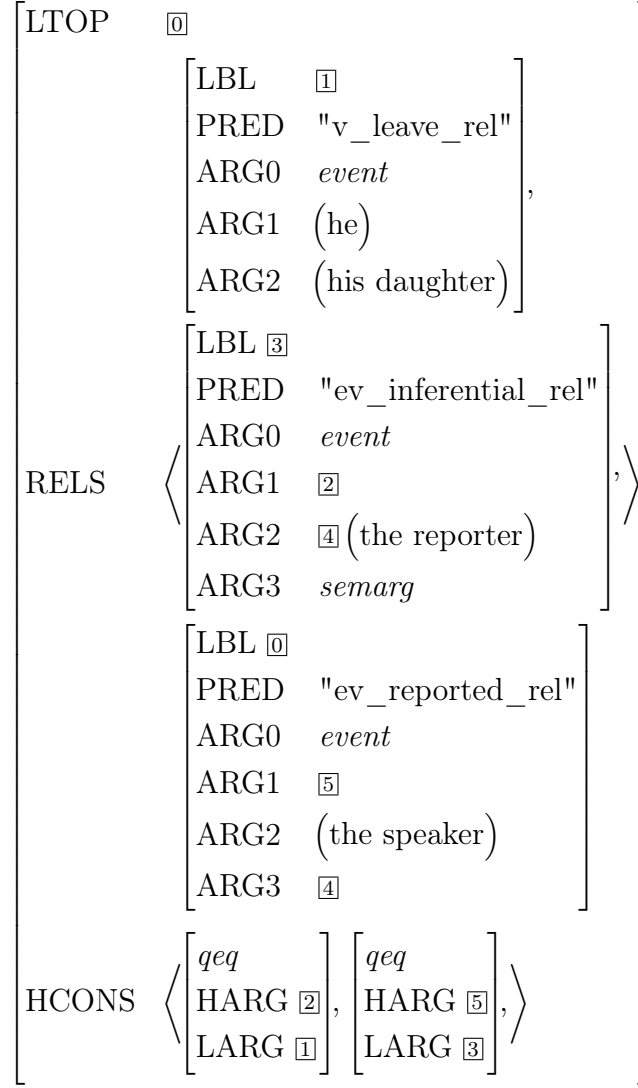


Figure 4.3: Evidential semantics of *He must have left his daughter-in-law there, they say.*

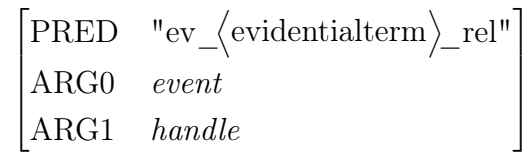


Figure 4.4: The evidential semantic template used in this library

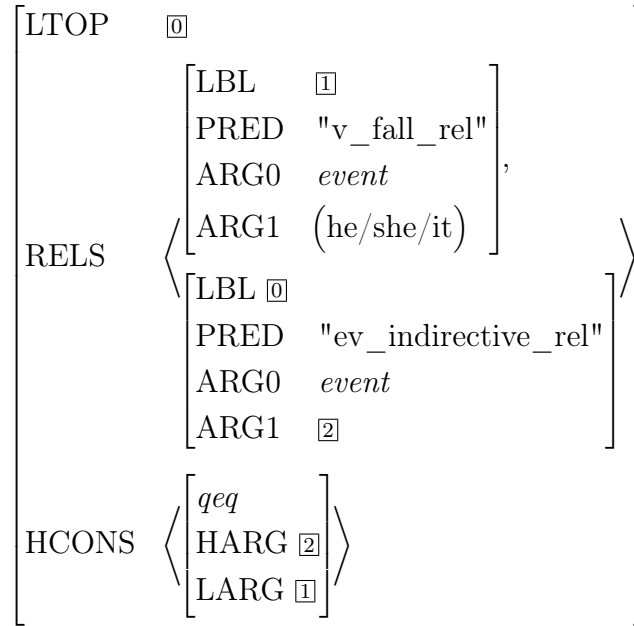


Figure 4.5: Evidential semantics of *He/she/it evidently fell*.

## 4.2 Syntactic Means of Expressing Evidentiality

Evidentiality can be expressed by many means, some grammatical, some lexical. In this library, I focus on providing support for the grammatical means. Based on my typological review, the three main ways of expressing evidentiality appear to be verbal inflection, verbal auxiliaries, and clitics. In this section I develop an analysis of how to tie these morphological and syntactic means of expression to the semantics proposed in the previous section.

### 4.2.1 Verbal Inflection

The first formal means for expressing evidentiality that the Grammar Matrix must support is verbal inflection. In the Grammar Matrix, inflection is handled by types called *lexical rules*. In order to support lexical rules that add evidential semantics to the verb, there needs to be a type that can link up the semantics of the evidential predication and main predication correctly.

```

evidential-lex-rule := cont-change-only-lex-rule &
  [ C-CONT [ RELS <! event-relation &
    [ LBL #ltop,
      ARG0 event,
      ARG1 #harg ] !>,
    HCONS <! qeq & [ HARG #harg,
      LARG #larg ] !>,
    HOOK [ LTOP #ltop,
      INDEX #mainev,
      XARG #mainagent ] ]
  DTR [ SYNSEM.LOCAL [ CONT.HOOK [ INDEX #mainev,
    XARG #mainagent ],
    CAT.HEAD verb ] ] ].

```

Figure 4.6: The evidential-lex-rule supertype

The type *evidential-lex-rule* in Figure 4.6 maintains the main EP's index and external argument (the INDEX and XARG features in HOOK) in the rule's result's HOOK. This allows the rest of the sentence to interact with the semantics of the main EP. The LTOP feature of HOOK is identified with the evidential EP's label (LBL), predicting that anything scoping over the verb's main EP also scopes over the evidential EP. The relationship between the main EP and the evidential EP is handled by the *qeq* constraint in HCONS, constraining the ARG1 of the evidential predication to be equal modulo quantifiers to the main predication. Further, this type inherits from the *cont-change-only-lex-rule*, meaning that the evidential lexical rules can only contribute semantic information; they may not alter the syntactic properties of their daughter. In addition to the *evidential-lex-rule* supertype, there must be individual types for each evidential term that is expressed in inflection, in order to correctly specify the PRED relation. This is demonstrated in Figure 4.7 for an inferential evidential term.

Finally, specific lexical rule types, representing the specific inflectional affixes that may appear in a language, can inherit from one of these *<evidential\_term>-evidential-lex-rule* types to tie evidential semantics to individual affixes. With these types in place, it will be

```
inferential-evidential-lex-rule := evidential-lex-rule &
  [ C-CONT.RELS <! [ PRED "ev_inferential_pred" ] !> ].
```

Figure 4.7: The inferential-evidential-lex-rule type

straightforward to add lexical rules that produce evidential semantics. In order to express evidential semantics, a lexical rule type only needs to inherit from one of these types.

#### 4.2.2 Auxiliary Verbs

Currently the Grammar Matrix provides support for auxiliary verbs, which may take verbs, verb phrases, or sentences as their complements. This library will use the existing analysis for auxiliary verbs that add a predicate scoping over the auxiliary’s complement. In this case, several auxiliary verb types are developed by the Grammar Matrix to handle the interaction of the auxiliary verb and its complement, both syntactically and semantically. A few types like this are shown in Figure 4.8. These types were generated from the Grammar Matrix for an auxiliary verb that takes a VP complement and appears after its complement. The *aux-lex* type marks the auxiliary verb as AUX +, while the *subj-raise-aux* handles the identification of the auxiliary verb’s subject with the complement’s subject. Finally, *subj-raise-aux-with-pred* is what auxiliary lexical entries inherit from, combining the constraints of three types, including *subj-raise-aux* and *trans-first-arg-raising-lex-item-1*. In this example, the *trans-first-arg-raising-lex-item-1* type from *matrix.tdl* handles the identification of the argument of the introduced predicate and the label of the complement, as shown in Figure 4.9.

The final main component here is to specify the relation of the introduced predicate. This is handled in the lexicon; an example of this is shown in Figure 4.10, where the TDL for an inferential evidential auxiliary spelled *infer* is shown.

This analysis results in slightly different semantics for evidentials expressed by auxiliaries and those expressed by verbal inflection. Specifically, in the case of verbal inflection, the INDEX of the rule is identified with the INDEX of the DTR, while in the auxiliary case the



```

aux-lex := verb-lex &
  [ SYNSEM.LOCAL.CAT.HEAD.AUX + ].

subj-raise-aux := aux-lex & trans-first-arg-raising-lex-item &
  [ SYNSEM.LOCAL [ CAT.VAL [ SPR < >,
                             SPEC < >,
                             COMPS < #comps >,
                             SUBJ < #subj > ],
    CONT.HOOK.XARG #xarg ],
  ARG-ST < #subj &
    [ LOCAL [ CAT [ HEAD noun,
                    VAL [ SUBJ < >,
                          SPR < >,
                          SPEC < >,
                          COMPS < > ] ],
    CONT.HOOK.INDEX #xarg ] ],
  #comps &
  [ LOCAL.CAT [ VAL [ SUBJ < unexpressed >,
                      COMPS < >,
                      SPR < >,
                      SPEC < > ],
    HEAD verb &
    [ AUX - ] ] ] > ].

subj-raise-aux-with-pred := subj-raise-aux & norm-sem-lex-item &
  trans-first-arg-raising-lex-item-1.

```

Figure 4.8: Example of auxiliary verb types that take VP complements and appear after the verb

```

trans-first-arg-raising-lex-item-1 := trans-first-arg-raising-lex-item &
    basic-icons-lex-item &
    [ ARG-ST < [ LOCAL.CONT.HOOK [ ICONS-KEY.IARG1 #clause,
        CLAUSE-KEY #clause ] ],
        [ LOCAL.CONT.HOOK [ LTOP #larg,
            ICONS-KEY.IARG1 #clause,
            CLAUSE-KEY #clause ] ] >,
        SYNSEM [ LOCAL.CONT [ HOOK.CLAUSE-KEY #clause,
            HCONS <! qeq &
                [ HARG #harg,
                    LARG #larg ] !> ],
            LKEYS.KEYREL event-relation &
                [ ARG1 #harg ]]]].

```

Figure 4.9: The trans-first-arg-raising-lex-item-1 type

```

inf := aux-lex &
    [ STEM < "infer" >,
        SYNSEM.LKEYS.KEYREL.PRED "ev_inferential_rel" ].

```

Figure 4.10: An example lexical entry for an inferential auxiliary verb

INDEX is identified with the INDEX of the evidential. This follows how the Grammar Matrix currently handles negation.

### 4.2.3 *Clitics*

Some languages use clitics to mark evidentiality. These clitics often may be analyzed as auxiliary verbs, allowing us to use the Grammar Matrix’s current machinery to account for them. For example, in Tariana the tense/evidential marker is a clitic that usually immediately follows the verb (Aikhenvald, 2003, 131). Representing this as an auxiliary verb immediately following its complement is straightforward.

One case that requires more thought is that of second-position clitics. The Grammar Matrix currently supports auxiliary verbs in the second position, as long as the rest of the

sentence has free word order. Thus, if evidential-marking second-position clitics do not constrain word order, the analysis developed in the previous section for evidential-marking auxiliary verbs would also apply to second-position clitics, requiring no further analysis.

Aikhenvald cites only two languages using second-position clitics to mark evidentiality: Shipibo-Konibo (shp) and Quechua (que) (Aikhenvald, 2006, 68). In the case of Shipibo-Konibo, Camacho notes that “word order is fairly flexible” (Camacho, 2010, 219). Likewise, Weber notes that Huallaga Quechua “has a fairly free word order, particularly in non-subordinate clauses” (Weber, 1989, 15). Thus, the treatment in the Grammar Matrix that second-position auxiliary verbs are correlated with an otherwise free word order appears to hold, requiring no special work for supporting evidential second-position clitics.

It is worth noting that in some languages, such as Quechua (Aikhenvald, 2006, 68), these clitics can also appear attached to a focused element of the sentence. This behavior is not be covered by this library.

### **4.3 Summary**

In this chapter I have developed two analyses of evidential semantics, one that should be generally applicable, based on the work by Murray (2017), and a reduced analysis that omits those arguments not affected by this library. If grammar engineers need these arguments for grammars created by the Grammar Matrix, it should be straightforward to add them as necessary. Further, I have identified the analyses for the grammatical means by which evidentiality is usually expressed: verbal inflection and auxiliary verbs, which includes evidential clitics. In Table 4.1, I summarize the phenomena discussed in the Typology chapter in another table, this time noting whether the phenomenon is supported by the analysis developed in this chapter.

Table 4.1: Coverage of evidentiality-related phenomena in the present library

<b>Phenomenon</b>	<b>Supported in the Present Library</b>	<b>Relevant Section</b>
Evidentials as verbal inflection	Y	3.2, 4.2.1
Evidentials as (second-position) clitics	Y	3.2, 4.2.2, 4.2.3
Evidentials as clitics appearing on focused element	N	3.2, 4.2.3
Evidentials as sentence-final particles	Y	3.2, 4.2.2
Evidentials as nominalizer + copula	N	3.2
Combination of evidentiality and tense	Y	3.2
Evidentials scattered across multiple position classes, word types, etc.	Y	3.3.1
Co-occurrence of semi-redundant evidentials (e.g., Jarawara)	Y (though each introduces its own EP)	3.3.2
Constraints on evidentials based on clause type	N	3.3.2
Multiple non-redundant evidentials present in one clause (e.g., Qiang, Bora)	Y (With a simplified semantic representation)	3.4.1
Scopal relationship between evidentiality and negation following phrase structure (e.g., Japanese)	Y	3.4.2
Evidentials with their own time reference (e.g., Tariana)	Y (but no support for idiosyncratic evidential tense rules)	3.4.3
Complex interaction between tense and evidentiality (e.g. Western Apache)	N	3.4.3

## Chapter 5

### IMPLEMENTATION

As mentioned in Chapter 2, the Grammar Matrix consists of a core grammar and a customization system. The customization system includes the questionnaire, which is a web app that produces a *choices file*, and a body of Python code, which produces a grammatical model in TDL from the choices file. In order to update the Grammar Matrix to support evidentiality, both the questionnaire and the grammar-producing code need to be modified, which I describe in this chapter.

#### 5.1 Questionnaire

The questionnaire consists of multiple web pages, each one dedicated to a particular grammatical phenomenon, such as Tense/Aspect/Mood, Morphology, Sentential Negation. In addition, there are pages for defining the lexicon and test sentences. I have added an “Evidentials” web page to the questionnaire, which allows the user-linguist to define the inventory of evidential terms in the language. This can be done either by selecting common terms with checkboxes, or by producing a custom inventory by means of an iterable. A screenshot of this page is found in Figure 5.1.

The questionnaire treats evidentiality as a feature, able to take any of the terms as values. Then it can be constrained, for example, in the Morphology page’s treatment of a lexical rule type, as shown in Figure 5.2. However, evidentiality is properly conceived of as a pseudo-feature, since it will appear as a predication, not a feature, in the final TDL-format grammar. How this is accomplished is described in the next section. The content of a choices file of a small pseudo-language that exhibits evidentiality is included in Figure 5.3.

Evidentials - Mozilla Firefox

Evidentials

matrix.ling.washington.edu/customize 80% Search

Fedora Project Free Content Inbox Google Calendar Facebook YouTube CLMS

## Evidentials [\[documentation\]](#)

Evidentiality refers to the grammatical expression of information source, how the speaker knows what he/she is saying. Common evidential meanings include "I heard it from someone else," "I saw it myself," "I inferred it from evidence," etc. Evidentials are most commonly expressed through inflection on the verb or through auxiliary verbs, often described simply as clitics or particles in the literature.

Here, you may define an inventory of evidential terms. On the Morphology and Lexicon pages, you may then add an evidential feature either to a lexical rule type on the Morphology page or an auxiliary verb on the Lexicon page. Note that even though evidentials are specified as features in this interface, in the grammar produced by the Grammar Matrix, evidential semantics will be expressed by an independent predicate, not a feature.

NOTE: For auxiliary verbs expressing evidentials, the evidential feature should be an auxiliary feature, not a complement feature.

NOTE: For auxiliary verbs expressing evidentials, select "No predicate." If you specify an evidential feature AND define a predicate for the auxiliary verb, the evidential semantics will overwrite the defined predicate.

NOTE: You should not specify more than one evidential value on each lexical rule type or auxiliary verb.

### Semantic Features

☐ No evidentiality in this language

☒ Select among common hierarchy elements

Which of the following are evidential hierarchy elements in this subsystem?

☒ firsthand

☒ non-firsthand

☐ visual

☐ non-visual sensory

☐ inferential

☐ reported

☐ quotative

☐ "everything else"

☐ Specify your own hierarchy

Add an evidential term

[Main page](#)  
[\\*Gen Info](#)  
[\\*Word Order](#)  
[Number](#)  
[\\*Person](#)  
[Gender](#)  
[\\*Case](#)  
[Dir-inv](#)  
[TAM](#)  
[Evidentials](#)  
[Features](#)  
[Neg](#)  
[Coord](#)  
[Y/N Qs](#)  
[Info Str](#)  
[Arg Opt](#)  
[?Lexicon](#)  
[Morph](#)  
[Tb Import](#)  
[Test S](#)  
[TbG Options](#)  
[Choices file](#)  
 (right-click to download)  
[Save & stay](#)  
[Clear form](#)  
 Create grammar: #  
 tgz, zip

Figure 5.1: Evidentials Questionnaire Page

Activities Firefox Thu 2

Morphology - Mozilla Firefox

Morphology

localhost/cgi-bin/matrix.cgi# 90% Search

Fedora Project Free Content Inbox Google Calendar Facebook YouTube CLMS

## Verb Inflection

▼ verb-pc1

**Verb Position Class 1:**

Position Class Name:

Obligatorily occurs: ☐

Appears as a prefix or suffix: Prefix ▾

Possible inputs: Any verb ▾

Morphotactic Constraints:

Add a Require constraint

Add a Forbid constraint

Lexical Rule Types that appear in this Position Class:

▼ indir-suffix (verb-pc1\_lrt1)

**Lexical Rule Type 1:**

Name: indir-suffix

Supertypes:  ▾

Features:

**Name:** evidential ▾ **Value:** indirective ▾ Specified

**on:** The verb ▾

Add a Feature

Valence-changing operations may modify the valence structure of a verb by adding or removing either a subject or object, possibly including changes to e.g. case frames or adding predicates. **(Experimental)**

[Main page](#)

[\\*Gen Info](#)

[\\*Word Order](#)

[Number](#)

[\\*Person](#)

[Gender](#)

[\\*Case](#)

[Dir-inv](#)

[Evidentials](#)

[TAM](#)

[Features](#)

[Neg](#)

[Coord](#)

[Y/N Qs](#)

[Info Str](#)

[Arg Opt](#)

[?Lexicon](#)

[Morph](#)

[Tb Import](#)

[Test S](#)

[TbG Options](#)

[Choices file](#)  
(right-click to download)

[Save & stay](#)

[Clear form](#)

Create

grammar: #

tgz, zip

Figure 5.2: Evidentiality on the Morphology Page

```

section=evidentials
evidential-definition=choose
firsthand=on
nonfirsthand=on
{\ldots}
section=morphology
verb-pc1_name=evid-pc
verb-pc1_order=suffix
verb-pc1_inputs=verb
verb-pc1_lrt1_name=evid-fh
verb-pc1_lrt1_feat1_name=evidential
verb-pc1_lrt1_feat1_value=firsthand
verb-pc1_lrt1_feat1_head=verb
verb-pc1_lrt1_lri1_inflecting=yes
verb-pc1_lrt1_lri1_orth=-fs
verb-pc1_lrt2_name=evid-nf
verb-pc1_lrt2_feat1_name=evidential
verb-pc1_lrt2_feat1_value=nonfirsthand
verb-pc1_lrt2_feat1_head=verb
verb-pc1_lrt2_lri1_inflecting=yes
verb-pc1_lrt2_lri1_orth=-nf

```

Figure 5.3: The evidentials and morphology sections of a choices file



## 5.2 Grammar-producing Code

The customization system outputs a formal grammar of the language being studied by automatically producing TDL code based on the selections made in the choices file. In the semantic analysis I've developed for evidentials, evidentials are elementary predications (EPs), rather than features. Because they are represented as (pseudo-)features in the questionnaire, some special processing is necessary to produce the correct semantics. In this section I first explain this processing as it is relevant to evidential verbal inflection, then I move on to discussing the processing of auxiliary verbs marking evidentiality.

The Grammar Matrix organizes inflection into a hierarchy of position classes and lexical rule types. Each position class represents a morphological “slot” on a word and has a number of associated lexical rule types; a lexical rule type represents a set of affixes that produce the same results. Each lexical rule type then has a series of lexical rule instances, each of which indicates a phonological/orthographic form that expresses the lexical rule type's effects. In order to model an evidential affix on the verb, it's necessary to define a lexical rule type that inherits from the appropriate types defined in Chapter 4.

First, these rules must be added to the TDL. I have updated the morphotactics module of the customization system to automatically introduce the necessary evidential inflectional rule types. If any lexical rule types defined in the choices file constrain the feature evidential, then the *evidential-lex-rule* type is introduced. Also, the subtypes corresponding to the lexical rule types' evidential values are also introduced. The code that adds the evidential lexical rule types is found in the morphotactics.py file in a function called `write_evidential_behavior`. The code is shown in Figure 5.4.

In addition to defining these types in the TDL, it is also necessary to make the correct lexical rule types inherit from them. To this end, I further modified the morphotactics module of the customization system. When features are being processed, each feature is checked to see if it is an evidential. If it is, the normal processing that adds a feature to the relevant TDL feature structure is averted. Instead, the value of the evidential feature

```

def write_evidential_behavior(lrt, mylang, choices, pc_evidential):
    EVIDENTIAL_LEX_RULE = '''evidential-lex-rule := cont-change-only-lex-rule &
    same-spr-lex-rule &
    same-spec-lex-rule &
    [ C-CONT [ RELS <! event-relation &
        [ LBL #ltop,
        ARG0 event,
        ARG1 #harg ] !>,
        HCONS <! qeq & [ HARG #harg,
            LARG #larg ] !>,
        HOOK [ LTOP #ltop,
            INDEX #mainev,
            XARG #mainagent ] ],
        DTR.SYNSEM.LOCAL.CONT.HOOK [ LTOP #larg,
            XARG #mainagent,
            INDEX #mainev ] ].
    ''',
    if lrt.evidential:
        lrt.supertypes.add(lrt.evidential + '-evidential-lex-rule')
        prev_section = mylang.section
        mylang.set_section('lexrules')
        mylang.add(EVIDENTIAL_LEX_RULE)
        infl_evid_def = lrt.evidential + '''-evidential-lex-rule :=
            evidential-lex-rule &
            [ C-CONT.RELS <! [ PRED "ev_''' + lrt.evidential + '''_rel" ] !> ].
        ''',
        mylang.add(infl_evid_def)
        mylang.set_section(prev_section)
    elif pc_evidential:
        lrt.supertypes.add("add-only-no-ccont-rule")

```

Figure 5.4: Production of inflectional supertypes

```

if sem == 'add-pred' or evid_present:
    pred = 'ev_' + str(evid_value) + '_rel'
    if not evid_present:
        pred = stem.get('pred')
    typedef = TDLencode(id) + \
        ' := [ SYNSEM.LKEYS.KEYREL.PRED "' + pred + '" ] .'
    lexicon.add(typedef, merge=True)

```

Figure 5.5: Addition of evidential predicates for auxiliary verbs

is read, and the lexical rule type being defined is made to inherit from the corresponding lexical rule supertype. For example, if the evidential pseudo-feature is marked *indirective*, the lexical rule type will be made to inherit from *indirective-evidential-lex-rule*. Inheriting from the appropriate subtype of *evidential-lex-rule* will introduce the correct predication structure required for all evidentials as defined in the *evidential-lex-rule* type, as well as the specific PRED value provided by the subtype.

According to my analysis laid out in Chapter 4, in addition to verbal inflection, evidentiality is also expressed through auxiliary verbs. In order to get auxiliary verbs to produce the correct EP-based semantics, I leveraged the existing code that handles auxiliaries introducing predicates. The code for this is shown in Figure 5.5. The variable *sem* is taken from the choices file, and it indicates that the user explicitly specified a predicate for the auxiliary to add, while *evid\_present* is a variable that indicates whether an evidential constraint has been placed on the auxiliary. In this implementation, the auxiliary is assumed to only ever contribute one predicate; this seems to be the case for evidential markers. However, if an evidential is ever found that introduces another predicate in addition to the evidential predicate, this implementation will have to be revised. Further, if the user both specifies a predicate explicitly and constrains the evidential pseudo-feature on an auxiliary verb, the evidential predicate takes precedence.

### **5.3 *Summary***

This chapter provided an overview of the implementation changes made to the Grammar Matrix to support the analysis of evidential semantics proposed in the previous chapter. The customization system's treatment of both verbal inflection and auxiliary verbs have been updated to express evidential semantics, and the questionnaire has been updated to allow users to specify the expression of evidentials.

## Chapter 6

# EVALUATION

In order to evaluate the coverage and effectiveness of the analysis and implementation described in the preceding two chapters, I employ a testing strategy common to most libraries extending the Grammar Matrix. The testing is split up into regression tests, pseudo-language tests, illustrative language tests, and held-out language tests.

The regression tests are a suite of tests already compiled for the Grammar Matrix. The purpose of these tests is to ensure that any changes a new library introduces to the software does not break any of the previous features of the Grammar Matrix. The pseudo-language tests are created by the library developer to check whether the library behaves the way expected. These pseudo-languages are small grammars developed to test the possible logical combinations of grammatical forms supported by the library. The illustrative language tests are used to test whether the library supports the relevant linguistic phenomena in natural languages. These are languages that may have been consulted in the development of the library. The held-out language tests are used to test whether the library is sufficiently robust to support the relevant phenomena in natural languages not consulted during the development of the library. For this reason, these languages' grammars must be examined by the library developer only after the final changes are made to the library. Further, these held-out languages should be selected from different language families to ensure broad coverage.

The files for these language tests are organized in pairs of a choices file and a test suite file. The choices file saves the input to the questionnaire. The test suite includes grammatical and ungrammatical sentences in the language in question. In addition to these files, gold standard MRS representations of every parseable test sentence are generated and stored. In

order to run these tests, the `matrix.py` script is invoked with the `regression-test` argument. This automatically generates grammars from the tests' choices files, attempts to parse all test items, and compares all MRS representations produced by those parses to the gold standards. If all grammatical examples parse, all ungrammatical examples do not parse, and all MRS representations produced are the same as the gold standards, the regression tests pass.<sup>1</sup>

The next three sections describe the test languages I've selected for evaluating this library. In these sections I provide tables summarizing my test results. In these tables, coverage refers to the percentage of grammatical sentences that parse; overgeneration refers to the percentage of ungrammatical sentences that parse; and correct semantics refers to the percentage of grammatical, parseable sentences that produce the MRS representation I expect.

## 6.1 *Pseudo-language Tests*

In order to test the basic functionality of this library, I produced four 'pseudo-languages', two using inflectional marking of evidentiality, and two using auxiliary verbs to mark evidentiality. Further, for each way of marking evidentiality, I specify the evidential inventory using pre-defined terms in one pseudo-language and user-defined terms in the other. I developed a test suite of sentences to test and built grammars of the pseudo-languages with the Grammar Matrix to test the present library's basic functionality.

### 6.1.1 *Test Languages*

**evidentials-auxiliary-build:** In this pseudo-language, the word order is SVO, with auxiliary verbs coming after their complements, which are verbs (not verb phrases). There are

---

<sup>1</sup>The files for the tests described in this section can be found in the Grammar Matrix repository at Revision 39811. The regression test files are found in the directory `trunk/gmcs/regression_tests`. The test suites are located at `regression_tests/txt-suites/{testname}`, the choices files are located at `regression_tests/choices/{testname}`, and the MRS gold standards are located at `regression_tests/home/gold/{testname}`. The names of the individual tests are all prepended by 'evidentials'. The pseudo-language and illustrative language tests have been added to the regression testing setup in the Grammar Matrix repository, but regression tests based on the held-out language tests have not been incorporated yet.

$$\langle h_0, \left[ \begin{array}{l} h_4: \_person\_n\_rel(ARG0\ x3), h_5: \_exist\_q\_rel(ARG0\ x3, RSTR\ h_6, BODY\ h_7), \\ h_8: \_read\_v\_rel(ARG0\ e_9, ARG1\ x_3, ARG2\ x_{x10}), \\ h_{11}: ev\_directive\_rel(ARG0\ e_2, ARG1\ h_{11}), \\ h_{12}: \_book\_n\_rel(ARG0\ x_{10}), h_{13}: \_exist\_q\_rel(ARG0\ x_{10}, RSTR\ h_{14}, BODY\ h_{15}) \end{array} \right] \{ h_0 =_q h_1, h_6 =_q h_{14}, h_{11} =_q h_8, h_{14} =_q h_{12} \} \rangle$$

Figure 6.1: Pseudo-language test sentence MRS

two evidential terms in this language, ‘directive’ and ‘indirective’. To test this language, I developed a test suite consisting of 6 items, all of them grammatical. Three test transitive sentences, and three test intransitive sentences. Each set of three consists of an evidentially unmarked sentence, a sentence marked ‘indirective’, and a sentence marked ‘directive’. The lack of ungrammatical sentences is due to the flexibility of this language, which does not impose constraints on the evidential system that would render a sentence ungrammatical. This test language, as with the other pseudo-language tests, is meant only to check the semantic representation of the test sentences. I selected the terms ‘directive’ and ‘indirective’ to test the questionnaire’s ability to define a custom inventory of evidential terms. In Figure 6.1 I show the text representation of the semantics of one of the sentences in this test suite.

**evidentials-auxiliary-choose:** Like the previous pseudo-language, the word order is SVO, with auxiliary verbs coming after their verbal complements. The only difference is that the system has an evidential system consisting of the terms ‘firsthand’ and ‘non-firsthand’. Again, the test suite consists of 6 test items, all grammatical, with two groups of three sentences, one for transitive and one for intransitive verbs, each group consisting of an evidentially unmarked sentence, a ‘firsthand’ sentence, and a ‘non-firsthand’ sentence. The terms ‘firsthand’ and ‘non-firsthand’ were selected to test the questionnaire’s ability to create evidential inventories from a list of suggested terms.

**evidentials-inflection-build:** This pseudo-language has a basic SVO word order and expresses evidentiality through optional, mutually exclusive suffixes on the verb. It contains two evidential terms, ‘directive’ and ‘indirective’. Similar to the other pseudo-language tests, the test suite contains 6 grammatical test items, to test both transitive and intransitive verbs with neutral, ‘directive,’ and ‘indirective’ markings. These terms were selected to test the ability of the questionnaire to combine inflection and a user-defined evidential term inventory.

**evidentials-inflection-choose:** Like the previous pseudo-language, this pseudo-language’s basic word order is SVO, and it expresses evidentiality through optional and mutually exclusive suffixes on the verb. The evidential system consists of the terms ‘firsthand’ and ‘non-firsthand’. The test suite contains 6 grammatical test items to test transitive and intransitive sentences with each of the possible evidential values (neutral, ‘firsthand,’ ‘non-firsthand’). I chose the terms ‘firsthand’ and ‘non-firsthand’ to test the questionnaire’s ability to produce an evidential term inventory from suggested terms that works with inflection.

### 6.1.2 Results

The results of these tests are summarized in Table 6.1. Not shown is the number of parses; each sentence that parses has a single parse. Also, note that the “Correct Semantics” percentage is out of sentences that parse, not out of the total number of sentences. The system was able to parse all examples, and I checked to verify that the semantic representations were what I expected them to be.

## 6.2 Illustrative Language Tests

In order to verify that the evidentiality can cover phenomena found in natural languages, I developed grammar fragments of seven natural languages with the Grammar Matrix, focusing on their evidentiality systems. I developed these grammars for Kazakh (kaz) (Turkic), Qiang (cng) (Tibeto-Burman), Western Apache (apw) (Athabaskan, Shipibo-Konibo (shp) (Panoan), Kolyma Yukaghir (yux) (Yukaghir), Eastern Pomo (peb) (Pomoan), and West



Table 6.1: Pseudo-language test results

Language	Gram. Items	Ungram. Items	Coverage	Over- generation	Correct Semantics
evidentials- auxiliary-build	6	0	100%	0%	100%
evidentials- auxiliary-choose	6	0	100%	0%	100%
evidentials- inflection-build	6	0	100%	0%	100%
evidentials- inflection-choose	6	0	100%	0%	100%

Greenlandic (kal) (Eskaleut). The geographic distribution of these languages is shown in Figure 6.2 (Dryer and Haspelmath, 2013). The grammaticality and semantic correctness judgment for these languages have not been verified by native speakers, but are based on my understanding according to the sources cited in the description of each language.

### 6.2.1 Test Languages

**Kazakh [kaz] (Turkic):** Kazakh is an SOV language that in simple nominal sentences lacks a copula, instead directly inflecting the final word of the nominal predicate. The evidential system is split between two terms: directive and indirective. The directive is technically evidentially ambiguous, being applicable both when the speaker has directly gained the knowledge s/he is expressing and when there was an intermediate information source. In the past tense, evidentiality can be expressed by the choice of past tense suffix: the standard past tense *-DI* and the perfective past tense *-GAn* are directive, while the suffix *-IptI* expresses an indirective past tense. There is also an auxiliary verb *eken*, which takes both nominal and verbal predicates. Nominal predicates are morphologically unmarked for person, while verbal

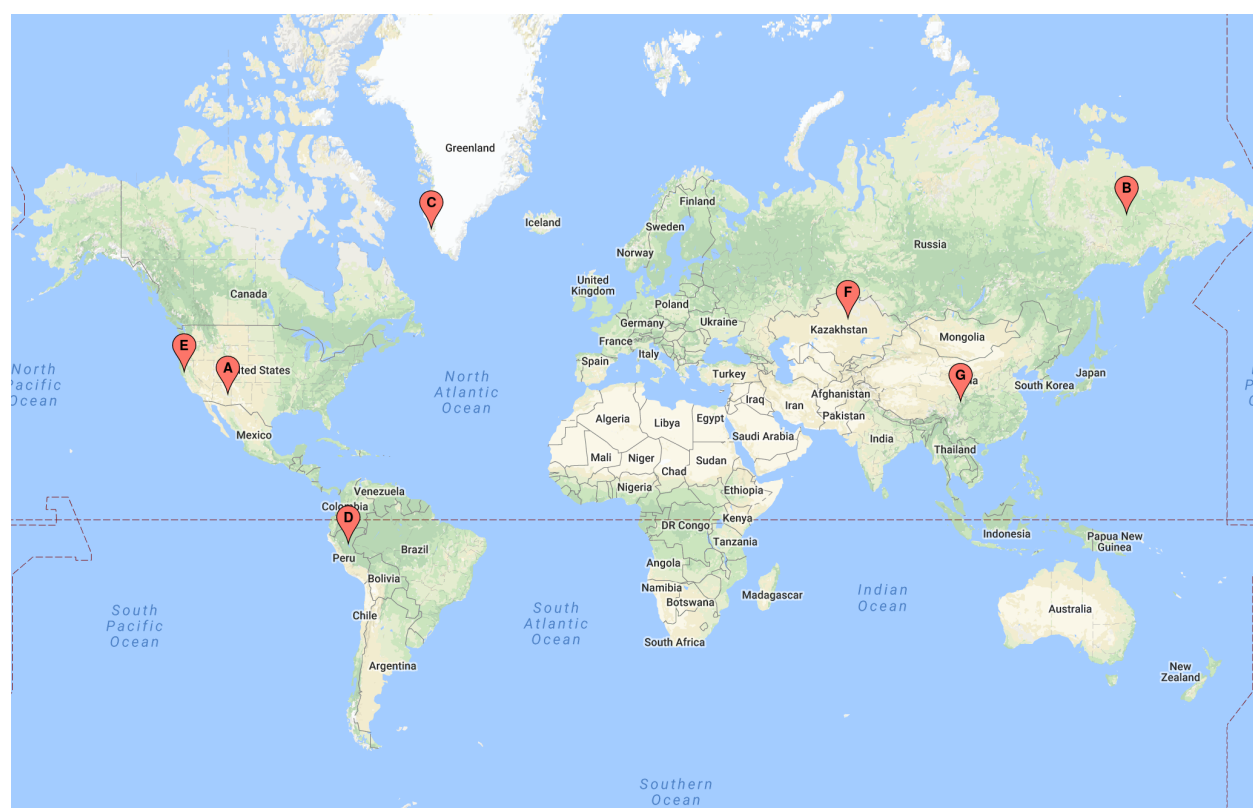


Figure 6.2: Geographic distribution of the illustrative languages

```

bar-a-di
bar-di
bar-a-min
bar-ipti
bar-ipti-m
bar-a-di eken
bar-a-di eken-min
*bar-a-min eken
*bar-a-min eken-min
*bar-ipti eken-min
qi8z kitap oqi8-di eken
*qi8z kitap oqi8-di eken-min
kitap oqi8-di eken-min

```

Figure 6.3: Test suite for Kazakh

predicates are morphologically marked to agree with third-person subjects. Agreement with the true subject is thus marked on *eken*, not on the verbal predicate (Muhamedowa, 2015). I developed a test suite of 13 items, 9 grammatical and 4 ungrammatical sentences. I test both the auxiliary evidential *eken* and the past tense *-ipti*. This test suite is given as an example in Figure 6.3. Also, as an example I show the IGT of one of the sentences in the test suite and the text representation of that sentence’s semantics produced for the regression tests in Figure 6.4.

**Qiang [cng] (Tibeto-Burman):** Evidentials are expressed in affixes to the verb. Each evidential affix has its own position class. There are three terms: the inferential/mirative marker *-k*, the visual marker *-u*, and the hearsay marker *-i*. The inferential marker can co-occur with either the visual or the hearsay marker (LaPolla, 2003). In order to test this behavior, I developed a test suite of 13 sentences, 10 grammatical and 3 ungrammatical, testing all the combinations of evidentials. Figure 6.5 shows the IGT and semantic representation produced for one of the Qiang test items where two evidentials are marked.

- (36) qı8z kitap oqi8-di eken  
 girl book read-PAST EVID

‘The girl read the book.’ (Apparently; I didn’t see her read the book myself) [kaz]

$$\langle h_0, \left[ \begin{array}{l} h_4: \_qı8z\_n\_rel(ARG0\ x_3), h_5: \_exist\_q\_rel(ARG0\ x_3, RSTR\ h_6, BODY\ h_7), \\ h_8: \_kitap\_n\_rel(ARG0\ x_9), h_{10}: \_exist\_q\_rel(ARG0\ x_9, RSTR\ h_{11}, BODY\ h_{12}), \\ h_{13}: \_oqi8\_v\_rel(ARG0\ e_{14}, ARG1\ x_3, ARG2\ x_{x9}), \\ h_1: ev\_indirective\_rel(ARG0\ e_2, ARG1\ h_{15}) \end{array} \right] \{ h_0 =_q h_1, h_6 =_q h_4, h_{11} =_q h_8, h_{15} =_q h_{13} \} \rangle$$

Figure 6.4: Kazakh sentence and MRS

- (37) qa Zbuh Zete-k-a-i  
 I drum beat-INFR-1S-HEARSAY

‘I beat a drum.’ (I inferred I did this and was also told so) [kaz]

$$\langle h_0, \left[ \begin{array}{l} h_4: \_I\_n\_rel(ARG0\ x_3), h_5: \_exist\_q\_rel(ARG0\ x_3, RSTR\ h_6, BODY\ h_7), \\ h_8: \_drum\_n\_rel(ARG0\ x_9), h_{10}: \_exist\_q\_rel(ARG0\ x_9, RSTR\ h_{11}, BODY\ h_{12}), \\ h_{13}: \_beat\_v\_rel(ARG0\ e_2, ARG1\ x_3, ARG2\ x_{x9}), \\ h_{14}: ev\_inferential\_rel(ARG0\ e_{15}, ARG1\ h_{16}), \\ h_1: ev\_reported\_rel(ARG0\ e_{17}, ARG1\ h_{18}), \end{array} \right] \{ h_0 =_q h_1, h_6 =_q h_4, h_{11} =_q h_8, h_{16} =_q h_{13}, h_{18} =_q h_{14} \} \rangle$$

Figure 6.5: Qiang sentence and semantics

**Western Apache [apw] (Athabaskan):** The language is basically SOV, and evidential markers are particles that follow the verb. I analyze these as auxiliary verbs that take sentential complements. The terms in the system include a non-eyewitness experiential marker (*hiłts'ad*), a mirative inferential (*lāq̄*), a non-mirative inferential (*gołnī*), a physical inferential (*nol̄h*), and two quotatives (*ch'īn̄*, *lēk'eh*). When a sentence lacks an evidential marker, it “tends to be interpreted as a statement that the speaker is quite certain of, and such statements tend to imply that the speaker was an eyewitness of the event” (de Reuse, 2003, 83). The test suite for this language consists of 8 items, all of them grammatical, testing six evidential particles, an evidentially unmarked sentence, and the co-occurrence of the asserted past marker and an evidential marker. In my grammar of this language I do not have the lack of an evidential marker introduce a visual evidential term in the semantics. This is because, based on my interpretation of de Reuse’s wording “tend to imply,” the implication of being an eyewitness is not necessary to the semantics of the unmarked sentence; rather, the primary meaning of the unmarked sentence is certainty, rather than information source.

**Shipibo-Konibo [shp] (Panoan):** In pragmatically unmarked simple standalone sentences, a second-position clitic marks either direct (*=ra*) or hearsay (*=ronki*) evidentiality, with flexible word order otherwise, though with a tendency toward SOV. A third, optional inferential evidential term (*-bira*) occurs within the verb’s morphology. This term can, however, appear as a clitic attaching to a pragmatically emphasized constituent of the sentence (Valenzuela, 2003). This behavior is outside of the scope of this library. I developed a test suite of 8 items, 7 grammatical and 1 ungrammatical, testing *=ra* and *=ronki* occurring independently and with *-bira*. One test item demonstrates *bira* occurring as a clitic after an emphasized constituent. I have modeled the grammar of this language by analyzing the required second-position clitic as an auxiliary verb, with the basic word order being V2, with the inferential term analyzed as a suffix to the verb.

**Kolyma Yukaghir [yux] (Yukaghir):** The grammar is generally agglutinative, with an SOV word order. Verbs have several position classes, most of them optional. Evidentiality is marked by one of the optional position classes, which can express an inferential evidential term (*-l'el*) or a prospective (*-mož*). This prospective marks future time and could be analyzed as also evidential, since it indicates an expected future event based on current evidence (Maslova, 2003a,b). The test suite for this language includes 7 items, 5 grammatical and 2 ungrammatical. I test the combination of the inferential and prospective with the future tense marker and irrealis marker.

**Eastern Pomo [peb] (Pomoan):** Verbs have eight suffix position classes. Evidentiality is expressed by one member of the seventh position class, the logical inferential evidential *-ine*, and by three members of the eighth position class: the direct evidential *-ya*, the non-visual sensory evidential *ink'e*, and the hearsay evidential *-le* (McLendon, 1975, 2003). I developed a test suite of 12 sentences with 11 grammatical and 1 ungrammatical. I test the various evidential markers and their co-occurrence with aspect markers.

**West Greenlandic [kal] (Eskaleut):** Evidentiality is expressed in the extensive morphological system. The system's inventory is quite extensive, including terms for auditory (*-(r)pallaC*), nonfirsthand (*-(r)paluC*), sensory inferential (*-gunar*), hearsay or hearsay-based inferential (*-sima*), general knowledge-based inferential (*-jannarsi*), and an experience-based inferential (*-nnguatsiar*). In addition to these morphological means of expression, there are two further hearsay markers, the gossip hearsay marker *unnia*, which appears at the beginning of the sentence, and the quotative enclitic *=guuq* which appears in the second position (Fortescue, 2003). This language's test suite contains 12 items, 11 grammatical sentences and 1 ungrammatical sentence. I test the various evidential suffixes, as well as a grammatically unmarked sentence. I also test the placement of the two independent hearsay markers. I would analyze both of the independent quotative markers as auxiliary verbs, but since they appear in different positions and the Grammar Matrix only allows one order for all auxiliary

verbs in a language, I chose to model the sentence-initial marker *unnia*.

### 6.2.2 Results

The results of these tests are summarized in Table 6.2. Not shown is the number of parses; each sentence that parses has a single parse. Also, note that the “Correct Semantics” percentage is out of sentences that parse, not out of the total number of sentences. In most cases, the evidential systems of the languages described could be modeled effectively using this present library. However, there are some deficiencies. For example, in the case of West Greenlandic, the Grammar Matrix cannot correctly model the two hearsay markers *unnia* and *=guuq*, leading to one grammatical test item to fail to parse. Further, the Grammar Matrix would have to support more flexible word orders to support the range of positions that the inferential *=bira* occurs in, since it can appear after any focused element; this is what causes one grammatical test item in Shipibo-Konibo’s test suite to fail to parse. These issues could be addressed by supporting freer word order in the Grammar Matrix, especially when it comes to auxiliaries.

## 6.3 Held-Out Language Tests

I’ve selected five held-out languages to test the general applicability of this library to languages with evidential systems: Ladakhi (lbj) (Tibeto-Burman), (Khalkha) Mongolian (mon) (Mongolic), Gulf Arabic (afb) (Semitic), Wichita (wic) (Caddoan), and Basque (eus) (Language Isolates/Vasconic). The geographic distribution of these languages is shown in Figure 6.6 (Dryer and Haspelmath, 2013). In selecting these languages, I had both genetic and areal diversity in mind. I used the online edition of the World Atlas of Language Structures to see a map of languages based on type of evidential system (de Haan, 2013). I tried to pick out languages across a wide geographic area with different means of expressing evidentials that also were not related to each other.

Table 6.2: Illustrative language test results

<b>Language</b>	<b>Gram. Items</b>	<b>Ungram. Items</b>	<b>Coverage</b>	<b>Over- generation</b>	<b>Correct Semantics</b>
Kazakh (kaz)	9	4	100%	0%	100%
Qiang (cng)	10	3	100%	0%	100%
Western Apache (apw)	8	0	100%	0%	100%
Shipibo-Konibo (shp)	7	1	86%	0%	100%
Kolyma Yukaghir (yux)	5	2	100%	0%	100%
Eastern Pomo (peb)	11	1	100%	0%	100%
West Greenlandic (kal)	11	1	91%	0%	100%





(38) thuggu-yi spechhuh sil-dug  
 boy-ERG book read-OBSERVED  
 ‘The boy reads the book.’ (I see it happen) [lbj]

$$\langle h_0, \left[ \begin{array}{l} h_4: \text{\_boy\_n\_rel}(\text{ARG0 } x_3, h_5: \text{\_exist\_q\_rel}(\text{ARG0 } x_3, \text{RSTR } h_6, \text{BODY } h_7), \\ h_8: \text{\_book\_n\_rel}(\text{ARG0 } x_9, h_{10}: \text{\_exist\_q\_rel}(\text{ARG0 } x_9, \text{RSTR } h_{11}, \text{BODY } h_{12}), \\ h_{13}: \text{\_read\_v\_rel}(\text{ARG0 } e_2, \text{ARG1 } x_3, \text{ARG2 } x_{x9}), \\ h_1: \text{ev\_observed\_rel}(\text{ARG0 } e_{14}, \text{ARG1 } h_{15}) \end{array} \right] \rangle$$

$$\{ h_0 =_q h_1, h_6 =_q h_4, h_{11} =_q h_8, h_{15} =_q h_{13} \}$$

Figure 6.7: Ladakhi sentence and MRS

### 6.3.1 Test Languages

**Ladakhi [lbj] (Tibeto-Burman):** Evidentiality is expressed through a number of suffixes on the verb. Ladakhi has six evidential terms: observed, narrative, fact-based inferential, appearance-based inferential, attested inferential, and experiential. In addition to these, there is an evidentially neutral reportive (Koshal, 1979). I’ve developed a test suite of 13 items, 10 grammatical and 3 ungrammatical, testing that all these evidentials are correctly modeled and that ungrammatical combinations of multiple evidentials, such as combining the observed and the fact-based inferential. I modeled this language’s evidential system by developing the appropriate position classes on the Morphology page and adding lexical rule types for the evidential suffixes, as well as position classes for aspect and tense, so as to test the interaction between the evidentials and the tense-aspect system. Figure 6.7 shows the IGT of one of the sentences in the test suite and the text representation of its semantics produced for the regression tests.

**Mongolian [mon] (Mongolic):** Two past tense suffixes, *-jee* and *-laa* also encode evidentiality: *-jee* expresses non-firsthand semantics, while *-laa* expresses firsthand. These are in contrast with two evidentially neutral past tense suffixes, *-san* and *-v* (Street, 1963; Song, 2013). I test this with a test suite of 4 items, 3 grammatical, each testing one of the past tense suffixes, and 1 ungrammatical item to verify that the past tense suffixes cannot co-occur. I was able to model this system by defining a past-tense position class with four lexical rule types, each one requiring the past tense, and the two evidential suffixes also requiring their specific evidential value.

**Gulf Arabic [afb] (Semitic):** There is a single evidential auxiliary, *yikuun*, that precedes a sentence to express non-firsthand evidentiality. This auxiliary verb is identical to the third-person masculine singular form of the explicit copula *kaan* (Holes, 1990). A small test suite of 5 items, 3 grammatical and 2 ungrammatical, test that both evidentially-marked and unmarked sentences parse correctly and that ungrammatical locations of the evidential marker *yikuun* are prohibited. The usage of *yikuun* as an evidential marker is sufficiently different than *kaan*'s normal meaning that to model it I defined an invariable auxiliary verb *yikuun* that takes a saturated sentence as its complement, which it precedes, and in the questionnaire is constrained to the evidential value of non-firsthand. Holes also notes that the verb *yiguuluun*, literally meaning ‘they say’, can be used to mark hearsay. However, I see no reason to model this as a grammatical marker of evidentiality separate from a verb meaning ‘to say’.

**Wichita [wic] (Caddoan):** There are three means of expressing evidentiality in Wichita: the quotative prefix *kiya-*, the future quotative prefix *ehe-*, and the inferential particle *wéra'* (Rood and Charney, 1976). Though Rood and Charney use the different words quotative and inferential here, their description of their usage leads me to believe that these three markers all refer to a single non-firsthand term. In the test suite for this language, I test that the three evidential markers all parse correctly and that an evidentially unmarked sentence also parses

correctly. In addition, I test the ordering of evidential affixes and the word order involving the auxiliary. This results in a test suite with 6 items, 4 grammatical and 2 ungrammatical. I successfully model the two prefixes in the morphology system with evidential features set to non-firsthand, and I model the particle as an auxiliary verb preceding the verb phrase.

**Basque [eus] (Language Isolate/Vasconic):** Basque has two ways to conjugate verbs: synthetic and periphrastic conjugation. In periphrastic conjugation, by far the more common means of conjugation, a nonfinite form of the verb is followed by a finite auxiliary verb. A small class of verbs may be conjugated morphologically to produce a finite form without an auxiliary verb. There are two evidential terms in Basque, the hearsay marker *omen* and the inferential marker *bide*, which are proclitics that precede the finite verb (Rijk, 2008). I tested this with a test suite of 10 items, 6 grammatical and 4 ungrammatical. The 6 grammatical examples are split evenly between synthetic and periphrastic conjugation, testing hearsay, inferential, and unmarked evidentiality. In trying to implement this system, I’ve run up against a couple of restrictions in the Grammar Matrix system. First of all, all auxiliaries must share the same word order relationship with their complements. Thus, since the complement of the periphrastic conjugation auxiliary precedes it, and the evidential clitic precedes it, the clitic should be considered part of the complement. However, this will not work, because the Grammar Matrix does not currently support non-predicate-introducing auxiliaries (such as the conjugation auxiliary) taking [AUX +] complements. These two restrictions, when combined with my analysis of evidential clitics as auxiliary verbs and the understanding of the Basque evidential marker as a clitic, make it so that the Grammar Matrix cannot model Basque’s periphrastic conjugation combined with the evidential markers.

### 6.3.2 Results

The results of these tests are summarized in Table 6.3. Not shown is the number of parses; each sentence that parses has a single parse. Also, note that the “Correct Semantics” percentage is out of sentences that parse, not out of the total number of sentences. These tests

Table 6.3: Held-out language test results

Language	Gram. Items	Ungram. Items	Coverage	Over- generation	Correct Semantics
Ladakhi (lbj)	10	3	100%	0%	100%
Mongolian (mon)	3	1	100%	0%	100%
Gulf Arabic (afb)	3	2	100%	0%	100%
Wichita (wic)	4	2	100%	0%	100%
Basque (eus)	6	4	50%	0%	100%

show that the present library supports the evidential systems of most of these languages. The primary shortcoming is in modeling Basque, since in Basque conjugation auxiliaries follow their complement, while evidential auxiliaries precede their complement. This could be remedied by allowing multiple auxiliary verb word orders within a single language.

#### 6.4 Summary

The results of these evaluations demonstrate that, in a large majority of cases, this library operates correctly when handling sentences with a single evidential, as well as provides a simplified analysis of sentences with more than one evidential (see Figure 6.5). Evidentiality can also combine with other grammatical categories, such as tense, correctly. There are some insufficiencies, as revealed in the Basque example. These issues point a few ways forward for further development of the Grammar Matrix, which I will touch on in the next chapter.

## Chapter 7

# CONCLUSION

In this thesis I have described the linguistic foundation, formal analysis, implementation, and evaluation involved in developing a library for modeling evidentiality in the LinGO Grammar Matrix. The process of developing this library has turned up some potential avenues for further development of the Grammar Matrix. As described in Chapter 3, there are more complex evidential situations in some languages. Many of these complexities are idiosyncratic to particular languages, so altering the Grammar Matrix to support every way evidentials may be expressed, if it's even possible, would likely render the user interface so cumbersome as to be unusable.

That said, the evidentiality module described in this thesis could likely be refined to handle some of the identified complexities, such as producing a more nuanced analysis of how multiple evidentials interact. On the other hand, there are interesting grammar engineering challenges with regard to evidentials, such as how best to handle the interactions of the asserted past particle *ni'* with the evidentials in Western Apache (described in 3.4.3).

Considering the inability of the current library to handle evidentials with periphrastic conjugation in Basque, it may be desirable to alter some restrictions on the auxiliary verb system in the Grammar Matrix, allowing different orderings of auxiliary verb head and complement within a single language.

In this thesis I have reviewed the linguistic literature on a phenomenon known as evidentiality, the grammatical encoding of information source. I have developed an analysis in HPSG-style syntax and Minimal Recursion Semantics that should apply to evidential systems across the world's languages. I have also implemented support for the fundamental phenomena related to evidentiality in the Grammar Matrix. This project's aim has been

to facilitate linguists in developing computational grammars of languages, for NLP applications, linguistic research, or both. There is still more to be done in this area, but the work presented in this thesis should provide a foundation on which further research can be conducted.

## BIBLIOGRAPHY

- Aikhenvald, A. (2006). *Evidentiality*. Oxford linguistics. Oxford University Press.
- Aikhenvald, A. and Dixon, R. (2003). *Studies in Evidentiality*. Typological studies in language. John Benjamins Publishing.
- Aikhenvald, A. Y. (2003). Evidentiality in Tariana. In Aikhenvald and Dixon (2003), pages 131–164.
- Aoki, H. (1986). Evidentials in Japanese. In Chafe and Nichols (1986), pages 223–238.
- Bender, E. M., Drellishak, S., Fokkens, A., Poulson, L., and Saleem, S. (2010). Grammar customization. *Research on Language & Computation*, 8(1):23–72. 10.1007/s11168-010-9070-1.
- Bender, E. M., Flickinger, D., and Oepen, S. (2002). The grammar matrix: An open-source starter-kit for the rapid development of cross-linguistically consistent broad-coverage precision grammars. In Carroll, J., Oostdijk, N., and Sutcliffe, R., editors, *Proceedings of the Workshop on Grammar Engineering and Evaluation at the 19th International Conference on Computational Linguistics*, pages 8–14, Taipei, Taiwan.
- Callmeier, U. (2000). Pet – a platform for experimentation with efficient hpsg processing techniques. *Natural Language Engineering*, 6(1):99–107.
- Camacho, J. (2010). On the asymmetry of root versus embedded clauses: Evidence from shipibo second position clitics. In *Edges, Heads, and Projections: Interface Properties*, Linguistik Aktuell/Linguistics Today, pages 215–232. Benjamins, Amsterdam, Netherlands.



- Carpenter, B. (2005). *The Logic of Typed Feature Structures: With Applications to Unification Grammars, Logic Programs and Constraint Resolution*. Cambridge Tracts in Theoretica. Cambridge University Press.
- Chafe, W. and Nichols, J. (1986). *Evidentiality: The Linguistic Coding of Epistemology*. Advances in discourse processes. Ablex Publishing Corporation.
- Copestake, A. (2002a). Definitions of typed feature structures. In Oepen, S., Flickinger, D., Tsujii, J., and Uszkoreit, H., editors, *Collaborative Language Engineering*, pages 227–230. CSLI Publications, Stanford, CA.
- Copestake, A. (2002b). Definitions of typed feature structures. In Oepen, S., Flickinger, D., Tsujii, J., and Uszkoreit, H., editors, *Collaborative Language Engineering*, pages 227–230. CSLI Publications, Stanford, CA.
- Copestake, A. (2002c). The lkb system.
- Copestake, A., Flickinger, D., Pollard, C., and Sag, I. A. (2005). Minimal recursion semantics: An introduction. *Research on Language and Computation*, 3(2):281–332.
- de Haan, F. (2013). *Coding of Evidentiality*. Max Planck Institute for Evolutionary Anthropology, Leipzig.
- de Reuse, W. J. (2003). Evidentiality in Western Apache (Athabaskan). In Aikhenvald and Dixon (2003), pages 79–100.
- Dixon, R. M. W. (2003). Evidentiality in Jarawara. In Aikhenvald and Dixon (2003), pages 165–187.
- Dryer, M. S. and Haspelmath, M., editors (2013). *WALS Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.
- Fortescue, M. (2003). Evidentiality in West Greenlandic. In Aikhenvald and Dixon (2003), pages 291–306.

- Holes, C. (1990). *Gulf Arabic*. Critics of the Twentieth Century. Routledge.
- Johanson, L. (2003). Evidentiality in Turkic. In Aikhenvald and Dixon (2003), pages 273–290.
- Koshal, S. (1979). *Ladakhi Grammar*. Motilal Banarsidass.
- LaPolla, R. J. (2003). Evidentiality in Qiang. In Aikhenvald and Dixon (2003), pages 63–78.
- Lawrence, M. (1987). Viewpoint in Oksapmin. *Language and Linguistics in Melanesia*, 16(1-2):54–70.
- Maslova, E. (2003a). Evidentiality in Yukaghir. In Aikhenvald and Dixon (2003), pages 219–235.
- Maslova, E. (2003b). *A Grammar of Kolyma Yukaghir*. Mouton de Gruyter.
- McLendon, S. (1975). *A Grammar of Eastern Pomo*. University of California Press.
- McLendon, S. (2003). Evidentials in Eastern Pomo with a comparative survey of the category in other Pamoan languages. In Aikhenvald and Dixon (2003), pages 101–129.
- Muhamedowa, R. (2015). *Kazakh: A Comprehensive Grammar*. Routledge Comprehensive Grammars. Routledge.
- Murray, S. E. (2017). *The Semantics of Evidentials*. Oxford University Press.
- Pollard, C. and Sag, I. (1994). *Head-Driven Phrase Structure Grammar*. Studies in Contemporary Linguistics. University of Chicago Press.
- Rijk, R. P. G. d. (2008). *Standard Basque : a progressive grammar*. Current studies in linguistics series ; 44. MIT Press, Cambridge, Mass.
- Rood, D. and Charney, J. (1976). *Wichita grammar*. Garland studies in American Indian linguistics. Garland Publishing.

- Shieber, S. M. (2003). *An introduction to unification-based approaches to grammar*. MIT Press.
- Slayden, G. C. (2012). *Array TFS storage for unification grammars*. University of Washington.
- Song, J. (2013). Evidentiality, past, and person in mongolian and korean1. volume 16, pages 67–85, Daegu. Academia Koreana, Keimyung University.
- Street, J. C. (1963). *Khalkha structure*. Indiana University. Uralic and Altaic series ; v. 24. Indiana University, Bloomington.
- Thiesen, W. and Weber, D. (2012). *A Grammar of Bora: With Special Attention to Tone*. Number v. 148 in A Grammar of Bora: With Special Attention to Tone. SIL International.
- Valenzuela, P. M. (2003). Evidentiality in Shipibo-Konibo, with a comparative overview of the category in Panoan. In Aikhenvald and Dixon (2003), pages 33–61.
- Weber, D. (1989). *A Grammar of Huallaga (Huánuco) Quechua*. UC Publications in Linguistics Series. University of California Press.