Arguments and Adjuncts at the Syntax-Semantics-Interface

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Dissertation

zur Erlangung des Doktorgrades (Dr. phil.) im Fach

Englische Philologie (Neuere englische Sprache),

der

Philosophischen Fakulatät
der Georg-August Universität Göttingen

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Chapter 1

Simpler Semantics

> *It is clear that sentences of any natural language have a great deal more structure than simply the concatenation of one element with another. Thus, to establish a complexity scale for string sets and to place natural languages on this scale may, because of the neglect of other important structural properties, be to classify natural language along an ultimately irrelevant dimension.* (Partee, ter Meulen and Wall, 1990:436-7)

In this thesis, I define a simplified semantic compositional mechanism based entirely on Event Semantics, and I provide the skeleton of a flexible syntax-semantics interface which is formally specified and at the same time open for functional explanations of grammatical phenomena and pragmatically enriched interpretations. This involves two major projects: First, I introduce a representational semantic mechanism which does with a minimal number of semantic types and only one basic type. Secondly, I define how the semantic representations are interpreted at discourse level to encode and exchange information. The project is completed by a proof-of-concept implementation in a syntactic framework (Head-Driven Phrase Structure Grammar).

1.1 Representational Semantics with Few Types

1.1.1 One Basic Type

Linguists working in formal semantics (a tradition which arguably dates back primarily to Tarski 1957, but without doubt brought successfully into the linguistic mainstream by Montague 1973a) and in proof-theoretical frameworks of the syntax-semantics interface like Categorial Grammar (dating back to Ajdukiewicz 1935) usually employ a specific kind of logic (mostly intensional higher-order λ calculi) and standard model theory in the semantic analysis of natural language. By making this choice, they set themselves apart from cognitively oriented linguistic theories and explore the relations between linguistic expressions and the objects or states of affairs in the material world rather than mental representations thereof. Every natural language expression is, from the straightforward viewpoint of formal semantics, a logical formula (in disguise) which *directly* receives a disambiguated interpretation in some model.

This highly successful mathematically founded approach has, especially since the 1980s, been complemented by theories like Discourse Representation Theory (DRT, Kamp 1984, Kamp and Reyle 1993) which provide indirect interpretations for natural language expressions by first translating expressions into representations (which could be but need not necessarily to be similar to mental representations) which then receive an interpretation at discourse level where concrete models are formed. Especially the loss of direct interpretation in such frameworks has been criticized by strict model theorists, a critique which has spawned alternative approaches to the problems solved within DRT, e.g. in the form of non-representational variants of dynamic logic (Groenendijk and Stokhof 1990, Groenendijk and Stokhof 1991, Stokhof 2006, etc.).

This thesis follows a representational approach while still keeping up a model-theoretic primary interpretation of linguistic expressions. How so? Normal model-theoretic semantics is truth-functional. That is, sentences extensionally denote truth-values and are of the corresponding type t (or **Bool** or **2**). Their truth can be checked in a given model. The types of the expressions from which the sentence is constructed have to be forged in a manner that their combination (usually function application) results in a **2**-typed expression.

Here, following an extended version of Event Semantics, I develop a theory where sentences denote sets of events rather than truth-values. A sentence is interpreted in a domain of events which contains *all possible* events, and it is interpreted as those sets of events (which naturally are subsets of the domain of all possible events) which make it true. Truth becomes a secondary semantic concept, and truth is not determined for sentences proper.[1].

For example, "*Every frog laughs.*" denotes all possible sets of laughing events such that every frog is the agent of at least one of these laughing events in every set. If com-

[1] The notion of truth present in this study, if there is any substantial notion of truth at all, resembles that of post-correspondence-theoretic philosophers advocating deflationary or especially coherence theories of truth (cf. Blackburn and Simmons 1999, especially the Bradley 1907 and James 1907 reprinted there). Since the scope of this study is rather a technical than a philosophical one, I do not discuss philosophical conceptions of truth, however

municated, such a meaning allows the hearer to form valid theories about the world (at least about the frogs and the laughings in the world). More on this communication-optimized interpretation can be found in section 1.2.

Events as individuals (introduced by the philosopher Donald Davidson in Davidson (1967)) thus have the advantage of functioning as reified properties and relations, as individuals which encode information. So, although they are model-theoretic entities and sentences are interpreted in a model, the purpose of the interpretation is not to derive a truth value for the sentence[2], but to gain information from it by a set-theoretic decoding process. There are some similarities to Infon/Situation Semantics since infons are means of encoding information similar to the events of the theory presented here. However, here the primary semantic interpretation is achieved by a simple model-theoretic device.

Disposing of the type t, the theory actually does with one basic type, the type of individuals, which is sorted into non-event individuals (objects, type **Obj**) and event individuals (events, type **Ev**). This follows suggestions recently published by Barbara Partee (for example in Partee 2007), who also discusses ways of abandoning the t type as a basic type. The type system does with the two sorts of individual types, set types for those two, and functional types.

1.1.2 One Type for Arguments and Adjuncts

A major part of the thesis is devoted to further simplifications of the system of functional types. Normally, semantic compositionality involves a lot of operations which adjust the type of some expression. Variables have to be made available for modification (by abstracting over it), especially so in traditional event-based frameworks where event variables both have to be existentially bound at an early stage (Parsons 1990) but can be modified by all sorts of adverbials applying later. Adjuncts which can apply at different stages of saturation (with arguments) of a predicate require polymorphic definitions. Also, displacement (like frontings of all sorts) usually requires the introduction of a variable, type-adaptation of the resulting expression, and later binding of the variable by an expression which also has to be adapted in type. At least, this is so in proof-theoretic frameworks like Type-Logical Grammar (cf. Carpenter 1997), but compare also complex type-adaptation operations in connection with quantifier raising in semantic theories based on transformational grammars (Heim and Kratzer 1998). Re-

[2] Given the domain of all possible events, all sentences (including contradictions) are *prima facie* assumed to be “true” in a shallow sense anyway.

cently, Dynamic Syntax (Kempson, Meyer-Viol and Gabbay 2001) has provided ways of reducing this huge type polymorphism for cases of displacement. That theory is fundamentally different from the one advocated here in that it focuses on incremental sentence processing, and I do not discuss it further.

Based on a concept casually used in Krifka (1992), I provide a semantics where verbs simply denote sets of events like laughing or walking events (type $\wp\mathbf{Ev}$), and both arguments and adjuncts are of the type of operators on sets of events $(\wp\mathbf{Ev} \to \wp\mathbf{Ev})$.[3] Thus, both can apply at any time, and at least arguments can take scope directly without any additional semantic operations.[4] This radical simplification of semantic compositionality requires some moderately complex interpretational tweaks, but in the end, a simple and powerful theory of compositionality emerges.

1.2 Discourse-Level Interpretation

As I said above, the framework is representational in that it does not interpret expressions directly in a correspondence-theoretic fashion. The famous argumentation in Montague (1970) in favor of direct interpretation can of course not be invalidated formally here. Montague assumes that linguistic expressions can be related to model-theoretic objects by a strict and well-defined interpretation procedure. Thus, language itself must be a formal system with discoverable principles of compositionality, because if it were not, then interpretation would be arbitrary and ambiguous at least to a certain degree. The *translation* of language into logic is thus not a translation proper but merely a way of providing a clearer view on the logical properties of natural language expressions.

Montague argues that, if there is a faithful translation from natural language to some symbolic logic, which then can be model-theoretically interpreted, then the translation would have to be a homomorphism (otherwise it would not be faithful). If it is a homomorphism, however, then it is essentially vacuous because the interpretation itself is a homomorphism, and an interpretative procedure can be specified for untranslated expressions directly.

I still assume that expressions are interpreted directly in a model. However, this model does in no way correspond to the material facts, it is rather the domain of conceivable

[3] Quantification will require raising these types to $\wp\wp\mathbf{Ev}$ (the type of sets of sets of events) and $(\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev})$ (the type of functions from sets of sets of events to sets of sets of events. Chapter 3 is devoted to this theoretical move.

[4] Additional operations are required when negation and certain types of modifiers take scope. This is discussed in section 4.3.

bits of information. Bits of information, as described above, are the maximally specific events of the theory. As in representational frameworks, there is a two-step interpretation process. However, the first step already produces a model-theoretic interpretation, and not a representation: The sentence denotes all possible sets of events which can be described by the sentence. From several such set objects (each denoted by a sentence) as collected within the course of a discourse, the language user then constructs concrete mental models which each contain at least one set of events from the denotation of each collected sentence.

Thus, there is no intermediate logical representation, but merely an intermediate interpretation, a representation as non-logical mental objects. Montague's argument for direct interpretation is thus not invalidated, but a different view of what it means to interpret a sentence is adopted.

The theory presented here is clearly communication-oriented, it defines how information is encoded, transmitted, and finally used to construct a mental representation. I will not try to answer the question of whether this is more or less feasible than those direct interpretation frameworks which claim immediate correspondences between linguistic expressions and objects and states of affairs in the real world (or in models, which are taken to correspond to *parts* of the real world). The current philosophical discussion seems to me to have gone far ahead of the merely technical disputes in linguistics (cf. the papers in the aforementioned Blackburn and Simmons 1999), and respect for the relevant work done by philosophers forbids the common linguist to attempt to contribute anything substantial about the deeper concept of truth.

To summarize: My framework uses direct model-theoretic interpretation of linguistic expressions (and thus resembles work in the Montagovian tradition), but it does explicitly not assume that the models have correspondence-theoretic *real world* import. Rather, a two-step interpretation procedure is defined which is similar in spirit (although not technically) to theories like DRT.

1.3 Overview

Within the general programme just outlined, this thesis concentrates on laying the semantic foundations complemented by a core syntactic mechanism. It should be kept in mind, however, that the semantics provided here is in principle compatible with any standard syntactic framework.

This thesis is structured as follows. **Chapter 2** first recapitulates the foundations of Event Semantics, and argues that adverbs can be easily modeled as operators within an Event Semantics, thus blurring the alleged opposition (in approaches to adverbial semantics) between so-called operator approaches (Thomason and Stalnaker 1973) and event-based frameworks. It is then shown that simple referring expressions can be also treated as operators (Generalized Operator Approach), and how sentence denotations (as sets of events) can be processed at discourse level.

Chapter 3 takes the Generalized Operator Approach (GOA) one step further and introduces quantification. Quantification requires raising the type of sentences from the type of sets of events to the type of sets of sets of events.

Then, **chapter 4** discusses how negation can be dealt with by introducing a polarity parameter for events. The introduction of negation requires the introduction of a semantics of focus and alternatives. Also, larger event structures (called *frame events*) are introduced, which are necessary to correctly represent scope distinctions when certain adverbial modifiers and negation are involved. In this chapter, I also switch from standard truth-functional model theory to a discourse-level semantics.

Chapter 5 provides a formalization of the theory.

As an appendix to the previous chapters, **chapter 6** mentions possible solutions to questions about collectivity and distributivity in the framework presented here.

Before some achievements and residues are discussed in **chapter 8**, **chapter 7** provides a proof-of-concept implementation of the current syntax-semantics interface in Head-Driven Phrase Structure Grammar (HPSG).

Chapter 2

Event Semantics

2.1 Foundations of Event Semantics

Event Semantics was introduced into the linguistic mainstream by the philosopher Donald Davidson in Davidson (1967). Davidson developed the concept of *event variables*, covert parameters (i.e., additional argument places) of action verbs which can be conjunctively modified by adverbials. A significant work cultivating the idea further is Parsons (1990), the main proponent of what is usually called Neo-Davidsonian Event Semantics, a framework which represents thematic structure in verbal entries by making roles explicit in the form of functions from events to individuals. Krifka (1989), Wyner (1994), Landman (2000), and Eckardt (1998) are among the works discussing mereological event structures, i.e. plurality in the event domain, which was the theoretically most fundamental further development in Event Semantics in the 1990's. Discussion of which types of predicates introduce Davidsonian event (or state) variables can be found, among others, in Davidson (1967) (rejects state modifiers), Parsons (1990) (assumes state modifiers), Kratzer (1995) (assumes state modifiers, but only with individual level NPs), Katz (2000) (rejects state modifiers).

Since more advanced topics will be gradually introduced in later chapters (starting with the assumption of simple sets of events in the present chapter), I will at this stage only recapitulate the main arguments in favor of Event Semantics and add some discussion. Later chapters will then discuss some of the advanced topics such as event quantification and mereologies. The presentation follows mainly the first three chapters of Landman (2000) and Eckardt (2002).

2.1.1 Arguments for Event-Based Theories

2.1.1.1 Entailment and Explicit Reference

First, let me summarize why and how Donald Davidson suggested Event Semantics in the first place in Davidson (1967).
(i) Davidson notes that in a very traditional logical framework, adding a modifier to an n-place predicate would be treated by forming an $n+1$-place predicate, as in (1), as it is still done in many introductory textbooks on applied predicate logic.

(1) a. Jones buttered the toast. $B(j,t)$
b. Jones buttered the toast with a knife. $B(j,t,k)$
c. Jones buttered the toast with a knife in the bathroom. $B(j,t,k,b)$

We immediately notice that the introduction of modifiers like *slowly* would be more difficult to implement since they do not involve a specific referent. Davidson argues that it is undesirable to have an infinite number of versions of the same predicate in store, just to account for every case of modification of that predicate. Indeed, this is also counterintuitive to most linguists who would view adjunct modification as a recursive process which requires a recursive semantics. Notice, however, that in principle, such polyadicity effects could be created by lexical rules lifting the adicity of any predicate, even introducing the correct syntactic types.[1] Davidson solves this problem through the introduction of event variables as demonstrated below.
(ii) The second problem or phenomenon involves explicit reference to events by anaphoric pronouns. Indeed, we can paraphrase (1c) as in (2), picking up reference to something from the first sentence by the pronoun *it*.

(2) Jones buttered the toast. He did **it** slowly. He did **it** with a knife. He did **it** in the bathroom.

One might ask what this *something* is that can be picked up by the anaphoric pronoun. Davidson assumed it was the event variable introduced by the previous sentence.
(iii) The third problem is related to the first one. Look at the inferences in (3).

(3) a. Jones buttered the toast slowly $\vdash_?$ Jones buttered the toast.
b. Mary stirred the porridge with a spoon. $\vdash_?$ Mary stirred the porridge.

[1] Such a treatment is similar to the argument extension theory in McConnell-Ginet (1982). In that paper, adverbs are assumed to modify representations of verbs (two-place predicates), adding more and more argument places for each modified parameter. The property of Permutation mentioned below cannot be explained by this theory without the addition of further meaning postulates, however.

(4) a. $B_1(j,t,s) \nvdash B_2(j,t)$

b. $S(m,p,s) \nvdash S(m,p)$

It seemed to Davidson that the inferences in (3) are logical inferences ($\vdash$), an assumption which can by no means be proven (hence, I write $\vdash_?$ and not just $\vdash$). I will challenge this view further in section 2.2.1. However, if these are valid inferences, then we might well ask how they come about. It is clear, that simple inferences will not go through with the representations in (4).

Davidson's final solution involves introducing an event variable with every action predicate, pushing any n-ary predicate to arity $n+1$. He devotes some discussion to the question of which predicates actually provide an event variable besides clear action predicates (cf. Davidson, 1967:119-20), but we can generalize the solution to make any verbal predicate provide such a variable. The additional argument, e in (5a), is introduced with the verb, and solves problem (i) by allowing cyclic predication over it. The modifiers are themselves represented as simple first order predicates over the event variable. This makes the analysis of a multiply modified event description similar to paraphrases such as in (2), cf. (5b).

(5) a. $B(j,t,e)$ (for *butter*, with j and t the nominal arguments, e the event)

b. $B(j,t,e) \wedge WITH(k,e) \wedge IN(b,e)$ (k for knife, b for bathroom)

The additional argument of the predicate also solves problem (ii): Ontologically, the event is a sort of individual, and thus open to be anaphorically picked up.

The event can even serve as a controller for subjects of infinitives (cases of so-called PRO). Cases like (6), quoted here in slightly modified form from Landman, 2000:21 can be analyzed as having the event of collision as the controller.

(6) The Elise collided with the Spider, PRO killing both drivers.

2.1.1.2 Existential Binding and Some Inferences

Finally, in Davidson's approach, the event variable is existentially quantified over as in (7a).

(7) a. $\exists e.B(j,t,e) \wedge WITH(k,e) \wedge IN(b,e)$

b. $\exists e.B(j,t,e) \wedge WITH(k,e) \wedge IN(b,e) \vdash \exists e.B(j,t,e)$

Davidson argues that this renders ordinary expressions like "*Brutus killed Caesar.*" most adequately, because "*[w]hen we [. . .] [think] a sentence [. . .] describes a single event, we [are] misled: it does not describe an event at all. But if [it] is true, then* *there is an event that makes it true.*" (Davidson, 1967:117). This is exactly what the semantics of the classical existential quantifier gives us. Thus, given the aforementioned sentence about Brutus and Caesar, there must have been at least one event which was a stabbing of Caesar by Brutus, but there might have been any number of such events.

As one can easily see, the Law of Simplification now gives the desired inferences from the modified to the unmodified sentences (cf. (7b)), which answers question (iii). In fact, such modification by pure manner adverbials can be characterized by two properties characteristic of modification of nouns by simple relational adjectives, properties dubbed *Permutation* and *Drop* (cf. Parsons 1990, Landman, 2000:7-11). Drop states that any of *n* modifiers can be dropped, and that the sentence containing the dropped modifier leads to an inference to the sentence where the modifier is dropped. This is exactly the case of (7b). Permutation states that permutations of modifiers lead to no change in meaning, i.e. that the permutations lead to mutual inferences as in (8).

(8) a. Marry stirred the porridge in the kitchen with a spoon. $\vdash_?$ Marry stirred the porridge with a spoon in the kitchen.

b. Marry stirred the porridge with a spoon in the kitchen. $\vdash_?$ Marry stirred the porridge in the kitchen with a spoon.

Notice that for scalar adverbials like *quickly*, which are relative to some comparison class, one might be tempted to argue that they do not allow *Permutation*, just as scalar adjectives like *big*, which are relative to a contextually determined scale. In fact, Davidson makes a remark along these lines on the second page of Davidson (1967) and excludes such adverbials from his analysis.[2] However, I cannot think of any example where this problem really occurs with Permutation and Drop when manner adverbials (as opposed to adjectives) are involved. If there are relevant examples, then we could always assume with Landman (2000:7) that the idea from Kamp (1975) is applicable to adverbials as much as to adjectives. Kamp argues that the relevant scale against which a scalar adjective is evaluated is contextually determined, and that cases of what appears as non-equality under Permutation are cases where the relevant scale has been changed implicitly.

Furthermore, with existentially quantified event descriptions we do not talk about identifiable individuals but just about minimal examples under existential quantification,

[2] Davidson's argumentation is much more on a purely ontological level than on a linguistic one. He assumes that we can say "*Joan crossed the channel slowly.*" and "*Joan swam through the channel quickly.*", and thereby refer to the same ontological event, because for a general crossing of the channel the crossing might have been slow, while Joan has maybe broken the record for swimming across the channel. From a linguistic perspective, however, we would always distinguish these two events, and the problem does not arise.

certain monotonic inferences which can be observed in the nominal domain, as in (9), are excluded in the verbal domain with adverbial modifiers, as illustrated in the examples in (10) and the formalization in (11) (Landman, 2000:5,11]).[3]

(9) a. John is a blond American.
b. John is a blue-eyed American.
c. $\vdash$ John is a blond blue-eyed American.

(10) a. If one talks to a crowd one moves his thorax.
b. John talked to a crowd through a microphone.
c. $\nvdash$ John moved his thorax through a microphone.

(11) a. $\forall e \forall x.\mathbf{talkTo}(e,c,x) \rightarrow \exists e'.\mathbf{move}(e',x,\mathbf{thorax}(x))$
b. $\exists e.\mathbf{talkto}(e,j,c) \wedge \mathbf{through}(e,m)$
c. $\nvdash \exists e'.\mathbf{move}(e',j,\mathbf{thorax}(x)) \wedge \mathbf{through}(e',m)$

The inference fails because Existential Instantiation in the second premise and in the consequent must be to fresh individual constants.

This concludes the brief introduction of the initial motivation that lead to the introduction of Event Semantics. Let me finally point out that one major ontological plausibility speaks in favor of an event-based approach, even in case some of the original motivations might turn out slightly eroded at the end of this chapter: One main conceptual problem one might (but of course does not need to) have with a classical treatment of n-place verbal predicates as sets of n-tuples of individuals is that it looses the ontological insight that the tuples of individuals for which the predicate is true are related not by mere pairing, but by their being involved in an event, process, state, etc. Even though at some index, the interpretation of predicates as sets of tuples is sufficient to determine the truth value of some predicate expression applied to a specific individual expression, it is hard to interface this notion to conceptual mechanisms involving events with all their temporal, aspectual, and spatial properties as perceived by humans. And even if one does not want to discuss matters of conceptual plausibility, explicit reference to events and the linguistically relevant (even language-driven) individuation of events, which I am going to discuss in section 2.1.2, show that events are an asset to any rich theory of natural language semantics.

Even a classical (not event-based) predicate's intension (a set of tuples of indices and

[3] In the consequent of (11a), I have omitted Landman's "$\wedge\mathbf{involve}(e,e')$". It seems to suggest some ontological connection which language just does not express. The formalization as given here renders the absurdity of the false inference more clearly, directly, and perfectly in line with our final ontological commitments.

such lists of tuples of individuals), provides no obvious direct anchor to attach information related specifically to the event/process/state/etc. in which the individuals are involved, although it is of course sufficient to characterize the predicate for all possible indices in some way. This intuition will be backed up by its power to solve a major problem in the semantics of adverbials in section 2.2.1 related to the extensionality/intensionality question.

I have shown in this section that language conveys some information about events in a very direct fashion, and that my argumentation which follows is therefore based on well-known linguistic and ontological observations.

2.1.2 Roles and Event Individuation

2.1.2.1 Finegraned Events

The Neo-Davidsonian approach, formulated most prominently in Parsons (1990), assumes that in the logical representation of a verb, arguments are added in a fashion similar to that in which adjunct modifiers are added. Making thematic roles explicit and turning them into relations between events and individuals (or functions from events to individuals), arguments are added conjunctively through thematic role predicates. For the classical Davidsonian form in (12a), (12b) is a sample lexical entry for a verb under the Neo-Davidsonian framework with roles as relations between events and individuals. (12c) gives an equivalent form which is preferred in Landman (2000), and which renders roles as functions.

(12) a. $\lambda y.\lambda x.\lambda e.\mathbf{push}(e)(x)(y)$

b. $\lambda y.\lambda x.\lambda e.\mathbf{push}(e) \wedge \mathbf{agent}(x)(e) \wedge \mathbf{theme}(y)(e)$

c. $\lambda y.\lambda x.\lambda e.\mathbf{push}(e) \wedge \mathbf{agent}(e) = x \wedge \mathbf{theme}(e) = y$

This makes the semantics of arguments and adjuncts similar to each other, a fact which I will exploit in section 2.2.1. Since the combinatorics of each of these three forms is the same (given by the λ prefix), the syntax-semantics interface for the three variants will look very much alike.

The Neo-Davidsonian representation, however, makes it easier to individuate events by roles, i.e. to make explicit the purely language-driven nature of the ontology behind natural language events (as opposed to real world events in a common sense meaning). Let me illustrate this by citing from Landman (2000:32), although the examples originate from Parsons (1990).

(13) a. i. I hit Brutus.

ii. $\exists e.\mathbf{hit}(e) \wedge \mathbf{agent}(e) = i \wedge \mathbf{patient}(e) = b$

b. i. I revenged myself.

ii. $\exists e.\mathbf{revenge}(e) \wedge \mathbf{agent}(e) = i \wedge \mathbf{experiencer}(e) = i$

c. i. My hitting Brutus was my revenge.

ii. *The event in (13a) is the same as the one in (13b).*

d. i. Hence, I hit myself.

ii. $\exists e.\mathbf{hit}(e) \wedge \mathbf{agent}(e) = i \wedge \mathbf{experiencer}(e) = i$ (with Law of Simplification)

I have some major concerns regarding this example (and most other similar examples), concerns which, I think, go beyond what Parsons and Landman wish to show. The identifying clause, (13c) should probably not be taken as a statement of simple identity, since natural language makes richer use of what looks like identity statements. The relation expressed between my hitting Brutus and my revenge in (13c) is far more complex than identity. It seems to me that the identifying clause must be taken as saying that it is the hitting of Brutus which *serves as a means of* achieving revenge. And this phenomenon is by no means restricted to events, as the equally nonsensical (14) shows.

(14) a. My Glock is my peace of mind.

b. I shot my foot with my Glock.

c. Hence, I shot my foot with my peace of mind.

On the other hand, the existential quantifier in (13a) and (13b) does not lead to the description of one uniquely identifiable event, but, as Davidson said, the sentences are merely true if there is at least one event which fits the description. Of course, we usually allow anaphoric reference to entities introduced via an existential quantifier (as in *"A man entered. He had a donkey with him."*), but it is not clear how the simple logical representation in (13d) is supposed to come about. Such general considerations should actually precede any suggested formal solution, and it might turn out that there is no need for a technical solution at all. But, aside from the argumentation from which it stems, the formal apparatus is still highly useful, and it does a great deal of work in other places.

Parsons and Landman assume three principles individuating events at the level of event type (what I call the *main event parameter*) and role specification, as listed in (15)-(17).

(15) **Lexical Finegrainedness Requirement (LFR)** (adapted from Landman, 2000:36)
If A and B are lexical predicates of events, then $[\![\lambda e.A(e)]\!] \cap [\![\lambda e.B(e)]\!] = \{\}$.

(16) **Role Specification (RS)** (adapted from Landman, 2000:38)
For each lexical predicate A it is specified which roles are defined for that predicate (and also which roles are obligatory).

(17) **Unique Role Requirement (URR)** (adapted from Landman, 2000:38)
Thematic roles are partial functions from events to individuals.

What effect do these principles, in turn, have? **Lexical Finegrainedness**[4] helps us to distinguish buyings from sellings and hittings from revenge-takings, etc. Without the LFR in place, we could be tempted to identify *Mary buying a piglet from John* and the (in space and time) quasi-collocated *John selling a piglet to Mary* as *one* event. Of course, this would bring about serious complications since, for example, adverbials like *without permission* might correctly modify the *buying*-expression but not to the *selling*-expression, and vice versa; a selling and the associated buying really are two events. The LFR thus detaches linguistic ontology from common-sense ontology to a certain degree. However, many adverbs contribute simple predicates over events just like verbs, and we do not want them to fall under Finegrainedness. It could very well be that the quick events and the violent events have a non-empty intersection, etc. It is not clear whether Landman avoids this by his definition of *lexical* in the formulation of the principle, but I will give a reverse implementation of Finegrainedness in section 2.2.1 in the form of FI (25). With that formulation (and in the general picture of my theory) the problem does not arise.
Role Specification deals with what is known as argument structure in syntactic theories. It blocks inferences such as the nonsensical one in (18), cited from Landman (2000:31).

(18) a. I dined tonight.
b. I ate falafel tonight.
c. The falafel was my dinner.
d. Hence, I dined falafel tonight.

Landman argues that the LFR could take care of this failure of inference, but that it would miss the true reason for the failure. I do not consider this argument fully adequate. It will not help us to be able to distinguish the *dining* from the *eating* by the LFR in this case, because the inference does not require the events to be extensionally identical. I could be *eating while dining* or *dining by eating*, just as with *chew* instead of *eat* and *eat* instead of *dine*, a similar inference would go through. We are not dealing with

[4] Landman actually later reconstructs this principle from other principles. Since I find Finegrainedness useful in my theory, I keep it as a (potentially not independent) axiom for convenience's sake.

a case of a logically faulty argument, but the sentence encoding the logical conclusion is simply ungrammatical (and hence blocked by RS). This demonstrates the uncontroversial insight that a grammatical theory needs lexically specified argument structure, encoded here by RS.

Finally, the **Unique Role Requirement** (dating back to Carlson 1984), puts a ban on events where the same role is filled by several individuals. In Parsons' framework it does that by requiring the role to be a function from events to individuals. If it is a function, then it is one-to-one. It must be partial, because it is not the case that for every event every role is actually specified (for example, there is no agent in a dying event). I will show in chapter 3 and especially chapter 6 (based on rich literature such as Scha 1981, Krifka 1989, Wyner 1994, Landman 2000), how object plurality might be related to event ontologies.

I have shown how events must be distinguished or individuated based on their main parameter and their role specifications.

2.1.2.2 The Ontological Independence of Events

To close this section, I will further demonstrate the ontological value of what was just said and add a few words on further disambiguations of events and the ontological independence of events, i.e. the fact that they cannot be reconstructed from other ontological objects like times/intervals, space coordinates, etc. (following Eckardt 1998 and Eckardt 2002, although many observations are from Parsons 1990).

Let us assume events can be reconstructed as time intervals. One simple example to refute this assumption is (19); there are two possible adequate dialogs in a situation where Alma slept from 2:00 to 4:00.

(19) A: Did Alma sleep between 3:00 and 5:00?

(20) a. B_1: Yes, she did.
 b. B_2: No, she didn't.

The first answer is correct because the sentence can be understood as a question about the time span mentioned, and of course Alma slept during that period. The second answer takes the question as a question about Alma's sleeping event, and that event was obviously not located between 3:00 and 5:00. Obviously, speakers attribute specific qualities to the event itself, independently of simple temporal properties of the event.

But maybe we could reconstruct events as time interval plus spatial coordinates? The case against this hypothesis rests on facts about ways in which an event expression can be modified. Take two obviously space-time-collocated events which should be one if events are really nothing more than spatio-temporal regions.

(21) a. The sphere rotated quickly and, during exactly the same time, warmed up slowly.

If events could be reconstructed from temporal and local primitives, then *slowly* and *quickly*, two obviously contradictory modifiers, would have to apply to the same event. Thus, Parsons concluded that, whenever a modifier is applicable to one event description but not to a second one, then the first and the second event must be distinct. The resort to scales, e.g. a postulation that some interpretation like *slow as warming up* and *quick for a rotation* is involved, would lead, in the case at hand, to the implication that rotations are usually slower than warming ups. We must conclude that (21) really describes two individuated events.

We see from the previous discussion that event individuation should be maximal. Differences in event type, in argument structure and thematic structure, and in modifiability all lead to maximally differentiated events. That we are sometimes tempted to perceive these events as one event (in a common-sense ontology) must not lead us to assume that they are one in the ontology of natural language.

In the next section, I discuss why we can use Event Semantics to overcome both the conjunctive/relational character of Event Semantics itself, and the problems with modifiers as operators. This leads to a generalization of the notion of operator for both arguments and adjuncts.

2.2 The Generalized Operator Approach for Referring Expressions

2.2.1 Operator-Based Approaches

First, this section gives a quick recapitulation of the discussion surrounding the operator approach (Thomason and Stalnaker 1973) and the conjunctionist approach (Davidson 1967 and his followers). I base this mostly on Eckardt (1998). Then, I introduce the semantics of the Generalized Operator Approach (GOA) for simple referring expressions. Please keep in mind that I present a fully formal solution for the fully developed approach in chapter 5.

The approach to adverbial semantics in Thomason and Stalnaker (1973) (similar to the sketchy treatment in Montague 1973a) assumes that verb phrases denote sets of individuals, i.e., that they are of a type $(\mathbf{Ind} \rightarrow \mathbf{2})$.[5] Under this classical Montagovian framework, the extensional meaning of a VP represented as **loves a woman** is, at the given index,[6] the set of individuals for which it is true that they love a woman. Given this interpretation, Thomason and Stalnaker (1973) discuss the option of modeling VP adverbs as operators (or functions-on-functions) on such extensional meanings. Since the result of adding an adverb to a VP is again a VP, under this approach the semantic type of a VP adverb has to be $((\mathbf{Ind} \rightarrow \mathbf{2}) \rightarrow (\mathbf{Ind} \rightarrow \mathbf{2}))$.

The meaning of an operator such as **passionately**, $[\![\mathbf{passionately}]\!]$, is a function reducing the denotation set of the VP to exactly those individuals who (following the example just given) love a woman passionately. Since an operator on such a set can in principle perform any kind of manipulation (i.e., it could also introduce elements which were not in the set which it received as its input), a meaning postulate would be in order, requiring all operators of type $((\mathbf{Ind} \rightarrow \mathbf{2}) \rightarrow (\mathbf{Ind} \rightarrow \mathbf{2}))$ to have the *subset property*. The subset property is the requirement that the operator only map its input set S to a set S' such that $S' \subseteq S$.

However, since under a plain extentsional semantics VP denotations are defined as sets of individuals without further meaningful semantic specification, it might happen that two or more VP extensions are identical. If by chance the set of runners were equal to the set of shouters at some index, the inference in (22) would go through, which is clearly undesirable.

(22) $\mathbf{quickly}(\mathbf{run}) \leftrightarrow \mathbf{quickly}(\mathbf{shout})$
because: $[\![\mathbf{quickly}(\mathbf{run})]\!] = [\![\mathbf{quickly}(\mathbf{shout})]\!]$

From such problems with an extensional treatment, Thomason and Stalnaker concluded that VP adverbs are intensional, i.e. that they require the expression of a property-in-intension as their input. In Montagovian semantics, such an approach is in principle valid, since it is generally assumed that an expression can require an input expression to denote an intension or extension. For the VPs in question, the type now has to be $(\mathbf{Idx} \rightarrow (\mathbf{Ind} \rightarrow \mathbf{2}))$. This makes the VP a function from an index (a possible world, type **Idx**) to a function from and individual to a truth value, which set theoretically amounts to the pairings of possible worlds and the set extensionally denoted by the

[5] Throughout this work, I use the notational conventions used in Carpenter (1997) and in many computationally oriented publications. I assume the type nomenclature (**Ind** for *individual*, **2** for *bool*, etc.) to be trivial at this point. Notice that non-logical constants are bold-printed instead of primed, e.g., **walk** instead of *walk*′.

[6] By index, I refer to a possible world w or a tuple $\langle w,t \rangle$ of a possible world w and a time t as in standard Montagovian semantics, cf. Montague (1973a) or Dowty, Wall and Peters (1981) for an introduction.

VP at that index. Even if at some index two predicates denote the same set, they do not denote the same set at all possible indices.[7] Obviously, the intension of a VP is never identical to that of another VP. If we now model the VP adverb as being of type $((\mathbf{Idx} \to (\mathbf{Ind} \to \mathbf{2})) \to (\mathbf{Idx} \to (\mathbf{Ind} \to \mathbf{2})))$, we can avoid the unwanted equalities demonstrated in (22).

With the intensional treatment, however, another problem arises, namely that within intensional VPs, opacity effects would have to be expected.[8] Opacity effects occur primarily with definite descriptions in contexts which are clearly intensional, since definite descriptions are not rigid, i.e., they change their denotation at indices. For example, (23) is true at an index where Yuri Gagarin actually was the first man in space only if the definite description *the first man in space* is evaluated inside the scope of the intensional *might*.

(23) Yuri Gagarin might not have been the first man in space.

In that case, the definite NP unfolds its full intensional meaning, and the sentence expresses the proposition that there are worlds at which Yuri Gagarin was not the first man in space. If the NP is evaluated outside the modal operator, it receives its extensional meaning at the aforementioned index, i.e., $[\![\textbf{the first man in space}]\!]=$ *Yuri Gagarin*. The resulting interpretation (roughly: *Yuri Gagarin might not have been Yuri Gagarin*) will of course be false.

Thus, if the verb creates an intensional context (in order to serve as an appropriate semantic input to the adverb), an embedded definite object NP like *the queen of Sweden* in *kissed the queen of Sweden* is not necessarily co-referring to the current queen of Sweden. Quoting the example from Eckardt (1998:5) in (24a) and (24b) with her analysis involving an intensional VP in (24c), the problem becomes obvious (i being the index variable).

(24) a. Tom kissed the queen of Sweden.

b. Tom kissed Silvia.

c. $\lambda i.\lambda x.\mathbf{kiss}_i(x,\mathbf{silvia}) \neq \lambda i.\lambda x.\exists y.\mathbf{kiss}_i(x,y) \wedge \mathbf{queenOfSweden}_i(y))$

d. Tom (tenderly) kissed Silvia. $\leftrightarrow$ Tom (tenderly) kissed the queen of Sweden.

e. Tom thinks he kissed Silvia. $\not\leftrightarrow$ Tom thinks he kissed the queen of Sweden.

The interpretation of an adverbial ADV could thus be a function modifying the set of individuals denoted by the predicate V **at each index** to the subset of individuals which

[7] There is at least the one possible index which is distinguished from the present one by exactly that difference in extension.

[8] On opacity, compare, among others, the classic Quine (1956).

are **ADV**-ly **V** at that index.[9] Unfortunately, however, the empirical observations usually associated with intensional contexts just do not show in the case of the VPs in question. (24d) (with or without the adverb) is a reliable equality with not the slightest ambiguity arising, whereas (24e) demonstrates clear opacity effects (because verbs of propositional attitude like *think* create opaque contexts). Assuming VP-intensions, we can successfully give an operator-interpretation to VP adverbials, since the inequality with intensional VPs as in (24c) makes predicates which are by accident co-extensional at some index nevertheless distinguishable. However by doing so, we trivialize the notion of intensional context and turns it into an escape argument which ignores powerful empirical facts.

The solution lies in Event Semantics, and it was hinted at in Eckardt (1998:12-3). As argued in section 2.1, events should not be reconstructed from other ontological objects like points in time and space. Events are ontological primitives. We can be sure that (25) always holds for two predicates over events E_1 and E_2.

(25) **Finegrainedness** (FI)
$\forall E_1, E_2. \neg \exists e. E_1(e) \wedge E_2(e)$

We could introduce (25) as a meaning postulate to shape our models appropriately and make sure that walking events are never talking events, etc. The postulate ensures that at no index will it be true that one event ever has two main event parameters, and it is such an implementation of the Lexical Finegrainedness Requirement as suggested by Fred Landman. Of course, since adjuncts also contribute simple predicates over events, FI must be restricted to such main event parameters (like **walk**, **talk**, etc.) to avoid a ban on walkings or talkings being at the same time quick, silent etc. I will have to say more about this later in the current chapter.

We could never have put such a strong restriction on models based on a classical ontology (which models one-place predicates as sets of individuals), because its parallel formulation would have such powerful and undesirable effects as forbidding that any individual have two properties. With the fact that every individual has at least the property of being identical to itself, no individual could then be assigned any useful property. With (25) in place, however, and if we assume that VP adverbials modify an event description, we can follow an operator approach without requiring all VPs to appear as predicates-in-intension. Instead of using an event-based semantics as an alternative to the operator approach, we use events to rescue the operator approach. It is not a logico-syntactic move (the introduction of the *e* variable) but an ontological

[9] Of course, the subset property is again required for the index-wise filtering of the predicate's extension.

commitment to events that provides a solution to the semantics of VP modification.
In the following illustration, I choose predicates which do not assign thematic roles for the sake of simplicity. Given FI, we can be sure (26a) always holds, i.e., a raining event will never be a snowing event. (26b) gives a set-theoretic definition of the operator denoted by some adverbial, such that (26c) receives the intended interpretation without resort to intensionality and without risk of extensional identity.[10]

(26) a. $\lambda e.\textbf{rain}(e) \neq \lambda e.\textbf{snow}(e)$

b. $[\![\textbf{intensely}]\!]$ = a function from a set of events S to a set S' of events which occur with high intensity s.t. $S' \subseteq S$

c. $[\![\textbf{intensely}(\lambda e.\textbf{rain}(e))]\!] = [\![\textbf{intensely}]\!]([\![\lambda e.\textbf{rain}(e)]\!])$ =the set of intense raining events

Because we have defined the subset property for the relevant operators, we can be sure that the empirical generalizations of Permutation and Drop are accounted for. If we stack several such operators for which the subset property is defined, all we do is reduce (or leave untouched) the set we started with. The definition actually guarantees that we end up with the intersection of the *raining*, *intense*, *loud*, etc. events, and nothing makes this solution more or less plausible than the Davidsonian variant.
Assuming GOA, we can now get rid of a somewhat intuitive but formally awkward restriction in FI (which was not encoded in the meaning postulate but only mentioned in passing), namely the restriction to *main event parameters* (or *event types*). We always know what the main event predicate is, but formally we cannot distinguish it straightforwardly from any (adjunct) predicate in the semantics. In the relational version of the Neo-Davidsonian theory, they are both predicates over events. Under GOA, adjuncts contribute operators (while verbs contribute event descriptions), and FI can be assumed valid for all predicates over events.
With the operator approach now established as one way of rendering adverbial modification in Event Semantics, I make the extension of the approach to arguments plausible in the next section.

2.2.2 Generalizing the Operator Approach

We have seen in section 2.1 that in Event Semantics properties of events are conjoined with the nuclear verbal representation (which has as its core an event description). Ar-

[10] We can always switch between set-theoretic definitions and the corresponding definitions in terms of characteristic functions of the sets we talk about. I went for sets here because talking about sets is usually much more transparent and less cumbersome than talking about functions.

guments (in the Neo-Davidsonian framework) are rendered as similar conjuncts, but as a part of the lexical representation of the verb. They take the form of thematic role predicates, the logical form then providing the necessary λ abstractions to allow arguments to combine with the verb. For adjuncts, it is assumed that they add further conjuncts, predicating over the event variable, or even, in the case of oriented adverbs, over the event and an argument variable. As far as their core semantic contribution to the growing semantic representation of the sentence is concerned, arguments and adjuncts are not in any way different from each other.

On the other hand, in the last section, we have seen that Event Semantics allows for an elegant solution of the classical problem of the operator approach which plagued the solution to adverbial modification in Thomason and Stalnaker (1973). Since it pushes the extension of the verb to a more complex (event set) object (instead of a set of (tuples of) individuals), we can distinguish between extensions via distinctions between events in cases where in a classical theory we could not.[11]

This section generalizes the event-based operator approach further to include arguments (starting with singular referring expressions) as operators, reducing the denotation of verbs to sets of events. The inspiration to do so comes from Krifka (1992), who casually treats verbs as denoting sets of events, assigning NPs a special thematic logical form in theta positions (see immediately below). The advantage of such an approach lies in the facts that (i) we can ultimately do with only one simple type (compare the ideas in Partee 2007), the type of individuals (objects and events), and (ii) all elements that combine with the verb have the same functional type of event-description modifier. This means that cumbersome abstractions over indices and meaningless polymorphism (on the side of adjuncts) become obsolete. There is never going to be a question of "an index not being available", every argument and adjunct can apply at any time.

2.2.2.1 Krifka 1992

Krifka, in the paper in question, commits to the following (Krifka, 1992:36): *"A verb is represented as a one-place predicate of events; the syntactic arguments have no counterpart in its semantic representation, but only in its syntactic categorization. The theta role information [. . .] is passed to the subcategorized NPs, where it is realized as a part of the semantic representation of the determiners."* For adjuncts, he assumes inherent case/role assignment by the preposition.

In (27), I give some of Krifka's (p. 37) lexical entries, which are tuples of an ortho-

[11] Remember that events are distinct if they have different properties. Main event predicates are never co-extensional by definition of FI.

graphic rendering, a syntactic category, and a logical form, separated by ‘;’ (I give them in exactly the notation used by Krifka).

(27) a. *drank*; S/NP[subj,ag],NP[obj,pat];$\lambda e[drink(e)]$

b. *pig*; N; *pig*

c. *Ø*; NP[obj,pat]/N; $\lambda P' \lambda P \lambda e \exists x[P(e) \wedge PAT(e,x) \wedge P'(x)]$
(the null determiner for determinerless NPs under patience assignment in object position)

d. *a*; NP[subj,ag]/N; $\lambda P' \lambda P \lambda e \exists x[P(e) \wedge AG(e,x) \wedge P'(x)]$
(the determiner ‘*a*’ under agent assignment in subject position)

We see that the verb itself contributes only a predicate of events, type $(\mathbf{Ev} \rightarrow \mathbf{2})$. Simple nouns are rendered as usual by a one-place predicate, type $(\mathbf{Ind} \rightarrow \mathbf{2})$. Determiners, in an appropriate thematic position, take a predicate of individuals contributed by the noun, then a predicate of events, to result in a predicate of events containing the necessary quantification. In the case of the determiner *a* under agent assignment in subject position applied to the noun *pig* and the verb like *love*, the result is a function from events to *true* iff there is at least one object such that it is the agent of that event, the event is a loving event, and the x is a pig, cf. (28). The type of determiners is thus $((\mathbf{Ind} \rightarrow \mathbf{2}) \rightarrow ((\mathbf{Ev} \rightarrow \mathbf{2}) \rightarrow (\mathbf{Ev} \rightarrow \mathbf{2})))$.

(28) *love a pig*; S/NP[subj,ag]; $\lambda e \exists x[love(e) \wedge PAT(x) \wedge pig(x)]$

This theory generates completely standard relational outputs, ultimately an expression of type $(\mathbf{Ev} \rightarrow \mathbf{2})$ which can be existentially closed. For quantificational NPs, this theory would still require classical scoping mechanisms like quantifying-in, storage, LF movement, or logico-syntactic underspecification. Thus, we would end up with final outputs that looks a lot like those in standard approaches to Event Semantics, only with a syntactic mechanism of assigning thematic roles and verbs as simple event-set-denoting expressions.

2.2.2.2 A First Idea of GOA

In this section, I take the three aspects introduced so far to develop them to their full consequences in GOA:

1. the technical idea about thematic assignment from Krifka (1992),
2. the insight that relational theories and operator-based approaches are equivalent in Event Semantics,

3. the insight that properties of and relations between objects (Montague style) and events encode the same information.

Notice, however, that readers who prefer a straightforward formal introduction can skip immediately to chapter 5, skipping the partly philosophical argumentative part of this thesis from here to chapter 4.

Under the Generalized Operator Approach (GOA) as presented here, we project participance information directly into event structures, a move which will later allow a treatment of quantification without variables, and which enables the unification of the types of arguments and adjuncts under the assumption of one simple type (of individuals) in a strictly set-theoretic formulation without intermediate layers of predicate logic.

We start by straightforwardly introducing the semantics of GOA for simple singular referring expressions (i.e., no plurality, no quantification).[12]

For the current purposes, we need a domain D_{Ev} of events in addition to domain D_{Obj} of non-event objects. Accordingly, from now on we adopt the simple sorted syntactic types **Ev** for events with domain D_{Ev}, **Obj** for non-event (i.e. classical) individuals with domain D_{Obj} and the supertype **Ind** with domain D_{Ind} such that $D_{Ind} = D_{Obj} \cup D_{Ev}$.

The set-theoretic formulation without predicate-logic requires us to introduce for every type α the power set type $\wp\alpha$ with domain $D_{\wp\alpha}$, the domain of sets of objects of type α. Functional types are constructed recursively as usual with functional domains and written $(\alpha \rightarrow \beta)$ for any types α and β with domain $D_\beta^{D_\alpha}$. However, I only include explicitly defined function in the functional domains. In absence of a λ calculus, full domains of anonymous functions are not required.

Core verb constants (**hit**, **eat**, etc.) are of type $\wp$**Ev**, and they denote pairwise disjoint sets of events by FI. Let us furthermore say that referring expressions (**piggy**, **kermit**, etc.) are of type **Obj**. A primary role function **role** (**agent**, **patient**, etc.) is of type $(\mathbf{Ev} \rightarrow \mathbf{Obj})$, denoting a partial function from events to role-bearing individuals. They are called primary role functions to clearly keep them apart from the corresponding thematic operators **Agent**, **Patient**, etc., which are of type $(\mathbf{Obj} \rightarrow (\wp\mathbf{Ev} \rightarrow \wp\mathbf{Ev}))$. Expressions of this type consume an object expression to form an operator on expressions denoting sets of events, an operator identical in type to simple adverbial operators such as the one corresponding to *fiercely*: **fiercely** is of type $(\wp\mathbf{Ev} \rightarrow \wp\mathbf{Ev})$.

While the semantics of **fiercely** simply reduces the event predicate's range to the subset such that the events in that subset are fierce, the function denoted by **Agent** reduces the range to the subset E' such that $\forall e \in E'.[\![\mathbf{agent}]\!](e) = i$, i standing in here for the individual denoted by the NP constant.

[12] Notice that this is the definition of a logical language, not English.

Since we have reduced the core meaning of the verb to a set of events, the verb's lexical entry not only has to specify this set, but it also has to specify which thematic operators Θ are assigned to the subcategorized NPs in their syntactic positions. We can identify case morphology and pre- and postpositions as overt realizations of the thematic operator. In this and the following chapters I represent lexical verbs as tuples of a core verb and a number of Θ operators appropriate for the argument structure of the verb.[13] The tuple has the appropriate linearization to generate SVO, SOV, or any other type of linearization.

The logical expression corresponding to the English verb *hit* is now rendered (for an SVO language) as in (29a), or rather, to avoid commitment to specific role labels, as in (29b), just marking the external and numbering the internal roles.

(29) a. $\langle \mathbf{Agent}, \mathbf{hit}, \mathbf{Patient} \rangle$

b. $\langle \mathbf{Ext}, \mathbf{hit}, \mathbf{Int_1} \rangle$

I now give an informal semantic derivation of (30a) in figure 2.1, where (30b)–(30e) provide the appropriate lexical entries (their type given in the exponent). Since any syntactic theory is in principle compatible with this approach, I do not go into syntactic details of the derivation. Notice that I do not specify categories, and that function application can occur leftward and rightward. (30) lists the lexical entries, and the tree in figure 2.1 starts with the verb tuple unbundled and all other material at the bottom, building up the sentence's logical form.

(30) a. Miss Piggy hits Kermit the Frog fiercely.

b. *Miss Piggy*: $\mathbf{piggy}^{\mathbf{Obj}}$

c. *Kermit the Frog*: $\mathbf{kermit}^{\mathbf{Obj}}$

d. *hit*: $\langle \mathbf{Ext}^{(\mathbf{Obj} \to (\wp\mathbf{Ev} \to \wp\mathbf{Ev}))}, \mathbf{hit}^{\wp Ev}, \mathbf{Int_1}^{(\mathbf{Obj} \to (\wp\mathbf{Ev} \to \wp\mathbf{Ev}))} \rangle$

e. *fiercely*: $\mathbf{fiercly}^{(\wp\mathbf{Ev} \to \wp\mathbf{Ev})}$

For (30e), we assume that $[\![\mathbf{fierce}]\!]$ is the set of fierce individuals. With an interpretation for the Θ operators and the adverbial as in (31), we can interpret this very simple logical form. Notice that $[\![\mathbf{fierce}]\!]$ can be elegantly taken to be the set of fierce individuals (objects and events). **ext** and $\mathbf{int_1}$ are, as defined above, functions from events to their external and first internal role bearer, respectively.

(31) a. $[\![Ext(\alpha)(\beta)]\!] = [\![\beta]\!] \cap \{e | ext(e) = [\![\alpha]\!]\}$

b. $[\![Int_1(\alpha)(\beta)]\!] = [\![\beta]\!] \cap \{e | int_1(e) = [\![\alpha]\!]\}$

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[13] In chapter 7 I will propose a solution which has the same effect but has the advantage of avoiding phonologically empty elements in the syntax.

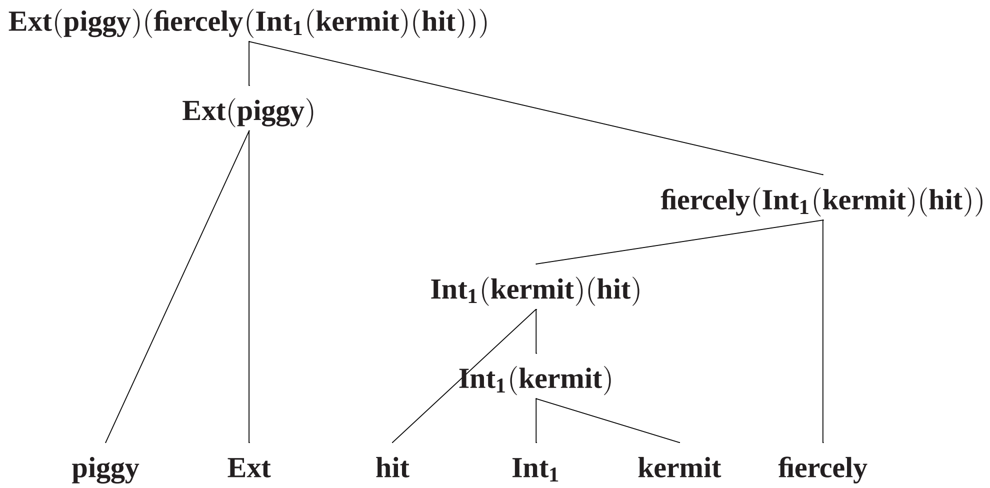

Figure 2.1: A simple derivation of (30a) in GOA

c. $[\![\textbf{fiercely}(\alpha)]\!] = [\![\alpha]\!] \cap [\![\textbf{fierce}]\!]$

As can be easily seen from the derivation, the final string is interpreted exactly like a classical Neo-Davidsonian logical form (provided in (32)) before existential closure takes care of the event variable.

(32) $\lambda e.\textbf{hit}(e) \wedge ag(e) = \textbf{piggy} \wedge theme(e) = \textbf{kermit} \wedge \textbf{fierce}(e)$

It denotes the set of fierce hitting events where Miss Piggy is the agent and Kermit the Frog is the theme. The GOA variant offers a much simpler compositional mechanism. It is composed without λ-types and abstractions, and the only semantic operation is function application. As a final note, let me point out that under a theory such as the one proposed here, all verbal predicates would have to be rendered as descriptions of events or states. I leave open the question of how to account for facts described for example in Kratzer (1995), who rejects state arguments for some predicates, and Katz (2003), who rejects state arguments entirely. At least the proposal by Katz is based mainly on the non-existence of certain state-specific modifiers. This is an interesting fact to be investigated further, but in no case hard counter-evidence to state arguments. I have argued that the operator approach fares at least as well as the relational approach for sentences containing only referring nominal expressions and simple adverbials. I now discuss shortly how semantic outputs like the one calculated in figure 2.1 can be interpreted at discourse level.

2.2.3 Models

I now say a few words about how sentence denotations as discussed in the previous section can be used to allow the construction of models in the flow of communication.
I provide mostly normal model-theoretic interpretations for the expressions generated by the grammar developed in this thesis. This means that, given a fixed model with a fixed domain of individuals (which would be, by Kripke's dictum, also fixed across possible worlds), the denotation of some expression in that model can be calculated. The interpretation procedure is given in a general way so as to guarantee that it can be performed in any *admissible model*. An admissible model is one which is a well-formed model of the language developed, well-formedness being guaranteed by a set of axioms on the structure of the model. Such an approach is customary in model-theoretic semantics, and the models constructed are usually taken as corresponding to facts of the world in a more or less correspondence-theoretic manner.

Additionally, semantics of natural language is usually done in truth-valued logic. Under such a framework, two types of basic expressions (and thus two basic types) are assumed: individual-denoting expressions (Montague's type e) and truth-value-denoting expressions (Montague's type t, corresponding to sentences). Other expressions are of derived functional types, like the type for expressions denoting functions from individuals to truth-values (unary predicates, type $\langle e,t\rangle$). If intensionality is incorporated, either a class of derived types for expressions denoting functions from possible worlds to some other type of denotatum is added ($\langle s,\alpha\rangle$ in Montague (1973a)), or an independent simple type of possible worlds (as in Gallin 1975). Ultimately, a derivation is successful if it results in a t-typed (or, intensionally, $\langle s,t\rangle$-typed) expression (a sentence).

The current approach differs in one way from such standard approaches. I do away with a special simple type of truth-valued (sentential) expressions.[14] A derivation in this event-based approach usually produces an expression denoting a set of events (in chapter 3 and later a set of sets of events), and existential closure is not assumed as part of the mechanism of the grammar. This is roughly like the treatment of indefinites in Discourse Representation Theory (DRT, Kamp 1984, Kamp and Reyle 1993 and much subsequent work) which also provide just an open variable to be bound beyond semantics proper, although the theory of DRT bears little similarity to my theory on the technical side. Partee (2007) suggests something similar (classical Neo-Davidsonian representations without existential binding) in her discussion of how the type of events

[14] Keep in mind that events are nothing but a sort of individual, and that thus the single type of individuals covers events and non-event objects.

could be made into the single type maybe suitable as the only required for natural language semantics.

Why is this so? The events (or sets of sets of events in later chapters) denoted by a sentence model *the different circumstances which would be sufficient to make the sentence true*, and I suggest that we can do without formulating truth as a primary notion at this point. Clearly, a hearer who is presented with an utterance which denotes such a set of events will assume that at least one of them is factual, but since he cannot necessarily verify whether this is so in many circumstances, forcing the expression to be truth-valued by introducing existential binding contributes nothing to the flow of information in a discourse.

What a hearer will be most likely to perform is an update of the set of models he considers adequate from his point-of-view to make it suit the new information. In constructing concrete mental models of the world, the sets of events denoted by sentences (one of which must be factual) act as constraints on models of the world which must be fulfilled.[15] This, however, is not informatively captured by a truth-functional semantics which statically evaluates formulae against models by some interpretation procedure. The hearer will (assuming that he believes the speaker) rather restrict the class of models he is considering to those which fit information (about events) gathered in the discourse.

In a psychologically realistic setting, this concept of models and denotations would probably have to involve some notion of probabilities of events and of disjunctions of events, as will be illustrated immediately. Assume someone who knows Laura but has not heard from or about her for five years is confronted with the utterance *"Laura went to Nijmegen."* out of the blue. Of course, there must be at least one event of Laura going to Nijmegen between some point in time five years ago and the speech time, and we can check the sentence as true or false against any model which either has such an event or not. The hearer usually does not have such a model when the sentence is uttered (assuming informative rational communication), but wants to construct one. The model which he can construct from that sentence is quite poorly specified, because for an immense number of possible events of Laura going to Nijmegen in the time frame in question, he can assume the same rise in the probability that it actually happened (= that the event exists). However, the probability for each of these events is siginificantly higher than before he heard the sentence, and the probability of the disjunction of all these events (the probability that at least one of them is factual) is (or is close to) 1.

I have mentioned the notion of *possible events*. How is it to be understood? The model

[15] In DRT, information contained in the Discourse Representation Structures also represents constraints on models, more precisely constraints on variable assignments.

a speaker enters a discourse with usually should consist of open and sorted sets of object individuals (probably involving complex kind-individual relationships between sorts[16]). Furthermore, for each individual, every event type and its roles, and each time interval, one token of the event type must be assumed to be at least possible (the same for state types etc.). This is a reasonable assumption, since in absence of knowledge about the structure with which events actually have unfolded, are unfolding, or possibly will unfold, each possible event has the same probability. To keep matters simple, I will always assume that both the set of object individuals is identical between speakers, and that all interlocutors always consider the same set of possible events, i.e., they share a language of event-specifying expressions.

By way of an example: As long as we do not know whether Laura was the agent in a drinking event at 12:35 a.m. last night, we must assume that such an event has happened with a certain probability. When we start talking about the world, we distribute probabilities for how things are (or could be) in a completely homogenous fashion, and each event has the same probability. In real life, world-knowledge and pragmatic factors will give us an actual distribution of probabilities far from this ideal state of entropy, but indeed rich in prespecified probabilities for how things might be or might have been.

Now assume that a speaker learns (33).

(33) Laura stirred the porridge.

(34) Laura stirred the porridge between 8:00 and 10:00 this morning.

Pragmatic factors will give the hearer a time frame for which, traditionally spoken, the sentence is supposed to be true. Say, the hearer can be sure that the sentence is a statement about 8:00-10:00 a.m. this morning, so the utterance is enriched to (34). Given this contextual restriction and the fact that our assumed hearer believes that the assumed speaker is informed, cooperative, and rational, the assertion of (34) will allow the hearer to assume that the probabilities of all construable stirring events involving the agent Laura and the theme the-porridge in the given time frame add up to (almost) 1. Besides that, the single construable events have the same probability, this probability being of course conditional on knowledge which excludes specific events from the basic set or specifically favors some of them.

To sum up, the hearer can be sure that one of the possible events of Laura stirring the porridge between 8:00 and 10:00 this morning actually occurred, which is similar to existential quantification over an event variable. Each of them has equal probability, and nothing prevents the hearer to assume that there was more than one event in case

[16] Compare theories of kinds and individuals in Carlson (1977) and subsequent work.

there is further evidence to back this up.
I am confident that a lot could be gained from such a theory, especially in the area of modality, evidential constructions, etc. But, without the tentative probabilistic background, we can still reduce this concept to a discrete one, the *Principle of Assertive Interpretation*, (34). It gives a denotation of positive sentences and a pragmatic instruction how to interpret the assertion of the sentence in terms of the formation of possible models.

(35) **Principle of Assertive Interpretation (PAI)** (simple event set version)
A positive sentence generally has the meaning $\lambda e.\varphi$, it denotes a set of events, and asserting it instructs the reader to mark the denoted events as positively assumable with at least one minimal example.

In other words, existential binding can happen as a result of the pragmatic impact of an assertive sentence.[17]
In this section, I have argued that a more pragmatic view of existential binding of event variables is feasible, introducing the notion of possible events and updates of models. Throughout the remainder of the text, I am often going to stick to a more traditional model-theoretic argumentation where possible, but many argumentations (for example those surrounding alternatives and focus in chapter 4) will only be accessible if this principle is kept in mind.

2.2.4 The Update Procedure

Based on the argumentation from the last section, I now make the update procedure performed by speakers after processing a sentence more precise.

2.2.4.1 Possible Events

We assume that each language-user grammar is at any time limited to a finite number of meaningful symbols. Furthermore, the number of non-event objects in the model is always given, fixed, and finite. We simplify further and assume that all objects are known to all language-users in a discourse.
The conceivable events are maximally individuated by the number of maximally specific expressions referring to singleton sets of events. If the number of core verbal

[17] Without the probabilistic background, the additional specification *with at least one minimal example* is required. It does not look very elegant and in fact like a complicated way of re-introducing existential quantification. I hope it is evident that there is a difference.

expressions, those denoting sets of events, is n, and the number of expressions specifying simple event parameters (i.e., (single) participants[18], manner parameters, spatio-temporal parameters, etc.) is m, then there are no more than $!m \times n$ possible expressions specifying individual events. The events specified by this class of expressions are the possible events (cf. also chapter 4).

A realistic model would be defined as specifying (besides the set of objects) the set of events from the set of possible events which are factual. However, in what I have called the **abstract ontology**, I now assume that the domain D_{Ev} of events is the set of possible events. The abstract ontology is useful in conveying meaning, as will become clear immediately.

2.2.4.2 Sentence Denotation

A sentence denotes under GOA a set of events. If we take the domain of events from the abstract ontology, then any sentence (which does not contain a contradiction) has a non-empty denotation. It must be non-empty, because the possible events are all those which can be referred to by linguistic expressions, and the language-user uses a linguistic expression.

This captures the fact that, even when a (well-formed) sentence is false with respect to the real world (or it is a lie), then it still specifies in an exhaustive fashion the events, each of which would make it true. In the case of a lie, this is explicitly used to manipulate the model of the interlocutor. Put differently, the denotation of a sentence in the abstract model specifies a class of realistic models the assumption (or construction) of which are licensed by the sentence.

Usually sentences are much underspecified in that they don't specify all or even many parameters. In the present theory, this is captured by the fact that sentences denote sets of events, each of which would make the sentence true in the traditional sense.

2.2.4.3 Constraints on Realistic Models

A realistic model is one which a language-user mentally constructs based on knowledge he has gathered. It corresponds to the world as it is perceived or believed to be by the language-user.

The abstract model $\mathfrak{M}$ be defined $\mathfrak{M} = \langle \mathfrak{Dom}_{\mathbf{Obj}}, \mathfrak{Dom}_{\mathbf{Ev}}, [\![\cdot]\!] \rangle$, where $\mathfrak{Dom}_{\mathbf{Obj}}$ is fixed, and $\mathfrak{Dom}_{\mathbf{Ev}}$ is also fixed and the totality of possible/conceivable events (derivable from

[18] The participant parameters are calculated by pairing each known object with each thematic role encodable in the grammar. The resulting set is the set of participant parameters.

the set of parameters of events). $[\![\cdot]\!]$ is the usual interpretation function. All language-users share $\mathfrak{M}$, i.e., it is identical and fixed for every language-user.

Assume a language-user has acquired, in the course of a discourse, any non-empty set of linguistic expressions $I^n = \langle \alpha_1, \ldots \alpha_n \rangle$ which are interpreted as $\langle [\![\alpha_1]\!]^{\mathfrak{M}}, \ldots, [\![\alpha_n]\!]^{\mathfrak{M}} \rangle$, namely sets of events, subsets of the abstract domain $\mathfrak{Dom}_{Ev}$. These sets of events are a full representation of the interlocutor's knowledge at some point in the discourse.

A **realistic model** then is a representation of the realistic facts which the language-user can assume based on this knowledge. There is at any point in the discourse characterized by n sentences a set K^n of construable mental models $\mathscr{M} = \langle \mathfrak{Dom}^{\mathscr{M}}_{\mathbf{Obj}}, \mathfrak{Dom}^{\mathscr{M}}_{\mathbf{Ev}} \rangle$, where for every $\mathscr{M} \in K^n$: $\mathfrak{Dom}^{\mathscr{M}}_{\mathbf{Obj}} = \mathfrak{Dom}_{\mathbf{Obj}}$ and $\mathfrak{Dom}^{\mathscr{M}}_{\mathbf{Ev}} \in \{\mathcal{E} | \forall n' \in \{1, \ldots, n\}[\mathcal{E} \cup [\![\alpha_{n'}]\!]^{\mathfrak{M}} \neq \{\}]\}$. However, if two sets of events from the denotations of the acquired sentences $\langle [\![\alpha_1]\!]^{\mathfrak{M}}, \ldots, [\![\alpha_n]\!]^{\mathfrak{M}} \rangle$ fully contradict, then it should be that $K = \{\}$. Two sets $\mathcal{E}_1$ and $\mathcal{E}_2$ fully contradict if there is no $\langle e_1, e_2 \rangle \in \mathcal{E}_1 \times \mathcal{E}_2$ such that e_1 and e_2 are not contradictory. A useful notion of contradictory events will be available once negative events have been introduced in chapter 4 and fully formalized in chapter 5. In principle, two events are contradictory if they either are identically specified except for their polarity, or if there is lexical/world knowledge (meaning postulates) which declares them to be contradictory.

An **update** is the process of adding a new expression α_{n+1} to I^n. Once α_{n+1} is added, the language-user can construct K^{n+1} from I^{n+1}. If $K' = \{\}$ (while the pre-update K was not), then the language-user will (under normal circumstances) reject α_{n+1} (disbelief) or remove any other α_i which contradicts α_{n+1} (persuasion).

This update procedure and the construction of construable mental models from denotations in the abstract model describe how what we know and what we learn in a discourse are related. It provides a way of dealing with (dis)belief, persuasion, and a secondary definition of falsity and truth.

2.2.5 Appendix: Permutation and Drop

I remains to be shown that for any two Subset Operators A, B, (36) holds, as much as for conjunctively added predicates over individuals (here: events) $\mathbf{a}, \mathbf{b}$, the inferences in (37) hold in a predicate-logical setting. E is a meta-variable ranging over sets (of events), e is a variable ranging over events.

(36) a. $A(B(E)) \Leftrightarrow B(A(E))$ [Permutation]

b. $A(E) \Rightarrow E$ [Drop]

(37) a. $\exists e.\mathbf{a}(e) \wedge \mathbf{b}(e) \leftrightarrow \exists e.\mathbf{b}(e) \wedge \mathbf{a}(e)$ [Permutation]

b. $\exists e.\mathbf{a}(e) \wedge \mathbf{b}(e) \rightarrow \exists e.\mathbf{a}(e)$ [Drop]

I assume standard Zermelo-Fraenkel set theory (as introduced in Stoll 1961, among many others).

Proof. **(ad 36a)** We need to prove that in every model $[\![A(B(E))]\!] = [\![B(A(E))]\!]$. The proof relies on the fact that by definition both $[\![A(E)]\!] \subseteq [\![(E)]\!]$ and $[\![B(E)]\!] \subseteq [\![(E)]\!]$. Thus, there exist possibly empty sets A' and B' such that (for $[\![E]\!] = E'$): $[\![A(E)]\!] = A' \cap E'$ and $[\![B(E)]\!] = B' \cap E'$. Thus, $[\![A(B(E))]\!] = A' \cap (B' \cap E')$ and $[\![B(A(E))]\!] = B' \cap (A' \cap E')$. Since intersection is commutative, (36) holds in every model where A and B are defined as Subset Operators. □

Proof. **(ad 36b)** What the slightly ill-formed (36b) is supposed to mean is that in any model where $[\![A(E)]\!]$ is non empty, $[\![E]\!]$ is also non-empty. This falls out because $[\![A(E)]\!] \subseteq [\![E]\!]$ by definition, and because of the definitions of set membership and subset-or-equal. □

Chapter 3

Quantification

The goal of this chapter is to incorporate quantification into the semantic theory sketched in the last chapter. Interpreting simple referring expressions as thematic operators (which have the only function of reducing sets of events) was easy, since with a single individual playing a simple role in one event, the set of events let through by the operator could easily be constructed. In this section, I will describe how quantificational NPs can be modeled as operators in event domains. The output of these operators will be sets of sets which (if not empty) represent all possible readings a sentence can have in a model after the respective NP has been integrated. This and the following two chapters are concerned only with fully resolved semantic analyses, and I completely ignore the problem of how such analyses are obtained from natural language expressions. In chapter 7, a small-scale implementation of derivations from proper English sentences will be given.[1]

In section 3.1, I review more arguments for a maximal individuation of events and against single thematic roles filled by multiple objects (section 3.1.1). The resulting axioms against multiple roles will be essential to motivate the mapping of object quantification onto event structures. Finally, section 3.1.2 gives the semi-formal definition of quantificational Generalized Operators as collectors of union sets from their input sets.

A formal spell-out of the whole system can be found in chapter 5, only after the introduction of negation in chapter 4. chapter 5 spells out the theory under the assumption of abstract models and discourse-level interpretation, whereas this chapter stays within a standard model-theoretic terminology since readers are probably more accustomed to the classical view.

[1] I call the mechanism introduced here *simple quantification* because cumulativity and distributivity are not yet accounted for. They are the subject of chapter 6.

3.1 The Generalized Operator Approach with Quantification

3.1.1 Against Multiple Roles

After this preliminary clarification, let me now turn to the problems of quantification in an Event Semantics. From the URR it follows that a sentence like (1a) cannot have the simple Neo-Davidsonian interpretation in (1b).

(1) a. Every frog loves Miss Piggy.

b. $\exists e.\forall x.\textbf{frog}(x) \wedge \textbf{love}(e) \wedge Agent(e) = x \wedge Theme(e) = \textbf{piggy}$

(2) a. No girl walked. (Landman, 2000:74)

b. $\exists e.\neg\exists x.\textbf{girl}(x) \wedge \textbf{love}(e) \wedge Agent(e) = x$

c. $\exists e \in \textbf{walk}.\neg\exists x \in \textbf{girl}.Agent(e) = x$

The analysis would give us that *there is **one** event such that every frog is its agent and Miss Piggy is the theme*. Intuitively, this is odd, but if we did not assume the URR, allowing multiple agents, themes, etc., then we could argue that the problem vanishes. Similar and even worse are cases which are independent of the URR are those involving (informally speaking) negative quantifiers like *no* in (2), where Landman's variant of the analysis with restricted quantification is given in (2c) as an alternative rendering. The analysis reads roughly: *There is a walking event and it is not the case that there was a girl as its agent.* Such cases could be dealt with by assuming that either the event variable is bound right after it enters the logical form (Parsons 1990) or by assuming that the scoping mechanism is constructed such that all noun phrase quantification is applied above the binding of the event variable. The last solution is the one advocated in Landman (2000), where a Quantifying-In mechanism for NPs and EC for the event variable is used, and the store is discharged strictly after EC. This gives us the analyses in (3) for the above sentences, respectively.

(3) a. $\forall x.\exists e.\textbf{frog}(x) \wedge \textbf{love}(e) \wedge Agent(e) = x \wedge Theme(e) = \textbf{piggy}$

b. $\neg\exists x.\exists e.\textbf{girl}(x) \wedge \textbf{love}(e) \wedge Agent(e) = x$

Either we say that the URR forces quantified NPs to scope over the existential binding of the event variable, and we automatically get the right logical representations. Or the URR could be disposed of and replaced by a technical requirement on the scoping mechanism. However, the problem is not solved this easily. The URR must also be active in cases with or without quantification and including modifiers containing anaphoric pronouns like (4) and (5), taken from Landman (2000:75).

(4) a. Mary kissed John and Bill on their lips.

b. $\exists e.\mathbf{kiss}(e) \wedge Agent(e) = \mathbf{mary} \wedge Theme(e) = \mathbf{john} \wedge Theme(e) = \mathbf{bill} \wedge$ $\mathbf{location}(e) = \iota\mathbf{lipsOf}(\mathbf{john}) \wedge \mathbf{location}(e) = \iota\mathbf{lipsOf}(\mathbf{bill})$

(5) a. Mary kissed every boy on his lips.

b. $\exists e.\forall x.\mathbf{kiss}(e) \wedge Agent(e) = \mathbf{mary} \wedge Theme(e) = x \wedge \mathbf{location}(e) = \iota\mathbf{lipsOf}(x)$

If John and Bill are in the model and are boys, in both cases it will follow that Mary kissed John on Bill's lips. With (5), one could even conclude logically that Mary kissed every boy on every boy's lips. At least for distributive readings, these examples exclude an analysis in terms of what Landman calls multiple roles. In (6), the case is extended to cases of collective readings, which also cannot be formalized in terms of multiple roles, because the logical inference in (b) is not at all desirable (since we could conclude "*Bill meets.*").

(6) a. John and Bill meet.

b. $\exists e.\mathbf{meet} \wedge Agent(e) = \mathbf{john} \wedge Agent(e) = \mathbf{bill} \vdash \exists e.\mathbf{meet}(e) \wedge Agent(e) = \mathbf{john}$

One last thing to mention on the subject of multiple roles are adjunct thematic roles (Landman, 2000:81). For certain agentive roles, *with* adjuncts can introduce what seems like an additional agent as in (7) (cited from Landman) with the putative multiple role analysis in (7b).

(7) a. Fred wrote a paper with Nirit.

b. $\exists e.\exists x.\mathbf{write}(e) \wedge Agent(e) = \mathbf{fred} \wedge Agent(e) = \mathbf{nirit} \wedge \mathbf{paper}(x)$

c. $\exists e.\exists x.\mathbf{write}(e) \wedge Agent(e) = \mathbf{fred} \wedge AdjunctAgent(e) = \mathbf{nirit} \wedge \mathbf{paper}(x)$

(8) Nirit wrote a paper with Fred.

(9) Carefully, Fred wrote a paper with Nirit.

However, (7) clearly differs in meaning from (8). Also, passive agentive adverbials associate only with the proper agent, *Fred* in (9). The only reasonable conclusion is that the analysis should be (7c), the *with* adjunct introducing an extra quasi-agent or adjunct-agent role (in accordance with Dowty 1991).

In this section, I have recapitulated some arguments against cases where one thematic parameter of an event is instantiated with multiple objects. This completes the argumentation for a maximal individuation of events by linguistically specifiable parameters. If two event expressions respectively allow and disallow some argument specification or some adjunct specification, they must be considered two distinct events. This view of events binds them tightly to a linguistic, in a sense abstract ontology, and it separates them from what might be perceived as "one event" informally in an arbitrary

ontology.
This has direct implications for the project of projecting object quantification onto event structures, since it was shown that the sentence *"Everyone walks."* cannot be assigned an analysis which says that there was one walking event with *everyone being the walker*. The next sections therefore introduce a more elaborate concept of object quantification in event structures.

3.1.2 Simple Quantification

3.1.2.1 An Attempt to Keep Up the Filtering Approach

We have now further strengthened the validity of the URR and can safely assume that for every event, only one object should fill a specified role parameter. Let us turn to a simple case of quantification as in (10) to see how this affects the construction of a GOA solution.

(10) Every frog loves Miss Piggy.

The VP *loves Miss Piggy* will be rendered as in the last chapter: The constant corresponding to *loves* denotes the set of loving events, and the thematic operator corresponding to *Miss Piggy* reduces this set to the set of events where Miss Piggy plays the internal role. By the URR, we are not allowed to simply assume that the thematic operator corresponding to *every frog* selects the subset from the VP denotation such that every man is the agent in each of the events which are not filtered by the operator. An obvious solution, however, is to raise the type of both the verb denotation and the NP/adjunct denotations.
Since in the presently defended version of Event Semantics, the verb (or rather VP) denotes not properties of individuals but properties of events, we cannot simply resort to generalized quantification over objects. Furthermore, this section shows that NP-quantification in the event domain is not trivially achieved by having quantifiers narrow down the domain of events. However, the following should be considered: If the mapping between events and their role-bearing objects is as defined above (with the URR and the other principles in place), then every traditional quantificational structure of objects involved in predicate relations must be mappable to a structure of events. This must be the case because the number of objects involved in an event is fixed by the lexical definition of the event predicate (RS and URR), and that the number of objects involved in the event is exactly the arity of the corresponding classical (non-event) predicate (cf. RS). Thus every classical non-event reading of a sentence containing quantification imposes constraints on the possible number of objects involved,

and these constraints are uniquely linked to the number of events in the corresponding event-based interpretation.

I will now assume that the core verbal predicate (e.g., **love**) denotes the power set of events which have the respective property, so that **love** denotes the power set of loving events. A thematic operator is formed out of the NP denotation under role assignment, but what is the raw denotation of the NP before a theta role is assigned?[2] The NP denotation can be taken as a subset of the power set of the set denoted by the noun. By way of example, in any model $[\![\textbf{frog}]\!]$ is the power set of the set of all frogs. Adding the determiner *some* to that noun amounts to filtering those sets which do not contain at least one frog. In the case of *some*, this means that only the empty set (contained in any power set) will be filtered. Simply speaking, $[\![\textbf{some}(\textbf{frog})]\!]$ will be just the unfiltered power set of frogs because every set of frogs trivially contains at least one frog.[3]

Under assignment of a role r (i.e., when the NP is consumed by a thematic operator), this NP denotation is used to construct a filter on the set of sets contributed by the core verb. We use the definitions in (11) of r-set (role bearer set).

(11) **Role Bearer Set** (r-set)
The role bearer set (or r-set) for a role r and a set of events E be the set $E^r = \{o | \exists e \in E . r(e) = o\}$ (i.e., the set of all objects o such that for some $e \in E$, it is the case that $r(e) = o$).

Assume now the operators were defined as filters on sets such that only those sets E of events pass the filter for which there is a set of objects O from the NP denotation such $O = E^r$.

A simple example will probably render the idea more intuitively. Be there a sample model where there are only two frogs, Kermit (k) and Ischariot (i), and there are two walking events e_1 and e_2 of which Kermit and Ischariot, respectively, are the agents. It does not matter what other information the model encodes, as long as the set of frogs is restricted to the two aforementioned ones.

The core verb **walk** denotes the power set of walkers, which is the following set of sets: $\wp\{e_1, e_2\} - \{\} = \{\{e_1\}, \{e_2\}, \{e_1, e_2\}\}$.

An NP like *some frog* denotes, by the definition given above, the power set of the set of frogs, which is in this sample model: $\wp\{k, i\} - \{\} = \{\{k\}, \{i\}, \{k, i\}\}$. The NP *every frog* (in this small model obviously coinciding with *two frogs*) denotes the set of those sets of frogs which contain every frog: $\{\{k, i\}\}$.

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[2] I call this denotation the *base quantifier*.

[3] Later, in chapter 5, an equivalent division of labor is used for technical reasons. There, **frog** is just a set of frogs, and the quantifier generates the relevant set of sets from that set.

To get to the events denoted by "*Every frog walks.*", under the current experimental definition we have to take the core verb denotation and filter out all sets E for which there is no set O in the denotation of *every frog* such that the agents of all events in E form O (i.e., for E^{ag} it holds that $O = E^{ag}$).[4] This procedure leaves us with $\{\{e_1, e_2\}\}$ since for the set $\{e_1\}$, the agent set is $\{k\}$, which is not in the denotation of *every frog* (and similarly for $\{e_2\}$). In the case of "*Some frog walks.*", the sentence ends up denoting $\{\{e_1\}, \{e_2\}, \{e_1, e_2\}\}$.

In case only Kermit walks (but Ischariot still exists), the core verb denotes $\{\{e_1\}\}$. This will lead to "*Every frog walks.*" denoting the empty set, because the agent set of the only set in the denotation of *walks* is $\{k\}$ in this case. This set, however, is not in $\{\{k, i\}\}$ (the denotation of *every frog*). If a sentence denotes the empty set in a model, it is typically false.

These results seem at first sight to be highly desirable, because the final sentence denotation contains all possible sets of events which, if factual, render the sentence true. To show that "*Every frog walks.*" always entails "*Some frog walks.*", it would have to be shown that whenever the first is defined in a model (i.e., it denotes a non-empty set), then the second one must also be defined. Cf. chapter 5 for such technical aspects.

However, we can already anticipate a problem. By successively filtering one set of sets of events in the application of every quantifier, we might risk running out of events or ending up with sets of the wrong cardinality. The next section discusses cases where exactly this happens, leading to a rejection of the filtering approach.

3.1.2.2 A Problem with the Simple Reconstruction

The disadvantage of the approach described in the last section is that it does not work generally. At least when there is more than one quantifier, a serious problem arises. There are both false positives (sentences made true although they should be false) and false negatives (sentences incorrectly diagnosed to be false). First, take sentence (12), a case with multiple quantifiers, where the approach apparently works in certain models.

(12) Every frog loves every pig.

[4] Since the events in E are all distinct, role bearers could be assigned to several events without harming the interpretation process. Agent sets can thus be smaller than the event set from which they are formed. The Generalized Operator only makes sure that the right number/portion of individuals from the noun denotation is involved in the right kind of events. Such situations arise quite often, but are probably most clearly grasped with sentences like "*Kermit pushed all buttons at once.*" or with temporally distributed events of the same type and with the same role player.

Assume there are two frogs, Kermit and Ischariot, and two pigs, Piggy and Bathsheba, and indeed both frogs love both pigs. In this case, *loves every pig* denotes the set given in (13), i.e., all configurations of events which contain at least one loving event for each pig as theme.

The relevant events of the model are schematically given in figure 3.1 on the left-hand side. The lines represent the loving events with the individual on the left as agent and the one on the right as theme. The presentation is informal and should by no means been taken to say that events are functions from individuals to individuals or similar.

(13) $\{\{e_1, e_2\}, \{e_1, e_4\}, \{e_3, e_2\}, \{e_3, e_4\}, \{e_1, e_3, e_2\}, \{e_1, e_3, e_4\}, \{e_2, e_2, e_4\}, \{e_1, e_2, e_3, e_4\}\}$

(14) $\{k\}, \{k, i\}, \{k, i\}, \{i\}, \{k, i\}, \{k, i\}, \{k, i\}, \{k, i\}$

The agent sets corresponding to these events are given in the list (14),[5] and as it happens there are many which are identical to the only set in the interpretation of *every frog*, $\{k, i\}$. The sentence, as expected, is true in the model.

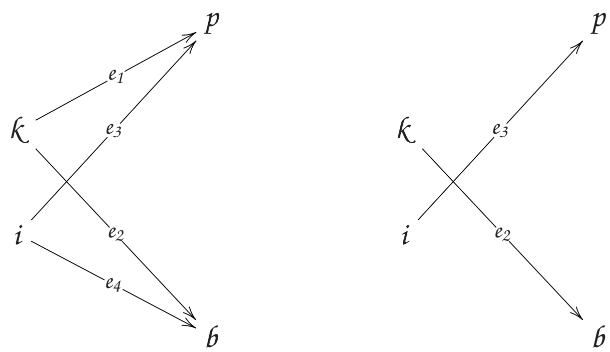

Figure 3.1: Two sample models for (12)

However, if we modify the model and take away the events e_1 and e_4, *loves every pig* denotes $\{\{e_2, e_3\}\}$ (cf. right-hand side of figure 3.1) the agent set of which is also $\{k, i\}$. This means that we incorrectly make (12) true in the withered model. What this interpretation procedure calculates is whether every pig is loved by a frog and every frog loves some pig This is a clear case of a false positive.

Consider now (15), distinguished only by the selection of a cardinal quantifier for the theme NP.

[5] The notion of a set of *r-sets* would be useless here, since by the axiomatization of set theory, two *r*-sets containing the same objects would be identical, and thus the set of such *r*-sets would loose the transparency of which *r*-set goes with which event set by eliminating multiple occurrences of the same *r*-set. Therefore, lists are used.

(15) Every frog loves two pigs.

Assume we have two additional pigs in the sample model for the evaluation of (15), Sarah and Judith. Kermit loves Piggy and Bathsheba (events e_1 and e_2), but Ischariot loves Sarah and Judith (events e_3 and e_4). Again, I provide a straightforward visualization of the events and their role bearers in figure 3.2.

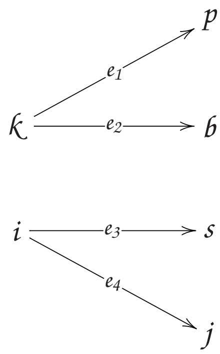

Figure 3.2: A sample model $\mathcal{M}$ for (15)

Under such circumstances, *loves two pigs*, derived with the procedure described above, denotes the sets of loving events such that their theme set contains two pigs. I present these in a more compact form in (16), omiting the first level of set brackets and commas and replacing all further levels of set brackets by simple brackets, i.e. $\{\{e_1\},\{e_1,e_2\}\}$ is rendered in compact form as $(e_1, e_1 e_2)$. I also use the shorthand notation $\mathbf{NP}^{\mathbf{Role}}$ for $\mathbf{Role}(\mathbf{NP})$

(16) a. $[\![(\mathbf{two}(\mathbf{pigs}))^{\mathbf{Int_1}}(\mathbf{love})]\!]^{\mathcal{M}} = (e_1 e_2,\ e_2 e_3,\ e_3 e_4,\ e_1 e_3,\ e_2 e_4,\ e_1 e_4)$

b. list of E^{ag} for all $E \in [\![(\mathbf{two}(\mathbf{pigs}))^{\mathbf{Int_1}}(\mathbf{love})]\!]^{\mathcal{M}}$: k, ki, i, ki, ki, ki

Notice that, for purposes of simplicity, the interpretation is more that for *exactly two* rather than that for *two*.

Since in this model all pigs are loved and there are only two of them, the VP denotation is exactly that subset of the power set of the pigs such that the cardinality of each contained set is two. The sentence will now turn out as true, because there are agent sets (given in compact notation also in (16)) which are equal to the only set in the denotation of *every frog*. But this means that the sentence is true because there is, among others, the set of events $e_2 e_3$. This, in turn, means that the sentence is true because Kermit loves Bathsheba and Ischariot loves Sarah. Even if this approach should turn out to give the right truth conditions under all circumstances, it would be completely unintuitive. The resulting sets definitely do not model the possible circumstances under

which a sentence can be true.
But it is actually only by accident (by a biased choice of conditions in the model) that the sentence turns out true. Assume a model where there are the frogs Kermit, Ischariot, Samuel, and the three pigs Piggy, Bathsheba, and Judith. Kermit loves Piggy and Bathsheba (e_1, e_2), Ischariot Bathsheba and Judith (e_3, e_4), and Samuel loves Bathsheba and Judith (e_5, e_6). The model is visualized in figure 3.3.

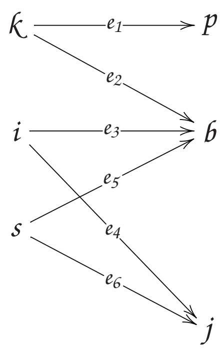

Figure 3.3: Another sample model $\mathscr{M}''$ for (16)

This gives us the event sets in (17) as the VP denotation.

(17) $[\![\textbf{two}(\textbf{pigs})^{Int_1}(\textbf{love})]\!]^{\mathscr{M}'} = (e_1e_2, e_1e_5, e_1e_4, e_1e_6, e_3e_2, e_3e_5, e_3e_4, e_3e_6, e_2e_4, e_2e_6, e_5e_4, e_5e_6, \ldots)$

I generally adopt the habit of omitting those sets (after quantifier application) which are not relevant, like larger sets such as $\{e_1, e_1, e_5\}$ in (17). This is indicated by '. . . '.
We do not go into a detailed checking procedure. As soon as there are as many or more lovers than loved ones, the cardinality of the resulting sets after the introduction of the theme NP isn't even high enough to provide an agent set sufficiently large to make the sentence true. Put differently, the VP denotation contains only event sets with cardinality *two*, and we have *three* frogs for which it is true that they love two pigs. The sentence would erroneously evaluate as false.
The problem is simply that whenever a quantificational Genralized Operator has been applied, the original domain (a power set of some set of events) has been very much reduced, and the result of the filtering operation does not let through enough set objects for subsequently applied Generalized Operators. I immediately suggest a solution in the next section.

3.1.2.3 Quantifiers Collect Sets of Events

The answer lies in a redefinition of the mapping performed by the quantificational Generalized Operator (QGO). The mapping can be easily constructed by meditating further about what it means to load quantification over objects into an event structure. The sets in the denotation of the base nominal quantifier (exact definition cf. below) are the sets of objects every single one of which must be involved as the *r*-bearer in the events of one of the input event sets. In other words, for *every single object* in some set in the base quantifier denotation, there must be *one event set* in the input such that the object is the *r*-bearer of all events in that set. The union of events corresponding to all objects in one such set from the base quantifier form one set in the output of the QGO.[6]
Before I proceed to the examples, some definitions are necessary. I call the **base (nominal) quantifier** the denotation of the noun with the determiner before a theta role has been assigned. In (18) and (19), I give some definitions of determiners which create base quantifiers. *Card* is a function from sets to integers, giving the cardinality of the set. Proper names are raised to the type of quantifiers in (19c), similar to the treatment in Montague (1973b).

(18) a. $[\![\textbf{frog}]\!]$ =the set of frogs

b. $[\![\textbf{pig}]\!]$ =the set of pigs, etc.

(19) a. $[\![\textbf{some}_{\textbf{sg}}(\alpha)]\!] = \{O \in \wp[\![\alpha]\!] | Card(O) \geq 1\}$

b. $[\![\textbf{every}(\alpha)]\!] = \{O \in \wp[\![\alpha]\!] | O = [\![\alpha]\!]\}$

c. $[\![^{\textbf{Q}}\textbf{piggy}]\!] = \{\{[\![\textbf{piggy}]\!]\}\}$

Under theta assignment, the NP turns into an operator for the role *role* on sets of sets of events. Before giving a definition of QGOs, let me turn to an example to render the idea clear. I use the model given in figure 3.3. Take (15) in its linear scope analysis in a distributive reading, i.e. we apply the NP *two pigs* distributively first. The QGO corresponding to the NP *two pigs* is constructed from the base quantifier which is rendered in (20a). It contains all sets which contain two pigs.

(20) a. $[\![\textbf{two}(\textbf{pig})]\!]^{\mathscr{M}''} = (pb, pj, bj, \dots)$

b. $[\![\textbf{Int}_\textbf{1}(\textbf{two}(\textbf{pig}))(\textbf{love})]\!]^{\mathscr{M}''} =$
$(e_1e_2, e_1e_3, e_1e_5, e_1e_4, e_1e_6, e_2e_4, e_2e_6, e_3e_4, e_3e_6, e_6e_4, e_5e_6, \dots)$

We start with the power set of loving events $\wp(e_1, .., e_6)$. The QGO $[\![(\textbf{two}(\textbf{pig}))^{\textbf{Int}_\textbf{1}}]\!]^{\mathscr{M}''}$ collects for each of the sets S^o in $[\![\textbf{two}(\textbf{pig})]\!]^{\mathscr{M}''}$ all sets S^e which fulfill the following requirement: S^e contains for each object *o* in S^o the events from one set in $[\![\textbf{love}]\!]^{\mathscr{M}''}$

[6] This chapter deals with distributive readings. In chapter 6, collective readings will be modeled.

such that *o* is the theme of the events in this set.
The result is given in (20b), and a visualization in figure 3.4. It shows which sets of objects are responsible for which sets of events appearing in the output.[7] In the next

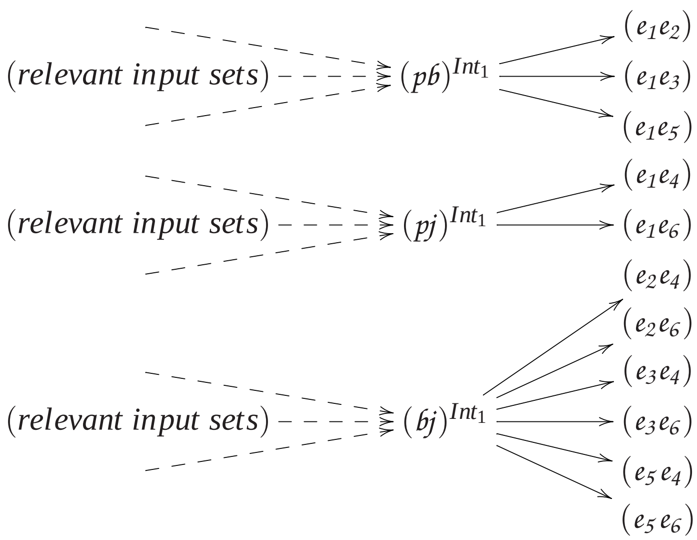

Figure 3.4: The construction of $[\![(\mathbf{two}(\mathbf{pig}))^{Int_1}(\mathbf{love})]\!]^{\mathscr{M}''}$.

step, the application of $[\![(\mathbf{every}(\mathbf{frog}))^{Ext}]\!]^{\mathscr{M}''}$, (20b) serves as the input. The base quantifier $[\![\mathbf{every}(\mathbf{frog})]\!]^{\mathscr{M}''}$ is given in (21).

(21) $[\![\mathbf{every}(\mathbf{frog})]\!]^{\mathscr{M}''} = (\mathcal{k}is)$

There is only one set contained, so we can maximally get one set in the output of the QGO $[\![(\mathbf{every}(\mathbf{frog}))^{\mathbf{Ext}}]\!]^{\mathscr{M}''}$. To see whether this one set exists, we must check for each of $\mathcal{k}$, i, s, whether we find a set in (20b) such that he is the agent of all events in that set. The union of those sets would be in the output. As visualized in figure 3.5, there is such a set, namely $(e_1, .., e_6)$.
Notice that the inverse scope reading denotes the empty set (the sentence is false under that interpretation), as expected. We first collect all possible sets of events where every frog is the agent of a single event in the set. In the next step, we take these as the input and apply the QGO corresponding to *two pigs* as theme. This means that we have to collect a union of two sets from the input such that either Piggy and Bathsheba, Piggy and Judith or Bathsheba and Judith are their unique themes. Since we only find

[7] Notice that I abbreviate the denotations here to exclude irrelevant sets. As given in figure figure 3.4 and (20b), sets like $(e_1e_2e_3)$ are missing. However, the minimal conditions used for the calculation here will always be satisfied, and all other sets are merely redundant and never contradict the minimal sets. Therefore I only work with the minimal sets.

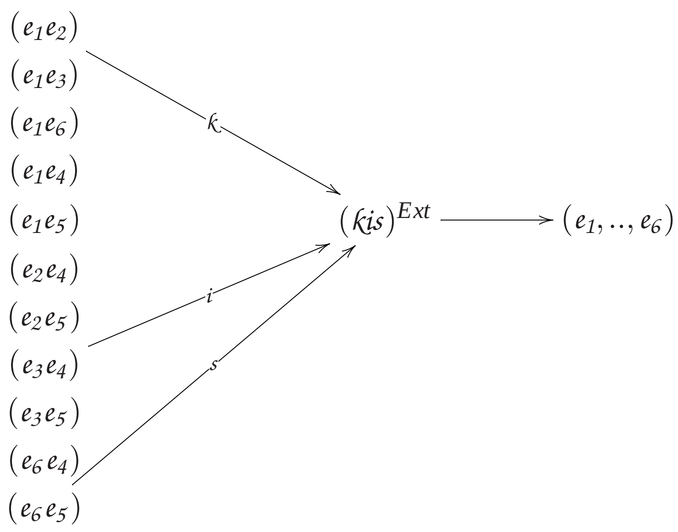

Figure 3.5: The final step in the calculation of the denotation of $[\![(\mathbf{every}(\mathbf{frog}))^{\mathbf{Ext}}((\mathbf{two}(\mathbf{pig}))^{Int_1}(\mathbf{love}))]\!]^{\mathscr{M}''}$.

a relevant set for Bathsheba in the input (she is the only one loved by all frogs), the sentence denotation remains empty, and the sentence is false (cf. figure figure 3.6).

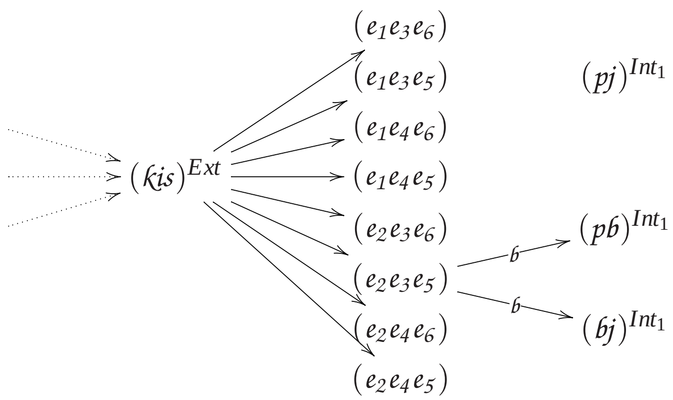

Figure 3.6: The construction of $[\![(\mathbf{two}(\mathbf{pig}))^{Int_1}((\mathbf{every}(\mathbf{frog}))^{Ext}(\mathbf{love}))]\!]^{\mathscr{M}''}$.

This concludes the demonstration of quantification in GOA. A formalization is found in chapter 5.

Chapter 4

Negation, Alternatives, and High Scope

The treatment of negation here will depend on my view of sentence denotation as constraints on updates of mental models and its pragmatic impact laid out in section 2.2.3. In that section, I argued that the events denoted by a sentence are those that the hearer can take to be positively assumable (with one minimal example in each constructible model). With the version of quantification of the framework introduced in the last chapter, the denotation changes from simple sets of events to sets of such sets, but still these sets can be taken to be positively assumable, also with one minimal example. A sentence is false in an existing model if no set of events in the sentence denotation is subset or equal to the set of events in the model. Falsity is thus diagnosed as the impossibility to integrate the constraint imposed by one sentence into the existing set of constraints. The intersection of the models-as-constraints would be empty.

We really do nothing but push the *existential binding of the event variable* (classical formulation) out of the semantics. As already said, there is a similarity to a DRT treatment of indefinites as providing free variables (cf. also a suggestion in Partee, 2007:4 for a DRT-like treatment of the event variable). The only substantial difference to classical Event Semantics is that because we project quantification over objects into event structures, we need slightly more complex set-theoretic objects as denotations of such open event expressions.

The events encountered so far have fairly traditional properties (also called parameters), like participant/role parameters (*r*-parameters), manner, various time parameters, intensity, and what not. In this chapter, I introduce the only parameter which stands out from traditional sets of parameters assumed for events: the polarity parameter. In traditional Event Semantics one speaks of *existing and non-existing events*, mainly because in those classical approaches the event variable gets existentially bound at some point to yield a closed formula of first-order predicate logic. To completely dispose of existential binding of event variables, one must try to also eliminate negated existential statements about events. This is the reason for the introduction of the polarity parameter.

The "negation of an event" is modelled by introducing events which have negative polarity in the models, much as negative information in Infon/Situation Semantics (e.g., Barwise and Perry 1983, Barwise 1989, and my primary source Devlin 1991) is modelled by infons carrying a 0 polarity marker. The model theoretic rationale is not too exotic or unintuitive as it might seem at first sight, however. After all, events as presented here are the minimal units which state *what the hearer should assume as being the case and not being the case*. Thus, the existence of an event with negative polarity encodes the fact that whichever other parameters it encodes are not manifested in a real event. Thus, events with positive and negative polarities can be restricted in occurrence to an abstract mental ontology, and we need not worry about negative events implausibly turning up in the real world. Anyway, I will keep the habit of trying to stay within conventional model-theoretic argumentations as far as possible, but it should always be kept in mind that a proper formalization (chapter 5) will be less standard.

As an ontological reconstruction of the Law of Excluded Middle, we then need to add the requirement that either a certain event or its negative mirror exists in fully specified models. The reconstruction of the Law of Contradiction will be mirrored by requiring that never both a positive event and its otherwise identical negative mirror exist.

Although it is not implausible in the sense just described, the adoption of a polarity parameter for events clearly touches upon the ontological status of events in a significant way, making them look even less like real-world event as they already do after the total individuation by parameters as argued for in the last chapter and in section 3.1.1. However, postulating a polarity parameter seems to me to be entirely within the spirit of an Event Semantics with total individuation.

4.1 Negation and Event Polarity

4.1.1 Event Polarity

This section introduces a notion of event polarity under the assumption that we have ordinary models against which the truth of a sentence can be evaluated. Since it will become obvious that this leads to technical complications, a revised version in the spirit of section 2.2.3 and section 2.2.4 will then be given in section 4.1.2.

The philosophical and logical discussions surrounding negation from Aristotle to Russell and contemporary linguists could fill whole libraries. Even a cursory account of the history of negation fills such stately an erudite volumes as Horn (2001), of which I am going to discuss at least a little bit soon.

However, in logics as applied to natural language semantics, negation is virtually always implemented by means of the truth-functional negation operator $\neg$. For sentential (boolean) negation, this is trivially adequate, and for property negation, a simple pointwise definition based on boolean negation does the trick. A definition of property negation is demonstrated in (1), taken from Carpenter (1997:91).

(1) $\neg P \stackrel{def}{=} \lambda x.\neg P(x)$

In standard Event Semantics, we can assume a negated existential quantifier over the event variable, such as $\neg\exists e.\phi$ (usually with at least one occurrence of e in ϕ). This, if true, excludes all events for which ϕ does not hold from models compatible with this sentence. It makes the sentence false in a concrete model if there is at least one event for which ϕ holds. Similar pointwise definitions could take care of non-sentential negation, down to negation of nominal predicates (such as the English nominal prefix *non*-).

As far as I can see, there is one semantic framework under which negation is modelled differently, namely Situation Semantics. My proposals owes a lot to Situation Semantics as an inspirational source, although maybe less on the technical side.

In Infon/Situation Semantics (Barwise and Perry 1983 etc. as cited above), infons are taken (informally speaking) to be the minimal building blocks of information. They are essentially tuples of relations (relation-objects) and objects which fill argument places of the relation. Infons *describe* situations, and in turn situations *support* (or do not support) infons. *Parameters* are open places within a given infon, which must be linked to concrete objects. Parameters are sorted corresponding to the types in the ontology of the framework (types are REL^n for n-player relations, IND for individuals, TIM for times, etc.).

Most importantly, every infon is straightforwardly specified for a *polarity* of 0 or 1. As also discussed by Devlin (1991), there are certain similarities between situations and Kimian events (Kim 1976) as property exemplifications.[1] Also in standard Event Semantics with full event individuation by parameters (as presented here, especially in

[1] I think the parallel could also be made between infons and Kimian events, but lack the space to discuss the implications. Since I am not presently concerned with the cognitive and computational questions which are much under focus in Situation Semantics, and since the strength of Situation Semantics lies in the modelling of context-dependence (which is also not required for this study), I will not elaborate further on similarities and dissimilarities with Situation Semantics past this paragraph. However, I think that a more thorough investigation of the parallels could eventually be of some profit, mostly to enrich the present theory with solutions to problems of context-dependency.

chapter 2), where events have no easily graspable ontological status outside the semantics of natural language, events are much better understood as abstract bits of information about configurations of objects or the relations between them. A single event compresses all information relevant to a specified collection of objects, in specified places, at a specified time, etc., with a certain primary action, process, etc. going on between them, etc. The main difference to infons as I see it is that the compressed object (the event) itself can be assigned properties directly which otherwise would have to be encoded as more complex relations between objects, times, etc. Parameters instantiated by adverbials like *manner* or *intensity* are prime examples. This is possible because the abstract events we are dealing with are explicitly **not** infons, but they still have physical properties like temporal stretch, spatial coordinates, manners of execution, etc. An event as constructed here might be the closest thing to an infon for people who prefer working with (albeit abstract) ontological objects and a more or less traditional model theory. Put differently, although events as presented here are very similar to infons, infons are not model-theoretic entities in the same manner as events.

Where does all this lead us with respect to negation? I propose that it backs up the postulation of events with a polarity parameter. Such a parameter encodes whether an event is factual or not (in a secondary, more "realistic" sense). A classical model with event polarities would therefore have to contain for every possible permutation of event parameters (except polarity) either the positive or the negative event. Despite the involvement of the word *possible* here, the notion of possible event is a completely extensional notion, and possible events can easily be calculated by the following line of reasoning. Language conceptualizes the individuals (objects and events) of the world by providing linguistic expressions which allow the language-user to discern between these individuals. Looking only at event individuals now, this means that the events we can possibly talk about are those discernible by linguistic expressions.

Imagine this scenario: If we have a language which only expresses two main parameters of events, **walk** and **talk**, two expressions referring to individuals (**kermit** and **scooter**), two manner expressions (**quickly** and **slowly**), two expressions about spatial locations in the universe (**onstage** and **backstage**), and no more than two points in time encoded by generalized operators $\mathbf{i_0}$ and $\mathbf{i_1}$. Whether the real world is actually as minimalist as this language suggests does not matter. As long as language-users reserve language to talk about Kermit or Scooter, on stage or backstage, talking or walking quickly or slowly on two famous historic occasions, our models are accordingly minimalistic. The reduced $\mathscr{L}_{\mathsf{GOA}}$ language of these language-users can generate a reduced array of maximally specific expressions, cf. (2) (in $\mathscr{L}_{\mathsf{GOA}}$ notation).

(2) a. $\mathbf{kermit}^{Ext}(\mathbf{quickly}(\mathbf{onstage}(\mathbf{i_0}(\mathbf{walk}))))$
b. $\mathbf{scooter}^{Ext}(\mathbf{quickly}(\mathbf{onstage}(\mathbf{i_0}(\mathbf{walk}))))$
c. $\mathbf{kermit}^{Ext}(\mathbf{slowly}(\mathbf{onstage}(\mathbf{i_0}(\mathbf{walk}))))$
d. $\mathbf{kermit}^{Ext}(\mathbf{quickly}(\mathbf{backstage}(\mathbf{i_0}(\mathbf{walk}))))$
e. $\mathbf{kermit}^{Ext}(\mathbf{quickly}(\mathbf{onstage}(\mathbf{i_1}(\mathbf{walk}))))$
f. $\mathbf{kermit}^{Ext}(\mathbf{quickly}(\mathbf{onstage}(\mathbf{i_0}(\mathbf{talk}))))$
g. ...

Since this language has no means of introducing recursion, the number of sentences will be finite, all in all we get a bounded number of possible maximally specific expressions, each denoting (under GOA) a singleton set of singleton sets of events. But even if there was an infinite number of compositionally derivable expressions (in a language with recursion), the maximum number of informative statements about the existence of events will always depend on the number of parameters expressible by the finite number of lexical entries.

Quantification introduces sets of events into the world of denotations, but the events in those sets must characteristically be expressible by simple statements without quantification (referring to single events), much as quantificational formulae in traditional semantics based on predicate logic can be expressed by conjunctions and disjunctions of non-quantificational formulae at least in finite models.

There is thus a possibly infinite but bounded set of events users of this language can talk about. These are the **possible events** maximally present in the models of that language. It is obvious that in a real world each of these possible events must be either factual or not, which is encoded straightforwardly by requiring that it exists with either positive polarity (i.e., it exists in the classical sense) or negative polarity (i.e., it does not exist under the classical model-theoretic view) in fully specified realistic mental models. For reasons to become clear soon, we must also posit that any operator (besides negation and maybe operators which can be decomposed involving negation) only and exclusively maps sets of events with polarity α to sets of events with polarity α.

Now, in how far are events with a polarity parameter conceptually justified and technically feasible? I think they are both if either (i) one is willing to give up a strictly correspondence-theoretic view of models for the interpretation of language, or (ii) if one is willing to accept that in the real world the *absence of some event* is actually rather the *existence of a negative event*.

I tend to opt for the first variant as can probably be guessed from what was said in previous chapters where I argued for a procedure which interprets sentences against an abstract informational ontology, then constructing a mental model of the world.[2] As I mentioned in section 2.2.3, an uninformed language-user who has not received any information is in a state where he must consider all possible events. That is, knowing that there are Miss Piggy and Kermit, that there are such things as hitting events, and that there was a point in time (say, Monday, August 7, 1978, 1:30 p.m.), he must at least entertain the possibility that there was a hitting event at that point in time with Miss Piggy as the agent and Kermit as the theme, or that there wasn't. Also, regardless of his beliefs, any language-user can talk both about the positive event and about the otherwise identical negative event, although if he does so affirmatively and in a single discourse, he will probably contradict himself. The fact remains that we can talk about non-factual events, and that we therefore absolutely need to have them in the ontology if we interpret sentences as (sets of) events.

This concludes the first introduction of the concept of positive and negative polarity for events, and I will now turn to questions of the technical implementation, starting with a more precise definition of negative events in the discourse-level update procedure introduced in section 2.2.4, including a recapitulation of the mutual exclusiveness of positive and negative events in section 4.1.2.

4.1.2 Truth, Falsity, and Updates

In the last section, I argued for the postulation of negative events, and I used a rather classical model-theoretic rethoric. A sentence was said to *denote positive or negative events*, and in a given model, these events were simply said to *exist or not to exist*, making the sentence *true or false*. This led to the postulation of a requirement that for every possible event there be either the positive or the negative event in the model. Event domains in such models would be multi-dimensionally dense, i.e., there would be very many exhaustively specified events.

To derive a notion of contradiction, I first need to discuss negative events and the update procedure (cf. section 2.2.4). For a start, as I said above, we talk about non-existing events all the time when we utter sentences with negation.[3] With some tweaking, we can even have explicit reference to negative events such as in (3).

(3) Kermit did explicitly *not* make the announcement, and it happened 23 minutes

[2] I clearly reject any interpretation of this as a Platonian regress to negation as a purely ontological matter, cf. Horn (2001:5f.). Events with a polarity parameter live in some kind of ontology, but an artificial one. I doubt that was what Plato (or any of his followers or successors) had in mind.

[3] Another good point in favor of negative events could be made by analyzing perception verbs which embed a negative clause as involving a negative event semantically.

into the show.

Furthermore, the non-existence of certain events must be encodable in our mental models, since there is a difference between not knowing about some event and knowing that some event didn't happen. Look at (4a) and its continuation (4b).

(4) a. A (to B): Kermit didn't make the announcement during this week's show.
   b. [the next day]
      C (to B): Did Kermit make the announcement during this week's show?
      B (to C): No, he didn't.

In this example, speaker B has learned the fact that something did not happen. In our parlance, he knows after hearing (4a) that of all possible events of Kermit making the announcement during the temporal instants covered by this week's show, only the negative events are factual. Thus, he can truth- and faithfully give a negative answer in (4b).

(5a)–(5b) are different, because in these examples we assume that B was not present at the show, hasn't watched it, and has not been informed about any events which went on during the show.

(5) a. [B has never been informed about Kermit and this week's show]
   b. C (to B): Did Kermit make the announcement during this week's show?
      B (to C): I have no idea.
   c. C (to B): Did Kermit make the announcement during this week's show?
      # B (to C): No, he didn't.

When confronted with the same question in (5b), he cannot give either a positive or a negative answer, because, again in our parlance, he does not know the polarity of the relevant events of Kermit making an announcement at the relevant time and place. In fact, answering as in (5c) is no responsible communicative behavior of B.

If B entertains a mental model where only positive knowledge is encoded, and the non-existence of some event makes a sentence describing this event false in a model, this mental model will look exactly the same in the situation in (4b) and (5b): The relevant events will just not be there. A solution within traditional model-theoretic semantics would have to resort to a more complex propositional store.

Within the current framework, the distinction can be derived in an elegant and simple fashion. First, we extend the notion of possible event to include all positive and their negative mirror events, i.e. the abstract domain $\mathfrak{Dom}_{\mathbf{Ev}}$ of the abstract model $\mathfrak{M}$ literally contains *all* possible events (including contradicting negative and positive ones).

Once again, possible events can be enumerated by calculating all permutations of parameters, *this time including polarity*.[4]

In this crowded and utterly contradictory model $\mathfrak{M}$ (which is shared by all language-users), sentences are first interpreted by $[\![\cdot]\!]^{\mathfrak{M}}$ as denoting subsets of this domain of events. A positive sentence denotes sets of sets of positive events, and negative sentences sets of sets of negative events. The definition of core verbs would have to specify that they always denote positive events to start with. I.e., no verb lexically contributes negative information.

Both positive and negative sentences are added to a discourse knowledge base, i.e., an update still consists of adding an utterance α_{n+1} to a previous discourse characterized by the sequence of sentences $I^n = \langle \alpha_1, .., \alpha_n \rangle$. Under the analysis of quantification from chapter 3, the generation of construable models from these sequences now involves sets of sets, i.e. the set K^{n+1} construable models $\mathscr{M} = \langle \mathbf{Dom}^{\mathscr{M}}_{\mathbf{Obj}}, \mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}} \rangle$ at the point where sentences $\alpha_1..\alpha_{n+1}$ have been uttered are those where $\mathbf{Dom}^{\mathscr{M}_i}_{\mathbf{Ev}} \in \{\mathcal{E} | (\exists \mathcal{E}_1 \in [\![\alpha_1]\!]^{\mathfrak{M}} [\mathcal{E}_1 \subseteq \mathcal{E}) \wedge \cdots \wedge (\exists \mathcal{E}_{n+1} \in [\![\alpha_{n+1}]\!]^{\mathfrak{M}} . \mathcal{E}_{n+1} \subseteq \mathcal{E}) \wedge (\neg \exists e, \bar{e} \in \mathcal{E} . \overline{p}(e) = \bar{e})]\}$, where $\overline{p}$ is the polarity inversion function.[5]

However, since we now allow positive and negative events to be denoted by a sentence, the definition of contradiction (failed update) becomes clearer. A sentence α_{n+1} must not be added iff it does not contain at least one set which can be unioned with the event domain of any of the models in K^n, i.e., it will contradict if $\forall E \in [\![\alpha_{n+1}]\!] . \exists e \in E . \forall \mathscr{M} \in K^n . \exists \bar{e} \in \mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}} . \overline{p}(e) = \bar{e}$.[6] This must be so, since by the definition of K^n as given, the addition of a fully contradictory sentence completely empties K^n, because the last conjunct in the definition makes sure only event domains which are completely free of contradiction are considered. A sentence is contradictory in itself if it always leads to update failure, such as *p and not p*. Falsity is thus the failure of a discourse update, and contradictions (in the logical sense) are sentences which inevitably lead to update failure.

The last conjunct in the definition of the update automatically requires that models do not contain even one pair of contradictory events. We express this once more explicitly in (6) as a condition on post-update models.[7]

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[4] The calculation is actually not that simple, as will be shown in chapter 5.

[5] Remember that $\mathfrak{Dom}_{\mathbf{Obj}}$ is fixed for all language-users and we do not have to give rules on how to construct it.

[6] A clash between positive and conflicting negative information is of course just the simplest case of contradiction. Others will be discussed later.

[7] Conflicting positive and negative information is of course not the only way in which contradiction can arise. More on this matter will be said in chapter 5.

(6) **Noncontradictory Events** (NCE)
For all models $\mathscr{M} \in K^n$ where n is an arbitrary stage in a discourse, it must not be the case that there are two events e and $\bar{e}$ where e and $\bar{e}$ only differ in polarity.

Some examples in (7)–(10).

(7) α_1: Miss Piggy entered the stage five minutes into the show.
α_2: Miss Piggy didn't enter the stage five minutes into the show.

(8) α_1: Miss Piggy entered the stage five minutes into the show.
α_2: Kermit didn't enter the stage five minutes into the show.

(9) α_1: Exactly one pig entered the stage five minutes into the show.
α_2: Miss Piggy didn't enter the stage five minutes into the show.

(10) α_1: If Miss Piggy puts on makeup before the show, she always enters the stage five minutes into the show.
α_2: Miss Piggy put on makeup before the show.
α_3: Miss Piggy did not enter the stage five minutes into the show.

(7) is very simple: The first sentence α_1 denotes $\{\{e_1\}\}$, where e_1 is the event of Miss Piggy entering the stage at the specified time. If we assume as an initial discourse model $K^0 = \{\langle\{piggy\},\{\}\rangle\}$, then $K^1 = \{\langle\{piggy\},\{e_1\}\rangle\}$.[8] The second sentence denotes $\{\{e_2\}\}$ where $e_2 = \overline{P}(e_1)$. It is not obvious that whatever model from K^1 (there is only one) we try to add some set from $[\![\alpha_2]\!]$ (again, there is only one) to, contradiction will always arise. K^2 cannot be $\{\langle\{piggy\},\{e_1,e_2\}\rangle\}$ because e_1 and e_2 contradict, and it also cannot be $\{\langle\{piggy\},\{e_1\}\rangle,\langle\{piggy\},\{e_2\}\rangle\}$, because bot models lack relevant information which was passed on in the discourse in this case.
In (8), the case is different, because the events do not contradict each other by virtue of being differently specified for the agent parameter, and the update will be successful.
(9) is interesting in that α_1 denotes the set of singletons were some pig but only one pig enters the stage at the given point in time. Assuming that our three pigs are Piggy (e_1), Bathsheba (e_2), and Esther (e_3), we get $K^1 = \{\langle\{piggy, bathsheba, esther\},\{e_1\}\rangle$, $\langle\{piggy, bathsheba, esther\},\{e_2\}\rangle,\langle\{piggy, bathsheba, esther\},\{e_3\}\rangle\}$, because $[\![\alpha_1]\!] = \{\{e_1\},\{e_2\},\{e_3\}\}$. Adding α_2 now eliminates $\{e_1\}$, because it denotes $\{\{e_4\}\}$ with $e_4 = \overline{p}(e_1)$, which is excluded by the last conjunct in the definition of the construction of K^n. However, adding e_4 to the other two possible models succeeds, and $K^2 = \{\langle\{piggy, bathsheba, esther\},\{e_2,e_4\}\rangle,\langle\{piggy, bathsheba, esther\},\{e_3,e_4\}\rangle\}$. Thus,

[8] The initial collection of discourse models K^0 in this case indicates that the interlocutors share no knowledge about events and states, and there is only one object which they both know, namely Miss Piggy.

we have gotten rid of all models where Piggy performs the relevant action, and we still carry the information in all our still construable models that she didn't perform it (via the presence of the negative e_4). The update would have failed if K^2 would have been empty.

Since I am not providing an analysis of conditionals at this point, I only mention (10) in passing. Here, α_2 contributes events which only contradict those contributed by α_3 if the conditional in α_1 is evaluated. This evaluation has to necessitate the presence of a positive event of Piggy entering the stage whenever there is an event of her putting on makeup before the show. This indirectly introduced event leads to contradiction with α_3.

As a final point, let me mention that the construable models in K^n are those against which, if taken statically as classical models (although having negative events) the sentences added at stages $K^{n,\dots,m}$ can be evaluated as true. In this case, NCE is really nothing but an ontologized Law of Exluded Middle (cf. section 4.2).

In this section, I have introduced negative events to encode information about matters that are not the case. It was argued that if we interpret sentences primarily against a model which contains all possible events, the resulting denotations can be used as constraints on construable mental models. Such construable models are calculated at the discourse-level, and it was shown that the inclusion of negative events makes no big difference to the previously discussed positive case, except that it can lead to contradiction for some models in the set of construable models when positive events and their mirror negative events collide. In these cases, the construable model is no longer considered (it is removed), and if all models are removed by an update, the update is usually not performed (it fails).[9] All the time, it was assumed that core verbs denote sets of positive events, and that only the explicit presence of a negation marker introduces negative events into the denotation of a sentence.

[9] This, again, only happens when the hearer does not disbelieve the speaker. The alternative strategy (persuasion) was not discussed. In the case of persuasion, the hearer would have to remove events from pre-update construable models, and then perform the update. Obviously, the more events from pre-update construable models the hearer would have to remove the less likely it is that he will actually be persuaded.

4.2 Types of Negation and Focus

4.2.1 Basic Distinctions and Phenomena

From Aristotle stems the distinction between term (or internal) negation and propositional (or external) negation, cf. discussion in Horn (2001:chap. 1), which is my primary source on these matters. They have their syntactic counterparts since Klima (1964) under the labels of *sentential* and *constituent negation*. Since all Aristotelian problems surrounding negation basically boil down to scope distinctions, I will not go through the whole history of the (often more philosophical than linguistic) discussion of the Aristotelian categories and just introduce the results as best suited for my technical implementation. To stay clear of specific philosophical views and quarrels, my terminology is syntactically oriented.
I begin with a definition of the types of negation which I distinguish.

4.2.1.0.1 Verb Negation I call verb negation, negations of the (verbal) predicate, which could also be called property negation.

(11) The King of France is not-big

It is traditionally held that sentences with verb negation behave like the non-negated counterpart with respect to undefined subjects. If the subject NP in (11) is undefined, then the sentence appears to many speakers to be not simply false, but problematic in that it predicates something (or, in the case of verb negation, *not-something*) of a non-existing subject. Such undefined subjects call either for a three-valued logic such as Kleene's (Kleene 1967), or some other theory which has a solution in terms of presupposition failure when subjects are not defined.
It is also suggested by Aristotle (and in Horn (2001:14ff.)), that verb negation falls under Aristotle's Law of Contradiction (LC), which roughly states that nothing can be *P* and not be *P* at the same time (captured by NCE here). However, they allegedly do not fall under the Law of Excluded Middle (LEM), which states that something either is *P* or is not *P*. For (11), this can be grasped by reading *not-big* as the corresponding privative *un-big*. In this case LEM tells us that it is not necessarily the case that the King of France is either big or un-big; he might for example be little instead. Most of the respective cases where LEM is clearly absent are just plain category mistakes (Horn, 2001:110ff.) (exemplified in (12) vs. (13)), which thus are not specific to negation. None of the sentences will ever be true, simply because numbers do not have colors.

(12) The number 7 is red.

(13) The number 7 is not-red.

Since the other cases need some philosophically sophisticated argumentation to go through as not falling under LEM (including (11)), I will treat them as falling under LEM. Current linguistic theories would rule out (12) and (13) by implementing semantic selectional restrictions, making such sentences ungrammatical rather than true or false. I strongly believe that whenever linguistic negation is involved in some sentence, the sentence excludes exactly those events which its positive counterpart affirms.

4.2.1.0.2 Constituent Negation What I call constituent negation is negation of any constituent that is not the verb or the verb-object complex (sometimes called VP here), but for example adjectives or adverbs, (14) and (15).

(14) Miss Piggy is a not-blue frog.

(15) Miss Piggy walks not-quickly.

As one can immediately see, cases of constituent negation also fall under the Law of Contradiction, since nothing can be a not-blue frog and a blue frog simultaneously. However, in what sense does this type of negation not fall under the Law of Excluded Middle? Can we be sure that it need not be the case that either (15) is true or (16)?

(16) Miss Piggy walks quickly.

I think this crucially depends on how one reads the sentence and the negation involved. Either it is a simple contrarification of the property expressed by the adjective/adverbial, in which case it can be paraphrased by (17).

(17) Miss Piggy walks unquickly.

In this case, the sentence clearly does not fall under LEM. Sentence (15), strange as it already sounds in English, has one other reading, however. Under this reading, it behaves like verb/sentential negation (cf. below) with accent on the adjective/adverbial, as indicated in (18b).

(18) a. Miss Piggy walks QUICKLY.
b. It is not the case that Miss Piggy walks QUICKLY.

Given the (18b) variant, it is perfectly correct to assume that either Miss Piggy walks QUICKLY or she does not walk QUICKLY, i.e., either (18a) or (18b) is true. Here, constituent negation assimilates to verb/sentential negation, both of which are assumed here to obey LEM. The sentence triggers other presuppositions than bare verb negation because of the non-neutral focus, but it must still be read as denying what the positive counterpart asserts: It is a negation of events. A majority of this chapter will be devoted to this problem, while the case of (17) will be mostly ignored as belonging more to the realms of lexical contrarification.

4.2.1.0.3 Sentential Negation Finally, like verb negation, cases like (14) and (15) (repeated here as (19) and (20)) behave like their positive counterparts in sentences with undefined subjects in either reading.

(19) Miss Piggy is a not-blue frog.

(20) Miss Piggy walks not-quickly.

It is only **sentential negation** which is different with respect to undefined subjects. And it is also the only case treated as clearly falling under LEM in the philosophical literature.

(21) The king of France is bald.

(22) The king of France is not bald.
(or in pseudo-disambiguated form:
It is not the case that the king of France is bald.)

Clearly, (22) is (as of the time of me writing this) not factual, no matter whether the subject is defined or not. And, if the subject is defined, then either (21) or (22) must be true; the Law of Excluded Middle holds.
After this short introduction of the two/three types of negation, I now turn to some other properties of negation. One phenomenon related to LEM could be called the *positive impact* of negation. As discussed at length in Horn (2001:chap. 1), both verb negation and constituent negation have been regarded as involving a positive affirmation in addition to the negative one throughout the history of philosophy and linguistics. Philosophers have even tried to walk the more extreme path of eliminating negation entirely in favor of positive assertions only, mostly because they had certain ontological or psychological biases. (11) (repeated here as (23)) appears to deny that the king of France is big, but at the same time also seems to assert that he *is something else*.

(23) The King of France is not-big

I talk about verb negation and constituent negation separately to make a distinction which is related to exactly this phenomenon. In (11) the accompanying assertion (that the king of France has some property but not that of being big) is obvious but not primary. Even though (14) and (15) (in the verb negation with focus reading) don't fall under LEM strictly speaking, the accompanying positive assertion is so strong that it might not possibly be taken as a presupposition anymore. In other words, the sentences are infelicitous unless Miss Piggy is a frog or Miss Piggy walks, respectively.

The next section will try to approach this problem by integrating a notion of focus into my event-based framework. To solve problems involved in negation interacting with other operators like frequency adverbials, section 4.3 will then refine the notion of sentence denotation to include larger objects called frame events (sets of events reinterpreted as primitive events, much like sums of events) which can be independently negated.

The most important fact to keep in mind from this section is that the three different kinds of negation (or the two in Aristotle's framework) all in some way exclude exactly those events which are positively asserted by their non-negative counterpart, which is why I treat them as falling under some version of LEM. This insight will guide the further argumentation.

4.2.2 Focus in GOA

In section 4.2.3, I will argue that the differences between the three types of negation introduced in the last section reduce to an interaction with focus. Therefore, I must first provide a definition of the machinery of focus in the current framework, which is the task in this section.

I take focus as relating strictly to relevant interpretational alternatives to some basic interpretation, in the tradition of Dretske (1972), Rooth (1985) and Rooth (1992), summarized for example in Krifka (2006). The focus value according to Rooth can be calculated by turning focused constituents into focus variables.[10]

(24) Kermit loves MISS PIGGY.

In this sentence, *Miss Piggy* is taken to be focused (indicated by uppercase spelling). Whereas the ordinary semantic value of the sentence is the proposition that Kermit loves Miss Piggy, the focus value would be obtained by replacing the constant denoting Miss Piggy by a focus variable which receives its interpretation by the normal model theoretic assignment function. Thus, the focus value would be the propositions that Kermit loves anyone.

The variant of Event Semantics developed here provides us with a very handy definition of alternatives, because whichever constituent is focused, we can capture the focus

[10] Focus need not always be marked phonologically. I use uppercase letters to indicate focus, even if possibly unmarked. Where more complex constituenthood is essential, I enclose the focused constituent in $[\,]_F$.

value (henceforth called **alternative value**) of the whole sentence by **complementing** the denotation of the focused constituent and then computing the semantics of the sentence exactly like for the ordinary value (called **primary value** here).

As an example, take (24). *Miss Piggy* is focused, and the corresponding logical constant **piggy** denotes the subsets from the power set of individuals which contain the famous pig starlet.[11] The complement of this denotation (the **value under focus**[12] of **piggy**) is denoted by $\overline{\textbf{piggy}}$, and it is the set of all sets of individuals which exclude her (the complement of $[\![\textbf{piggy}]\!]$ in $\wp\wp$**Obj**).

Now the treatment of quantification in GOA shows some of its advantages: We can interpret this inverted set as a theme QGO under thematic assignment, and form (by applying the QGO to **love**) the set of sets of loving events which correspond to all the sets from $\overline{\textbf{piggy}}$ as configurations of theme objects. Then applying **kermit** as agent operator will result in a denotation which contains all possible configurations of events where Kermit is the agent and some set of objects (where none of the contained objects is Miss Piggy) is the theme set. This corresponds nicely to the Roothian focus value, which would be the set of all propositions *that Kermit loves* x_{foc}. The classical focus value in this case would of course render *all* alternatives (including the one that is primarily asserted) and thus also contain the proposition *that Kermit loves Miss Piggy* There is no corresponding set of events in the alternative denotation under GOA, but I see no disadvantage in that, primarily because sentences like (24) taken in isolation (without context and any specific focus interpretation) have an intuitive reading along the lines of *"Kermit loves Miss Piggy and does not love somebody else."*

Turning to a modified example, in case the whole VP is focused, as in (25), the procedure works equally well.

(25) Kermit LOVES MISS PIGGY.

Here, we first take $\textbf{piggy}^{TH}(\textbf{love})$, one of the sets of sets of loving events. The alternative value is built up from the value under focus $\overline{\textbf{piggy}^{TH}(\textbf{love})}$, which is the set of sets of events which exclude those which are in the primary value. Since under GOA we do not have to worry about free variables and abstractions, we need not restrict the

[11] I hope this switch to a treatment of singular referring expressions as quantifiers is similar enough to the one in Montague (1973a) to be intuitively comprehensible. It will be explicitly formulated in chapter 5.

[12] What is usually called the *focus value* is called the *alternative value* here, and I assume it can be determined only of whole sentences, just like Rooth defines the focus value uniformly as sets of propositions. Therefore, I use the term *value under focus* for the contribution a constituent which is focused makes to the alternative value. Having a definition of value under focus allows the fully compositional approach to building up alternative values.

alternatives formed from the VP to *one-place properties*. The set contains all event configurations unless Miss Piggy is loved in at least one event of the configuration,[13] and the agent QGO is defined properly so as to operate on this set and generate sets where Kermit is the agent.

Obviously, we can build up the alternative value compositionally in parallel to the primary value of a sentence, with the only difference that at some point some operator performs a complementation operation in the derivation of the alternative value (and *not* in the derivation of the primary value). To have the formal means of spelling this out, it is most convenient to define the compositional mechanism in terms of tuples of a **primary and a secondary meaning**, where *meaning* here generally refers to the semantic contribution of some expression, the "translation" (in a Montagovian sense) of the expression. That is, the sentence will be interpreted as a tuple of functions $\langle f_1, f_2 \rangle$, such that f_1 generates the primary value, and f_2 generates the alternative value of the sentence. All normal lexical entries must provide the same component function for f_1 and f_2, only some special operators like the normal focus operator, negation, or *only* have a different contribution to the two composed functions. This can be most transparently implemented by defining all lexical entries also as tuples $\langle \alpha, \beta \rangle$, where α is the primary operator, and β the alternative operator, even if $\alpha = \beta$ in most cases. This will allow us to build up the primary and alternative value in an entirely compositional way.

For normal focus semantics, there must be an operator abbreviated **F**, which (by heuristic) spells out as $\langle \mathbf{Id}, \mathbf{Cmp} \rangle$, a tuple of the identity operator **Id** (which maps everything onto itself) for the primary function, and the complementation operator **Cmp** as its contribution to the alternative function. It must be a tuple under the assumption that all lexical entries are tuples of primary and alternative contribution. The **F**-operator is overtly manifested if focus is phonologically marked (or marked by particles etc.).

The derivation of (25) should thus look like figure 4.1. The sentence with focus on the VP denotes two sets: The primary one contains the event configurations corresponding to "*Kermit loves Miss Piggy.*", and the alternative one those corresponding to "*Kermit does anything but love Miss Piggy.*".[14] For simple focusing without any additional

[13] This includes events corresponding to *n*-place predicates (for arbitrary *n*). The logical syntax under GOA does not express the arity of predicates, because there is no notion of such predicates.

[14] A great deal of additional pragmatic information would have to provide a significant restriction of the domain of complementation. Already in his seminal paper, Dretske (1972), the alternatives are always assumed to be restricted to *relevant alternatives*. Just like the formal approach in Rooth's Alternative Semantics, my approach generates *all possible alternatives* if not further restricted. General discussion of the problem is found in Schwarzschild (1994) (*non vidi*, summarized in Kadmon 2001).

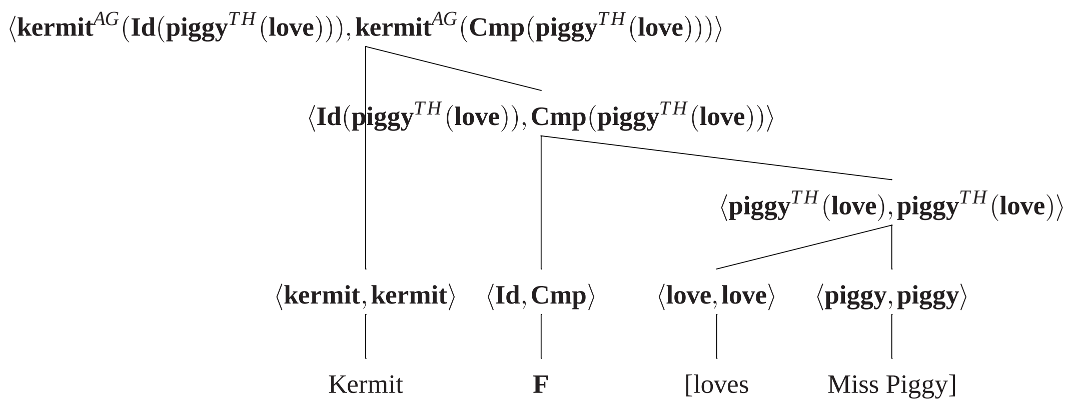

Figure 4.1: A derivation of (25)

operators, we can take this double denotation to be the input to whatever the pragmatics component does with sentences containing focus. Without any such additional operators or special contexts which enforce what is traditionally called truth-functional effects, let us assume that the function of focus is actually just pragmatically determined.

One final crucial remark is necessary. The analysis of focus presented here only works under the assumptions made in section 4.1.2. In a normal model-theoretic setting, the relevant alternative events might simply not exist, and the alternative value would be empty or only containing irrelevant alternatives. Roothian focus only works because the alternatives are ultimately alternative propositions. Under the current assumptions this is not required because both the primary and the alternative value can be interpreted against the abstract model which contains all events which might possibly be the case (cf. also section 4.2.3.1).

In the next section, I am going to take a look at negation which *associates with focus*, an effect covering in my view all cases of non-sentential negation. Sentential negation will be the topic of section 4.2.4 and section 4.3.

4.2.3 Focus and Negation

The term *association with focus* was also coined by Mats Rooth, and it is used by him for a wide variety of cases. I will focus on association of focus with negation. Take (26).

(26) Kermit doesn't love MISS PIGGY.

This sentence really seems to have the same truth and usage conditions as (27a), a sentence with constituent negation.

(27) a. Kermit loves not Miss Piggy.

b. Kermit loves not MISS PIGGY.

I assume that cases like (27a) always involve focus on the negated constituent as it is explicitly marked in (27b). That focus is obligatorily on the negated constituent can be tested by forcing focus intonation on some other constituent as in (28), or by trying to have two constituent negations in one sentence (which would mean coexistence of two disjoint foci) as in (29).[15] Both tests fail (if one excludes meta-linguistic "correctional" focus for (28)).

(28) * KERMIT loves not Miss Piggy.

(29) * Not Kermit loves not Miss Piggy.

It is evident that the negated constituent must carry focus, and that there is a unique focus in the sentence.

What is the effect of negation on the primary and the alternative value in the case of (26) and (27)? As argued for in section 4.1, negation involves the effect of transforming a set of sets of events e to a corresponding set of sets of events $\bar{e}$ such that there are unique pairs for every e and $\bar{e}$ such that $\bar{e}$ is distinguished from e only by having inverse polarity. The $\overline{\mathbf{P}}$ operator was defined to perform this transformation. If we apply this polarity inversion operator (at any point in the derivation) to the primary meaning but not to the alternative meaning, we get exactly what the sentence intuitively informs the hearer about: (i) The events corresponding to Kermit loving Miss Piggy (= the primary value) have negative polarity, and as such must not be assumed as factual. (ii) The events corresponding to Kermit loving any configuration of objects not containing Miss Piggy (= the alternative value) have positive polarity and can be assumed.

Contradiction between the primary value and the alternative value cannot arise, because the complementation in the alternatives (which is *not* performed in the primary value) makes sure that primary and alternative value are disjoint. Thus, we never have a situation where the primary value bans some event while the alternative requires it to exist.

I said above that the alternative value *can* be assumed, not that it *must* be assumed *with*

[15] I am aware that in the literature (e.g., Rooth 1985 or Krifka 1991) constructions are discussed which have multiple foci. I have the strong impression that these constructions are extremely marked, and that, if they are uttered in natural discourses at all, they involve some kind of meta-linguistic impact. Be that as it may, (28) and (29) seem to be ungrammatical in a parallel fashion (due to the same reasons). We can therefore assume that double constituent negation is as ungrammatical or infelicitous in the same way that one constituent negation plus one focus in the same sentence (but on different constituents) is without questioning theories of multiple foci in general. Also, the theory presented here could in general deal with multiple foci technically.

a minimal example. It seems slightly strange, however, that in the case of normal focus the alternative value provides events with positive polarity which are explicitly *not* to be assumed, and in the case of negation similar sets of events with positive polarity are offered which are explicitly to be assumed. One has to solve this by adding additional pragmatic restrictions on the interpretation of negation and focus. Especially, just taking plain focus to signal that both the ordinary and the focus value are to be assumed would make sentences containing plain focus very uninformative talk. I therefore suggest again that determining how primary and alternative value in simple cases of focus without specific operators are to be interpreted is really the task of the pragmatics component. In other words: For the semantic update procedure, only the primary value is relevant.

I would like to point out on the side that the semantics of *only*, could just use the inverted version of the negation tuple: $\langle \mathbf{Id}, \overline{\mathbf{P}} \rangle$. This comes very close to the solution in Rooth (1985), as far as one can compare his solution in terms of sets of propositions and the present solution at all. When the operator tuple is applied, the alternative value generates sets of events with negative polarity. If, this marked case, the hearer was to assume both primary and alternative value with full force, NCE would prohibit positive polarity for anything from the alternative value, and the primary value would really be the only positive event contrasted against the alternatives.

One advantage of the current proposal is that the alternative value is created compositionally by complementation at a specific point in the derivation, and it is thus in no respect technically inferior to Rooth (1985) and Rooth (1992). All contextual factors relevant for the determination of the *relevant* set of alternatives can therefore be boilt down to the determination of the relevant domain of complementation for the meaning of the focused constituent (by discourse salience, activation status, poset relations to active discourse entities, etc.). In most cases, even simple lexical sorting will be enough for the determination: A focused *WALK* will in most cases be complemented in the domain of sets of sets of events of motion, etc.

All this seems to suggest that (given that sentences are derived as tuples of primary and alternative meaning) focus, negation (which is always negation associated with focus), and tentatively even *only* can be captured by two basic operators: $\overline{\mathbf{P}}$ and **Cmp** (plus the operator **Id**, which is there mainly for simple technical reasons to become clear in chapter 5, and could just be omitted). **Cmp** always applies to the alternative meaning of the focused constituent, and $\overline{\mathbf{P}}$ is applied either to the primary meaning (if negation is present) or to the alternative meaning (if focus is associated with *only*). This gives us the simple permutation depicted in figure 4.2, of which only columns one and two are fully relevant at present. Assuming that (not considering scope effects with respect to

	focus	focus and negation	focus and *only*
$\overline{\mathbf{P}}$	—	$\langle \overline{\mathbf{P}}, \mathbf{Id} \rangle$	$\langle \mathbf{Id}, \overline{\mathbf{P}} \rangle$
Cmp	$\langle \mathbf{Id}, \mathbf{Cmp} \rangle$ (on $[\,]_F$)		

Figure 4.2: Operator permutations for negation and focus

other operators, cf. section 4.3) the negation operator can in principle apply at any time, we assume in the following example that it applies above the VP and after the focus operator. The derivation of both (30a) and (30b) is given in figure 4.3 (still disregarding surface syntax) and (31) will yield a final logical representation as in (32). Since they are vacuous, I omit **Id** operators in the actual derivation for reasons of brevity.

(30) a. Kermit loves not Miss Piggy.

b. Kermit doesn't love MISS PIGGY.

(31) Kermit doesn't LOVE MISS PIGGY.

(32) $\langle \mathbf{kermit}^{AG}(\overline{\mathbf{P}}(\mathbf{piggy}^{TH}(\mathbf{love}))), \mathbf{kermit}^{AG}(\mathbf{Cmp}(\mathbf{piggy}^{TH}(\mathbf{love})))\rangle$.

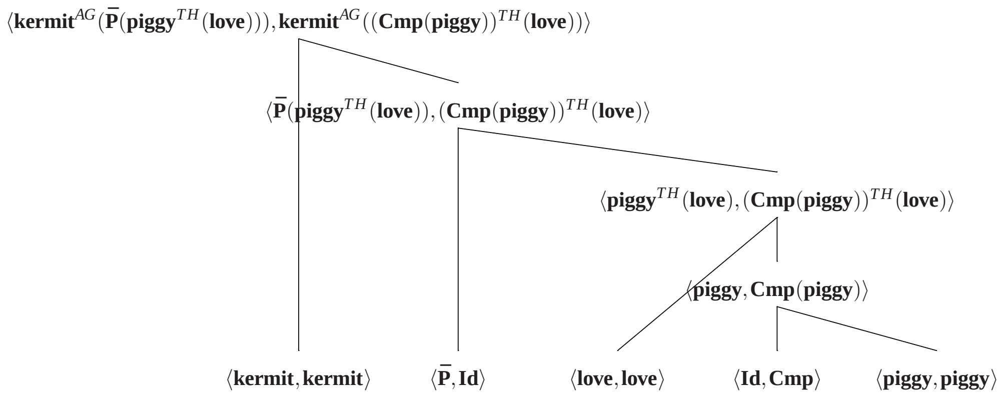

Figure 4.3: A derivation of (30a) and (30b)

Notice how the primary value (events with negative polarity) is identical for (30) and (31). Again, this is a desirable result because both sentences exclude the same events (cf. section 4.2.1), and they differ only in making different contributions as to which events they do explicitly *not* output with negative polarity. In the case of (30) (figure 4.3), the alternative value are the sets of events where Kermit loves any object configuration which excludes Piggy. In (31) as analyzed in (32), the alternatives are the sets of events where Kermit does anything except love Miss Piggy. That last alternative value could never be generated in a primary value, because presumably complementation never happens in primary denotations, and the core verbal operator applies first and reduces the events the sentence can talk about to those of one kind (*walk*, *talk*, etc.). This solution in a way gives a (modest and technical) answer to one question discussed throughout the history of negation, namely whether internal negation additionally includes or exclusively consists of a positive assertion (cf. section 4.2.1). In my framework, negation turns out to include *both* in an interaction with focus. We should keep in mind that so far it looks like the focus operator tuple has to apply in place, directly to the focused constituent, and that the negation operator tuple can apply at any time, preferably somewhere above the VP.

This last question (the natural language syntax and composition of negation) will be examined with significantly higher scrutiny in later sections and chapters. But first, I add some words on the problem of alternatives as derived here in traditional model theory in section 4.2.3.1. Then, I give a semantic explanation of sentential negation in terms of focus and negation in section 4.2.4. It actually constitutes an attempt to unify all types of negation. Finally, section 4.3 will introduce larger sum-like objects constructed from event configurations (so-called frame events) to explain scopal interaction between negation, quantifiers, and other operators.

4.2.3.1 Alternatives and Interpretation

This short section discusses how the interpretation of alternatives as defined above is only possible under the assumption of the theory provided in section 2.2.3 and section 2.2.4.

If classical model theory is assumed, then the alternatives generated by the current theory are inadequate.[16] Imagine a situation where Kermit sleeps and does nothing (relevant) else: He's not walking, eating, talking, etc. (whatever the context gives us as relevant alternatives). Under such conditions, I will evaluate (33).

(33) Kermit SLEEPS.

The alternative value, by definition, contains the sets of events where Kermit does anything but sleep, and context-dependence narrows this set down to the relevant alternatives. In this case, the alternatives are empty if we evaluate the sentence against a fixed model, which is not a useful result.

If the sentence is interpreted with respect to the abstract model, however, the interpretation of the alternative value is *not at all* empty. The domain $\mathfrak{Dom}_{Ev}$ contains all possible events, and consequently also those where Kermit walks, eats, talks, etc. In essence, although the interpretation procedure looks extensional, the abstract domain

[16] This is due to the fact that it uses almost extensional events to model alternatives and not propositions (like Rooth's theory).

of possible events provides a weak but sufficient notion of intensionality here.

It is therefore vital to keep in mind the two-stage interpretation and update procedure as described in section 2.2.3 and section 2.2.4. I suggest to take the elegant derivation of alternative values in the present theory as a point in favor of the plausibility of the theory of updates and discourse-level interpretation of open event descriptions.

4.2.4 Sentential Negation as Negation and Focus

In this section, I show how sentential negation can be treated on a par with verb negation and constituent negation. As I noticed above (section 4.2.1), I treat all three kinds of negation as denoting the negative mirrors (section 4.1.1 and section 4.1.2) of their positive counterparts.[17] Subsequently, if the negated sentence is true, the corresponding positive sentence is false and vice versa.

In section 4.2.3, constituent and verb negation were treated equally as negation associated with focus. The primary value was the same set of sets of negative events for a constituent-negated and an otherwise identical verb-negated sentence. I will now pursue the hypothesis that sentential negation behaves the same.

Again, we look at examples like (34) where the negated constituent (identical to the focused constituent) is indicated by round brackets.

(34) a. Kermit loves not-(Miss Piggy).

b. Kermit does not-(love Miss Piggy).

c. Kermit does not-(love) Miss Piggy.

d. It is not the case that (Kermit loves Miss Piggy).

(35) Kermit loves Miss Piggy.

(36) Kermit doesn't love Miss Piggy.

The sentences in (34) essentially all are negations of (35). In most cases, there isn't even a way of syntactically determining the negated constituent (without context or intonation), and all cases of (34) would be naturally expressed as (36).

Notice that even the allegedly disambiguated version of sentential negation formed with *it is not the case that* can be forced to be interpreted as verb or constituent negation, for example by putting strong focus accent on the respective constituent. Observe (37a) and the suggestive natural continuation in (37b).

[17] By the *mirror* or the negative/positive counterpart of an event e I informally refer to the event which differs from e only by polarity. The mirror of a set of events $\mathcal{E}$ is the set which contains exactly the mirrors of the events in $\mathcal{E}$ and nothing else.

(37) a. It is not the case that Kermit loves MISS PIGGY.

b. . . . but he loves Annie Sue.

One more observation must be added to this before I draw my conclusions: With respect to the question of whether all these negations presuppose or even imply some kind of positive assertion, there seems to be a gradual rise in the strength of the presupposition when the negated constituent (= the focused constituent) becomes narrower. In (34d), there seems to be no positive presupposition at all, while in (34b) it is at least strongly possible. In (34c) and especially (34a), it appears almost too strong to call it a mere presupposition.

In addition (and most importantly), when the subject of sentences like (37a) (with *it is not the case that*) is undefined and there is disambiguated focus on a lower constituent, they behave like sentences with lower negations (i.e., they appear undefined rather than false), as in (38) (assuming a situation where there is no host of the Muppet Show, for example because the show has been canceled).

(38) It is not the case that the host of the Muppet Show loves MISS PIGGY.

What if we took all this as indicating that sentential negation is nothing more than a special case of constituent negation with the whole sentence in focus? This would allow us to derive the primary meaning again by applying the polarity operator $\overline{\mathbf{P}}$, resulting in the same primary denotation as in the cases of lower negation. The alternative value would be obtained by complementing the positive mirror of the primary value in the power set of events, resulting in some giant disjunction of event configurations informing the hearer that anything might be happening (except Kermit loving Miss Piggy). Since, trivially, there is always something happening (which is very much what the alternatives tell the hearer), a presupposition ranging over such sets would be vacuous and undetectable, which explains why sentential negation triggers no such presupposition.

On the other hand, the narrower the negation (= the narrower the focus), the smaller the set of sets of events the alternative meaning denotes (at least in a domains not contextually restricted). If only an argument NP is negated as in (34a), the alternative value will still be restricted to the main event parameter contributed by the core verbal operator (since that operator is not in the scope of negation and thus not focused). If the V or VP level are negated, however, alternatives will be drawn from the power set of events, not restricted by the main parameter. In the case of maximal wipe-scope (sentential) negation, complementation will be in a completely unrestricted domain, and it will output sets of events which contain anything but the mirror events of the primary value. If there is a rough scale of cardinalities of the alternative values along such lines (i.e., if the alternative set becomes larger in cardinality the wider negational focus is defined), then it is clear why the presupposition becomes stronger with narrower negation. The presupposition becomes stronger with decreased cardinalities and thus increased specificity of the alternative value. This interpretation of the strength of the positive presupposition in negative sentences is just assumed as a heuristic here, since I will not perform the necessary proof about cardinalities of the alternatives.[18]

In figure 4.4 find the derivation of sentential negation as in (34d). I continue to apply the negation operator tuple always as high as possible.

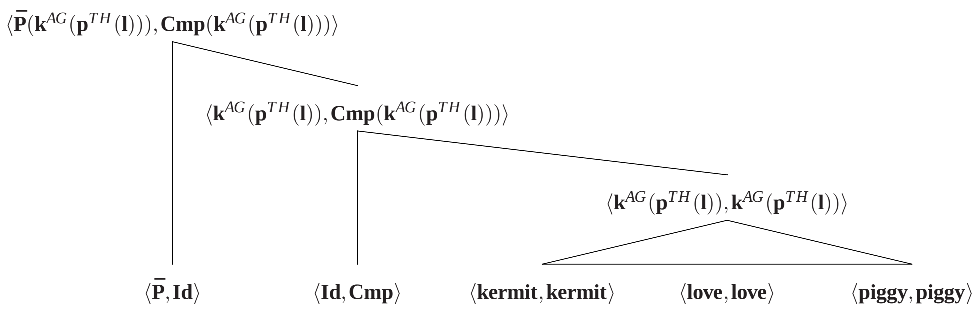

Figure 4.4: A derivation of (34d)

A final note on the problem of undefined subjects.[19] While I do not attempt to give an answer to the question of how exactly the ungrammaticality or inappropriateness or non-falsity of positive sentences with undefined subjects comes about, I can nevertheless give an answer to the question of why sentences with negation (or rather focus) taking a constituent which does not include the subject behave like positive sentences. Looking at figure 4.4 as a case of sentential negation, we can easily see that the primary content has negative polarity by virtue of being negated. The alternative meaning is derived like the positive counterpart of the whole sentence (including possibly undefined subjects), and it is *then* that the complementation operator applies. What this means is that in the case of sentential negation, the alternative value does not contain sets of positive events which are possibly specified for an undefined subject. In the case of lower negation, the subject is integrated *after* the complementation, and the derivation of the alternative content will yield a denotation which in fact does include sets

[18] A simple proof relying on cardinalities would essentially be fruitless anyway. For a valid argumentation, it would have to be settled how the interpretations as given here are actually computed by human language-users. Since there is most likely some form of lazy evaluation applied, we could expect that it is rather the complexity of the function that generates the set than the cardinality of the set which matters. Without an empirically backed up and robust theory of semantic processing, this is mere speculation, however.

[19] See also section 5.5.3 for a basic definition of what is generally the semantic effect of undefined subjects.

of events which have a specification for undefined subjects. It can thus be hypothesized that whenever a derivation leads to denotations including positive events which are specified for an undefined subject, be it in the primary or the alternative content, then the familiar effect arises. This explanation makes sentences with lower negation and undefined subjects false in the current framework, but lets them fail along some other dimension as well, because their alternative denotation contains positively specified events with undefined subjects.

In the last sections, I have established an implementation of negation as negative polarity of events including a simple theory of focus/alternatives and its interaction with negation. I have not said anything about scoping alternations between negation and quantifiers and between negation and other operators, for example modals *possibly*, frequency operators like *often*, etc. To give a satisfactory account of adverbial modification, scope distinctions between such operators must be modeled, of course. The next section is devoted to constructing *frame events*, larger entities derived from sets of events, which bear some similarity to sums, and which allow the formalization of such scope distinctions.

4.3 High Scope and Frame Events

This section examines what I call high scope, i.e., scope phenomena that are not explained by the inter-quantifier scope interpretation naturally introduced by the definition of QGO in chapter 3. The phenomena to be discussed here crucially involve NP-quantifiers, negation, certain adverbial operators, as well as modal and temporal operators. Ignoring all intensional phenomena (tense and modality), I show that the remaining extensional operators and negation receive a natural interpretation if we allow sets of events to be reinterpreted as frame events if needed (in a type-shifting kind of manner). Such frame events have much in common with sums of events in that they are exhaustively defined by their constituting events. Their spatio-temporal properties are computed from the spatio-temporal properties of the constituting events, and they inherit participance parameters from their constituting events in case the constituting events have homogeneous participants.

I call the phenomenon *high scope* because the scope distinctions discussed here are those which are usually treated as involving scope at a propositional level. While in the present theory it is not necessary to assume raising of quantified NPs in order for them to take scope as long as a linear scoping is intended (because the scope effect then arises from the definition of GOA quantifiers), some kind of operator raising is neces-

sary once negation and scopal adverbials are taken into account.
First, I turn to examples of scoping relations which absolutely necessitate the concept of frame event in section 4.3.1 before giving a small-scale typology of cases where frame events are needed and when they must not be formed. The concept of frame event will be unified with the generation of alternatives in section 4.3.3.
I would like to warn readers that in what follows negation will *not* be redefined, it will be kept as a simple polarity switching operation (temporarily ignoring the focus effects discussed above). In all its interactions with the other operators, it is *passive* in that it negates what it receives as an input without, for example, generating frame events itself.

4.3.1 Scopal Negation and Some Adverbial Operators

4.3.1.1 Introduction to the Data

We have seen above that without scope interaction, negation and its different sub-sentential "scopings" can be reduced to association with focus and be formally dealt with by the simple polarity-inverting operator $\overline{\mathbf{P}}$ (which can safely apply at some locus at the sentence-level) and a mechanism for determining focused constituents and alternative values. There are, however, scope interactions of negation with other operators which so far we cannot account for.
The question I want to answer now is how scope distinctions between, for example, adverbs of duration or modal adverbs, negation, and quantifiers can be modelled.[20] Notice that I am presently not yet examining how natural language *ambiguity* arises (or is resolved), but only how the definitions of the operators need to be forged so as to render the correct semantics, *given that these operators can (in principle) take relative scope*.
It is commonsense that negation can take scope relative to at least quantifiers, modal operators, temporal operators, and operators of duration and frequency. Since I want to exclude tense, aspect, and modality from this study to stay clear of more intricate problems of intensionality, I am going to take a look mainly at operators of frequency and duration (usually expressed by adjuncts) as well as negation and NP-quantifiers. For frequency and durative adverbials, which are sensitive to the temporal distribution of events, we can assume that our domain contains events from any point in time, and

[20] We have seen in chapter 3 that scope distinctions between two or more quantifiers fall out as a consequence of the interpretation given for quantificational Generalized Operators. With frame events introduced in this section, there will actually be two different analyses with two QGOs taking scope (namely with or without frame formation), but they result in equivalent analyses.

that we can determine those points in time to check for restrictions on the temporal distribution and the duration of the event without needing a more complex intensional temporal logic.

In the following examples, I try to disambiguate certain readings as much as possible with natural language means, using simple past to enforce an episodic reading. I am aware that scope readings other than the intended ones might be available under certain circumstances. Please assume scope readings faithful to the surface order.

(39) a. It is not the case that every Muppet often sang.

b. Often, every Muppet didn't sing.

(40) a. It is not the case that Annie Sue held Kermit's hand for a long time.

b. For a long time, Annie Sue didn't hold Kermit's hand.

(39a) is true in terms of Event Semantics iff there is at least one Muppet character for whom there is no *often* distribution of events (at the relevant instants in the past) which were singing events. So far, we seem to have no way of formalizing that this sentence expresses such a ban on a whole distribution of events. (39b) is true iff there were often occasions at which the singing event for each Muppet had negative polarity. The next pair of examples is simpler: (40a) is true iff (at the time in question which lies in the past) the event of holding hands between the two with long temporal stretch has negative polarity. (40b) states that for a long stretch of time there were no events with positive polarity which were hand-holdings between the famous frog confère and the young pig dame.

Such scoping phenomena are, however, not all there is to be taken into account. From Lewis (1975), where frequency adverbials appear within the larger class of adverbs of quantification, come examples like (41), where it seems not even to be scoping involved between the two adverbials, but really modification of two different types of semantic objects.

(41) Kermit often/always appears on stage now and then.

This sentence contains two frequency adverbials, one (*now and then*) introduces the restriction that the events of Kermit appearing on stage were frequent, the other one (*often* or *always*, where *always* is in Lewis' original example) seems to contribute the requirement that the totality (or the sequence) of these events happen often or on any (relevant) occasion, respectively.

4.3.1.2 Frame Events as Clusters of Events

While Lewis, in the aforementioned paper, rules out quantification over events as a suitable model for adverbs of quantification (based on his view of examples like the one just given), I would like to give such a solution a try. For the set-theoretic objects encountered so far, formulating an operator corresponding to *often* would be moderately easy given occurrences in sentences like (42), which do not show the scope phenomena under examination.

(42) Fozzie often told a joke.

Given a function from events to the time interval covered by those events (cf. Krifka 1989), the *often* operator would have to be defined so as to only let through sets of events containing joke-telling events by Fozzie which have a (random) temporal distribution dense enough to warrant calling their occurrence *often*.[21]

If *often* occupies the higher position in sentences like (41), however, such an interpretation simply cannot be available, since it would lead to contradictory requirements imposed by *now and then* and *often*. The events (if they are events, which I am arguing for) which are required to have an *often*-distribution in those cases must be larger events, states, situations, or something similar.

It could for example be the "events" of different episodes of the Muppet Show, in the course of which Kermit appears on stage now and then. But such events surely are not events as defined so far within the current theory, but they are determined entirely from contextual knowledge. An episode of the Muppet Show cannot be an event in the sense entertained here, mainly because is is not constituted by a linguistic expression of events in the sentences in question (core verbal operator plus specification by argument and adjunct operators), and we have established that the events we are investigating are strictly individuated by linguistic expressions.

Although we are probably looking for some larger events which are space-time collocated with episodes of the Muppet Show (and which can thus be matched in space

[21] The distribution should be random because *often* covers, just like *occasionally* etc., cases where the occurrence of the single events is not regular. Cf. Schäfer (2007) and Cohen (1999) on probabilistic interpretations of irregular frequency modifiers. Regularity is an extreme case of the randomized case and mostly covered by special adverbials like *regularly*. I should also mention that the definitions to be given for adverbials like *now and then* and *often* in this section will be made so that *often* entails *now and then* etc., because if something occurs randomly very often, it also occurs randomly at more sparsely distributed instants. Since the relation between the definitions puts them along a scale, an implicature is certain to kick in to force an ***only*** *now and then* interpretation in cases where *now and then* is used, and to force the use of *often* in situations where *now and then* would be semantically correct but uninformative.

and time with those based on contextual/world knowledge), we must search for some object which is constructed from linguistic means applied in the sentence. The larger events in question, I suggest, are defined solely by sequences or collections of smaller events as encoded by the core predicate. Using such a construct, (41) says that there were larger events with an *often-like* distribution, and each larger event is defined as being composed of (in principle) any number of events of Kermit appearing on stage. And these smaller events have a *now-and-then-like* distribution. I call the larger events **frame events**.

Now, notice how in absence of the lower modifier, the frame event reading seems to be far less easily available, but how we can still force ourselves into seeing such a reading, as in (43).

(43) Kermit often appeared on stage.

This can be read as saying that (for example), during each of many (or rather *often-like* distributed) frame events (which are probably in temporal congruence with episodes of the Muppet Show), Kermit appeared an unspecific number of times on stage.

How can such a meaning be forged? The sentence without the adverbial describes all possible sets of (temporally distributed) events where Kermit appears on stage. These sets are re-interpreted as frame events, the power set of the resulting set of frame events is formed, and only those sets from the power set of frame events are admitted in the output of the operator *often* which have a distribution appropriate for *often*. In the case of (41), these smaller events are made explicitly visible through the presence of the lower adjunct *now and then*, forcing an interpretation in terms of frame events to avoid contradiction between *now and then* and *often*. If we didn't type-shift from simple events to frame events, then the two frequency operators would impose two completely contradictory requirements on the same sets of events.

As can be grasped immediately, heavy contextual restrictions must enter into the determination of what the general measure of *often* is in such sentences, as it might differ wildly for, for example, frequencies of collisions of galaxies and the frequency of emissions of single neutrinos from the sun. This contextual dependency of interpretation is inevitable for relative frequency modifiers, and not a problem specific to the current proposal (cf. also Schäfer 2007). Also, in cases where the frequency of frame events is involved, it interacts in subtle ways with the determination of which sets of frame events are reasonable candidates.

Since in the interpretation of the sentence at hand, every possible non-singleton set of *Kermit-appear-on-stage* events is turned into a frame event, and we continue with the power set of those, there might well be a set containing a frame event constructed from one event each from the first and the second episode. In fact, there will also be all frame events constructed from the events of two adjacent episodes, and we want to avoid making claims about these and *often* distributions in most situations, but not in every situation. In fact, overriding world knowledge defaults, we can force the frame events to be made space-time congruent to almost anything. Look at the text in (44), were the context very specifically determines along which time spans the frame events must be constructed.

(44) The backstage scenes were most stressful in the episode with John Cleese since everything kept going wrong. Everyone was running in and out frequently during those scenes, but Kermit was very calm. Often, he would only come in now and then to refill his cup.

often (in context) must thus determine whether such sets of frame events will be appropriate. We have seen that defaults from world knowledge probably fix the relevant frame events to those temporally congruent with single episodes of the Muppet Show in the case at hand, but that this need not be the case.

4.3.1.3 Some Formalization

Let me stick to the raw semantics and neglect the role of contextually determined factors for the moment. However, I now introduce a first definition of frame events in (45) and (46).

(45) **Frame Events**

We extend the previously given definition of $\mathfrak{Dom}_{\mathbf{Ev}}$ by closure under both positive and negative frame formation: For any non-empty, non-singleton set of events $\mathcal{E}$ in the domain $\mathfrak{Dom}_{\mathbf{Ev}}$, there are a positive and a negative frame event: $\mathfrak{e}$ and $\overline{\mathfrak{e}}$, respectively. $\dot{\mathbf{r}}$ denotes a function from sets of events to the corresponding positive frame events where $\mathfrak{e} = [\![\dot{\mathbf{r}}]\!](\mathcal{E})$ inherits no parameters from the events in $\mathcal{E}$ unless specified explicitly.

(46) **Thematic Properties**

Iff for every event e in a set of events $\mathcal{E}$ and some object o and a role function r (denoted by an expression of type $(\mathbf{Ev} \rightarrow \mathbf{Obj})$), $r(e) = o$, then for $\mathfrak{e} = [\![\dot{\mathbf{r}}]\!](\mathcal{E})$ it is the case that $r(\mathfrak{e}) = o$. Else, $r(\mathfrak{e})$ is not defined.

The two-stage interpretation procedure which starts with the abstract model $\mathfrak{M}$ now pays off again. Because, had we chosen to work with more standard models where *either* a positive event e or its mirror negative event $\overline{e} = \bar{p}(e)$ exists, it would be considerably more difficult to construct the frame events as needed here. I will explain why in the following paragraphs.

Informally speaking, frame events encode meta-information about the polarity of basic events in construable mental models.[22] If a sentence denotes a positive frame event (derived from positive or negative basic events), all the basic events from which it is reclustered must be assumed as factual.

What does this mean in practice? Assume a sentence α_{n+1} denotes a set of sets of frame events instead of basic events. When updating K^n with $[\![\alpha_{n+1}]\!]$, the hearer forms unions of event domains from K^n with sets from $[\![\alpha_{n+1}]\!]$. The only thing we must change from previous versions of the update procedure is the checking condition for contradictory events, since all basic events which constitute the frame event must be assumed in each of the output models. So the update can only proceed when there is no event already in the domain which contradicts any of the basic events implicated by the frame event.

What about negative frame events? Besides from the fact that they, too, can be added in the standard fashion to the event domains in the K^n models, they have slightly more complicated implications. A negative frame event can only be added to models where *not the totality* of its constituting events exists, because this totality is what it negates. An example is given in (47) and (48).

(47) a. $\mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}} = \{e_1, e_2, e_3, e_4\}$ where $\mathscr{M} \in K^n$

b. $[\![\alpha_{n+1}]\!] = \{\{\mathfrak{e}_1\}\}$ where $\mathfrak{e}_1 = [\![\dot{\mathbf{r}}]\!]\{e_1, e_2\}$

In the case of (47), the model $\mathscr{M}$ from K^n cannot be updated with $[\![\alpha_{n+1}]\!]$, because the only update could be performed with $\{\mathfrak{e}_1\}$. However, the totality of constituting events for $\mathfrak{e}_1$ (which is $\{e_1, e_2\}$) is in $\mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}}$.

Under the circumstances in (48), the update is possible because the totality of $\{e_1, e_5\}$ is *not* in $\mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}}$, although one event ($e_1$) is.

(48) a. $\mathbf{Dom}^{\mathscr{M}}_{\mathbf{Ev}} = \{e_1, e_2, e_3, e_4\}$ where $\mathscr{M} \in K^n$

b. $[\![\alpha_{n+1}]\!] = \{\{\mathfrak{e}_1\}\}$ where $\mathfrak{e}_1 = [\![\dot{\mathbf{r}}]\!]\{e_1, e_5\}$

This interpretation of negative frame events is mainly why we do not simply "unbundle" frame events into their basic events when an update is performed. In the case of negative frames, we cannot simply add all the basic events nor all the basic events with inverted polarity. Instead, one would have to multiply the number of construable models in

[22] I call *basic event* any event which contributes to the formation of a frame event. It might, however, be a frame event itself, because a recursive definition was given. For the current purpose, it suffices to think about basic events as strictly non-frame events.

K^{n+1} to include specific ratios of the basic events and polarity mirrors thereof. The only construable models would be those where *not all of the* basic events are present, and where for those basic events which are not present, there is the polarity mirror. Only this would make sure that in the respective models there would *never* be the totality of basic events from the negative frame event. A modification of the update strategy seems the much more elegant strategy.

The interpretation of frames just given has the major advantage that both positive and negative frame events can be exhaustively constructed in the ontology from the domain of basic events. We do not have frame events reclustered from basic events which do not exist. However, frame events can be constructed just like sums by turning the domain of events into a join semi-lattice closed under reclustering; cf. chapter 5 for a proper formalization.

Now, let me introduce a definition of reclustering for ordinary semantic composition. The expression which provides the input to the reclustering operator denotes a set of sets of events, and the output must be a set of sets of (frame) events, as defined in (49).

(49) **Event Reclustering**

Given a set $\mathcal{E}$ of sets $\mathcal{E}'$ of events, the reclustered set $\mathfrak{E}$ of sets of frame events derived from $\mathcal{E}$ is given: $\mathfrak{E} = \wp\{\mathfrak{e} | \mathfrak{e} = [\![\dot{\mathbf{r}}]\!](\mathcal{E}')\}$. $\dot{\mathbf{R}}$ denotes exactly the function s.t. $[\![\dot{\mathbf{R}}]\!](\mathcal{E})$=$\mathfrak{E}$.

Besides the handy and intuitive dynamic parlance (*reclustering*, frame events *constructed from* events, etc.), I hope it has become clear that frame events are static within given models to the same degree as basic events. They are normal model-theoretic objects which can be calculated exhaustively based on the distribution of (positive and negative) events in the model.

The function $\dot{\mathbf{R}}$ is a handy abbreviation. It takes a set of sets of events and reclusters them by turning each set into a frame event, then forming the power set of the set of those frame events. Its input is thus a set of sets of events, and its output is of the same type, only it contains frame events instead of basic events. $\dot{\mathbf{R}}$ must be applied before operators which require frame event inputs to be interpreted properly (e.g., when *often* scopes over some other frequency operator in the manner displayed in (41)). It sets the polarity of the resulting frame events to 1, just as the core verbal operator does, because in the absence of a negation marker *above* the reclustering, we talk only about positive frame events. Since this is explicitly defined, the polarity is not inherited from the constituting events, and a positive frame event can thus contain negative events.

Finally, I now formulate two additional conditions on post-update models which regulate the interpretation of positive and negative frame events in (50) and (51).

(50) **Positive Frame Condition** (PFC)
No $\mathbf{Dom}_{\mathbf{Ev}}^{\mathscr{M}}$ in a post-update model $\mathscr{M} \in K^{n+1}$, where there is a positive frame event $\mathfrak{e} \in \mathbf{Dom}_{\mathbf{Ev}}^{\mathscr{M}}$, may contain any $\bar{\mathcal{P}}(e)$ where $e \in \mathcal{E}$ and $\mathfrak{e} = [\![\dot{\mathbf{r}}]\!](\mathcal{E})$.

(51) **Negative Frame Condition** (NFC)
No $\mathbf{Dom}_{\mathbf{Ev}}^{\mathscr{M}}$ in a post-update model $\mathscr{M} \in K^{n+1}$, where there is a negative frame event $\overline{\mathfrak{e}} \in \mathbf{Dom}_{\mathbf{Ev}}^{\mathscr{M}}$, must be a superset or equal to $\mathcal{E}$ where $\mathfrak{e} = [\![\dot{\mathbf{r}}]\!](\mathcal{E})$ and $\overline{\mathfrak{e}} = \bar{\mathcal{P}}(\mathfrak{e})$.

These two conditions add to the definition of the update procedure given above.

I have now shown how frame events can be constructed in a similar fashion to sum formation from the event domains of the abstract primary model. The reclustering operation $\dot{\mathbf{R}}$ takes sets of sets of basic events, derives the frame events from the sets and provides the power set of the derived frames. Thus, reclustering can be applied anywhere in the derivation, and no operator which operates both on the level of basic events and on the level of frame events has to receive a polymorphic definition. In the update procedure, frame events are added to domains of construable models just like any other event, although two additional clauses on post-update model construction had to be added.

In section 4.3.2, I will show that reclustering can derive some readings introduced in section 4.3.1.1. Reclustering is assumed as a general type-shifting operation which can apply to force certain interpretations. First, however, I discuss double negation in section 4.3.1.4 to render the idea of reclustering clearer.

4.3.1.4 A Demonstration of Double Negation

To render the idea of frame event formation clearer, let me demonstrate how the Law of Double Negation from well-known propositional calculi is reconstructed in my approach in two different ways depending on whether there is reclustering in between the negations. Double Negation is, in line with the general programme, not given as a deductive rule in a logic calculus, but it emerges as a consequence of the axiomatization of the model structure.

The Law of Double Negation states in essence that two negations cancel each other out, and it follows in the present theory from the definition of $\overline{\mathbf{P}}$ if we do not recluster. The function denoted by $\overline{\mathbf{P}}$, $\bar{\mathcal{P}}$, maps sets of sets of events with some polarity to the sets of sets which contain the polarity mirror events. For example, (52), where negative events are marked by the bar ($\bar{e}$).

(52) a. $\bar{\mathcal{P}}\bar{\mathcal{P}}\{\{e_1,e_2\},\{\bar{e_3},\bar{e_4}\}\} = \bar{\mathcal{P}}\{\{\bar{e_1},\bar{e_2}\},\{e_3,e_4\}\} = \{\{e_1,e_2\},\{\bar{e_3},\bar{e_4}\}\}$

Applying $\bar{\mathcal{P}}$ an even number of times simply switches polarities back and forth.
Now, take any sentence with a single negation which trivially does not require reclustering, such as (53a). It denotes sets of negative events, since $\bar{\mathcal{P}}$ has applied once as in the representation (53b):[23]

(53) a. Kermit doesn't walk.

b. $\overline{\mathbf{P}}(\mathbf{kermit}^{AG}(\mathbf{walk}))$ – or – $\mathbf{kermit}^{AG}(\overline{\mathbf{P}}(\mathbf{walk}))$

c. It is not the case that Kermit doesn't walk often.

d. $\overline{\mathbf{P}}(\overline{\mathbf{P}}(\mathbf{kermit}^{AG}(\mathbf{often}(\mathbf{walk}))))$

Since in this first interpretation of double negation which is shown in (53d) we do not recluster, we essentially apply the same polarity switching operator again, and end up with sets of positive events. Even though the sets denoted by the sentence must be sufficiently temporally dense to warrant the use of *often*, the events in these sets just get their polarity switched twice. It is important to keep in mind that the use of *it is not the case that* does not automatically cause reclustering, but that there are certain readings (involving specific operators) which only arise if it is applied (to be examined more thoroughly in section 4.3.2).
But now look at (54a).

(54) a. $\overline{\mathbf{P}}(\dot{\mathbf{R}}(\overline{\mathbf{P}}(\mathbf{kermit}^{AG}(\mathbf{often}(\mathbf{walk})))))$

$[\![\mathbf{kermit}^{AG}(\mathbf{often}(\mathbf{walk}))]\!]$ contains *all possible* sets which contain walking events with Kermit as the agent and an *often*-like distribution. If we negate the events in all these sets, then no construable model can contain a *Kermit-often-walk* configuration of events. We now recluster these sets and negate the corresponding frame events. After an update with such a sentence, any construable model must never contain any totality of negative *Kermit-walk* events which have an *often*-like distribution. In other words, the sentence with reclustering is compatible to situations where Kermit walks often, but this is in essence all it says.
The distinction is subtle, but there seems to be some pragmatic use which is made out of the interpretation with reclustering, which might even be the prototypical one. Sentences like (53c), if they appear in a natural discourse at all, are often not used to simply express double negation (= positive affirmation), but they invite *but* continuations like in (55), and I personally even get a good reading for (56).

(55) It is not the case that Kermit doesn't walk often, but he could actually walk more often.

[23] I omit the alternative meanings until section 4.3.3.

(56) It is not the case that Kermit doesn't walk often, but one cannot really say that he walks often either.

Now consider that the reclustered interpretation only blocks the possibility that Kermit does explicitly *not* walk often, but does not affirm straightforwardly that he walks often.[24] The more indirect interpretation with reclustering seems to be very well suited to express that one cannot exclude that something is the case, but that one can at the same time not affirm it.

This concludes the general introduction of frame events, and I will now set out to explain some scope phenomena using this notion. To be kept in mind from this and the previous sections is that there is one big advantage to a treatment of high scope phenomena which involves frame events and reclustering. In chapter 1, I embarked on the mission to define a semantic theory based on set theory which allows flexible placement of arguments and especially adjuncts without needing a higher-order logic including a full-fledged λ calculus and lots of polymorphism on the side of adjuncts. Not only has the definition of a unified type for arguments and adjuncts (chapter 2 and chapter 3) done part of the job, but we can now, after the introduction of frame events, even deal with advanced and very subtle scope phenomena in terms of a unified type.

This is true because above and below reclustering (even if it had to be applied cyclically), we exclusively encounter the type of sets of sets of events. It might be noticed that frame events bear some similarity to facts, situations, or propositions, depending on the angle from which they are viewed. I admit this, but at the same time I am hesitant to commit to any simple equivalence of frames with propositions or any other semantic object. It is very much possible that events (basic and frames) and sets thereof are *not* enough to model all of the semantic phenomena that we know of, and that an introduction of propositions proper (or some equivalent notion suitable for the semantic mechanisms advocated here) might be required at some point. Therefore, I rather deal exclusively with those phenomena of which I am convinced that they can be appropriately rendered without notions of propositions etc.

The next section examines the question of where frame events are needed, also making the general mechanisms of the interpretation of frame events clearer.

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[24] It just blocks the numbers/distributions of negative events which would absolutely ban *often*-like distributions of positive events from construable models. At the same time it does not specify any positive events of Kermit walking.

4.3.2 Where are Frame Events Needed?

4.3.2.1 A First Permuation

Equipped with a formal notion of frame events and reclustering, we can turn back to negation. It must be noticed that negation can scope relatively freely with respect to the operators examined in section 4.3.1.1 and section 4.3.1.2. Look at (58) through (60), which are examples of disambiguated scope readings of (57) to be discussed.[25]

(57) Kermit often didn't appear on stage now and then.

(58) $\mathbf{often}(\overline{\mathbf{P}}(\dot{\mathbf{R}}(\mathbf{nowAndThen}(\mathit{Kermit\text{-}appear\text{-}onstage}))))$

How is the reading in **(58)** to be interpreted? It says that every construable model should contain an *often* distribution of negative frame events which have *now and then* basic events of Kermit appearing on stage. That is, in larger *often* intervals it is banned that Kermit appear often enough to warrant calling it *now and then*. He might appear *rarely* or *not at all*, but he must not appear *now and then*. As a helper-reading: In many of the episodes of the Muppet Show it was not the case that Kermit appeared on stage now and then.[26]

(59) $\mathbf{often}(\dot{\mathbf{R}}(\mathbf{nowAndThen}(\overline{\mathbf{P}}(\mathit{Kermit\text{-}appear\text{-}onstage}))))$

(59) tells a slightly stranger but still conceivable story: There are often positive frame events, and these are reclustered from sets containing a *now-and-then-like* distribution of negative events of Kermit appearing on stage. Again, in a more intuitive formulation/exemplification: In many episodes of the Muppet Shows it was the case that now and then Kermit didn't appear on stage. I.e., at least occasionally during these frequent shows, Kermit did not appear, although he might have appeared with nerve-wrecking highly frequent regularity otherwise. The oddity of this reading is not semantic, but it simply applies to situations which we rarely encounter and talk about.

(60) $\overline{\mathbf{P}}(\mathbf{often}(\dot{\mathbf{R}}(\mathbf{nowAndThen}(\mathit{Kermit\text{-}appear\text{-}onstage}))))$

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[25] As usual with many operators artificially combined in a sentence, the acceptability of this sentence might be low. I do not think that this effect is strong enough to classify the sentence as ungrammatical/infelicitous, though. However, readers who find the analysis in terms of frame events complicated might consider the difficulties speakers have with such sentences as evidence for an analysis which involves increased complexity.

[26] Notice that the introduction of the episodes of the show in these helper readings is for illustrative purposes only, and that the sentence does not tell us anything about them. We only identify the (intervals covered by the) frame events with the (intervals covered by the) episodes to make the translations more readable.

The third example **(60)** is maybe a little more plausible or common again. It reads roughly: There is an *often*-distribution of negative frame events which are reclustered from positive *now-and-then* events. For clarity, I again point out that *often* would entail *now and then* by definition, and that it is thus excluded that Kermit appeared *often* in the respective negated frame events (which themselves have an *often* distribution).

What these examples demonstrate is that there are all sorts of scopings, and that the interplay between two frequency adverbials and negation can be explained in terms of basic events and frame events (which are actually nothing but events). I now examine pairs of operators to determine between which of them reclustering is required to yield the desired interpretations.

Under examination will be a quantified NP (*every frog*), negation, a frequency adverbial (*often*), and a durative adverbial (*for a long time*, abbreviated *longtime*). In this section and the next sections, I will conveniently abbreviate them Q, N, F, D, I will proceed pairwise, and I will give examples in disambiguated bracket notation.

The two adverbial operators are defined as in (61) and (62).

(61) **often** denotes a function from sets of sets of events to sets of sets of events s.t. only those sets from its input are in its output which contain events which have a random temporal distribution which is at least dense enough to warrant calling it *often*.

(62) **longtime** denotes a function of the same type as **often** s.t. only those sets from its input are in its output which contain events the temporal stretch of which is long enough to warrant calling it *a long time*.

I have now shown how reclustering can account for *available* differences in readings. The reclustering operator implements a sort of general shifting operation[27] which must be available to disambiguate readings when the discourse context or world knowledge require it.

Now, I turn to a more systematic discussion of two crucial cases where differences in readings based on reclustering arise or do not arise: highest-scoping quantification and negation.

4.3.2.2 Quantifiers with High Scope

The first set of permutations is given in figure 4.5. I indicate thematic roles only where transitive verbs are necessarily involved. Please read all the examples as containing *episodic* predicates.

[27] Since the type of the expression does not change, it would be incorrect to call it *type shifting*.

permutation	example
QQ	$\mathbf{every}(\mathbf{frog})^{AG}((\mathbf{every}(\mathbf{frog}))^{TH}(\mathbf{love}))$
QN	$\mathbf{every}(\mathbf{frog})^{AG}(\overline{\mathbf{P}}(\mathbf{walk}))$
QF	$\mathbf{every}(\mathbf{frog})^{AG}(\mathbf{often}(\mathbf{walk}))$
QD	$\mathbf{every}(\mathbf{frog})^{AG}(\mathbf{longtime}(\mathbf{walks}))$

Figure 4.5: Operator permutation with Q having highest scope

4.3.2.2.1 QQ The VP *loves every frog* denotes sets containing events such that each frog is loved in at least one event without any specific temporal restrictions. The agent NP operator selects one of these sets for every frog as agent (if they exist) and outputs the union of these sets of events denoted by the VP. Multiple sets are possible in the denotation of the sentence if several event configurations verify the sentence.[28] If reclustering takes place in between the two quantifiers, then the resulting frame events will have the same agent sets as the set from which they are constructed (by the definition of the thematic properties of frame events). And since a positive frame event requires the existence of its constituting events, the output of the version with reclustering and without reclustering is not equal, but equivalent.

4.3.2.2.2 QN The second case is simpler. Negation was defined as a function which maps a set of sets of events to the set of sets of events which differs from the events in the input by polarity. Thus, $\overline{\mathbf{P}}(\mathbf{walk})$ denotes the power set of negative walking events. If we turn the sets of not-walkings provided by the VP into frame events, these would be positive frame events, which entail *all* of the constituting (in this case negative) events. Forming the power set of these frames and then requiring that only those sets remain which are the union of frames such that every frog finds in that union one frame for which he is the unique agent will again be equivalent to the version without reclustering. I want to illustrate this generally with figure 4.6.

The (i) level display some simple events, and (ii) gives the power set of those. Assume (ii) is the denotation of some expression before reclustering, then (iii) shows the structure of reclustered sets of events (where one frame event corresponds to exactly one set in the power set formed in (ii) and vice versa). The full result of the reclustering operation is the power set of the frame events, which is started in the (iv) layer. (The full lattice is not given due to space constraints.)

[28] This is unlikely in the case at hand where there is an episodic non-progressive present predicate and both quantifiers are universal. In other words, each frog can only love each frog in one event at one time.

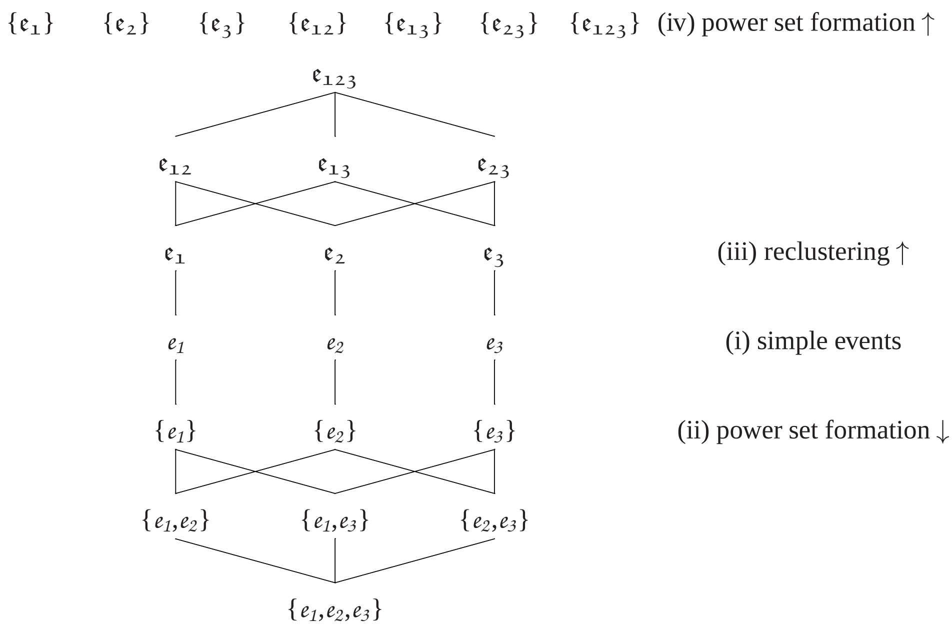

Figure 4.6: A visualization of reclustered power sets

It should be immediately obvious, that in the case of positive frame events every permutation of frame events can only require events to exist which would be required to exist by some set in the non-reclustered denotation as well. The frame events could only be used to require additional structure in the distribution of the single events. Also, if for every frog there is a set in the power set of basic events such that he is the homogeneous agent of that set, then there will be at least one set for every frog in the denotation of the reclustered expression.

4.3.2.2.3 QF In the QF case, we observe again the indifference of highest scoping quantifiers towards reclustering. In $[\![\textbf{often}(\textbf{walk})]\!]$ we find sets which contain all possible permutations of walkings, such that they have an often distribution (by some contextually given measure). There are also those sets of *often* walkings which have frogs as the agent. Whether we collect them as sets of the basic events or as sets of frame events which entail these sets, again, does not make any difference.

4.3.2.2.4 QD Given an episodic reading of *walk*, the QD example also receives equivalent interpretations with and without reclustering. $[\![\textbf{longtime}(\textbf{walk})]\!]$ denotes sets of events which have a long stretch. Since reclustering is supposed to take place *above* the duration modifier, again we do not get any substantial difference in reading if we allow reclustering or if we do not. The quantifier collects for every frog either sets of long events or sets of frame events which require the existence of long events.

One must not confuse examples like these with examples where reclustering applies *below* a duration or frequency modifier as in (63). These are cases where it almost always matters whether we do recluster or not.

(63) a. For a long time, Kermit sang (= used to sing) for a short time.

b. $\mathbf{longtime}(\dot{\mathbf{R}}(\mathbf{kermit}^{AG}(\mathbf{shorttime}(\mathbf{sing}))))$

Examples like (63) tend to involve a habitual interpretation.

4.3.2.3 Negation with High Scope

Now, let us turn to cases where negation has highest scope. From the cases shown in the table in figure 4.7, I have already dealt with NN in section 4.3.1.4, where I found that reclustering makes a subtle difference.

In the case of NQ, the interpretation will be equal to that of QN if we do not recluster. $\mathbf{every}(\mathbf{frog})(\mathbf{walk})$ is interpreted as a set of sets which contain walking events such that there is for each frog at least one event such that it (the frog) is the agent. Applying

permutation	example
NQ	$\overline{\mathbf{P}}(\mathbf{every}(\mathbf{frog})^{AG}(\mathbf{walk}))$
NN	$\overline{\mathbf{P}}(\overline{\mathbf{P}}(\mathbf{kermit}^{AG}(\mathbf{walk})))$
NF	$\overline{\mathbf{P}}(\mathbf{often}(\mathbf{kermit}^{AG}\mathbf{walk})))$
ND	$\overline{\mathbf{P}}(\mathbf{longtime}(\mathbf{kermit}^{AG}(\mathbf{walk})))$

Figure 4.7: Operator permutation with N having highest scope

$\overline{\mathbf{P}}$ without reclustering just maps these sets onto sets which contain events identically specified except for polarity. This is not what the NQ analysis (which reads like (64)) seems to express under normal circumstances, but rather the QN reading.

(64) It is not the case that every frog walks.

If we take the sets corresponding to $\mathbf{every}(\mathbf{frog})(\mathbf{walk})$, however, recluster them and apply negation, then the result is all collections of (negative) frame events which are constructed from positive sets which contain one event for every frog where the frog is the agent. By the NFC (51), this means that whatever positive frog-walking events there are, there must never be such an event for *each* frog. Thus, it cannot be that every frog walks, but it is by no means stated that every frog doesn't walk. In fact, all frogs but one might walk. This is exactly how (64) is read by default. Thus, this is an obvious case of mandatory reclustering.

The case of NF and ND should also be clear from the discussion in section 4.3.2.1.

I have now shown for a larger number of permutations involving negation and quantifiers how reclustering leads to different interpretations which are actually available. Although it is especially negation in combination with the concept of reclustering which brings about significant additional load for a theory which relocates negation in the ontology,[29] the concept still results in robust predictions about available readings, and it renders natural language semantics free of logical negation.

Using the previous cases as our basis, we can begin to see which operators are sensitive to reclustering applied below them. Quantifiers are completely insensitive to reclustering, but the other operators (the temporal ones and negation) lead to substantially different interpretations when they apply to reclustered sets of events, and the reclustered variant seems to be the default variant when these operators scope high. For the temporal ones, this is easy to motivate, because the reclustered events simply have their own temporal properties accumulated from those of their constituting events. That quantifiers are not sensitive to reclustering is also plausible considering the fact that thematic parameters are transparently inherited by the frame events from their constituting events.

These findings strengthen the similarity of the sets of events in the simple denotation of a sentence with propositions (or maybe facts). Consequently, once reclustering has taken place, the parameters of the single events (which are in the proposition-like sets of events which constitute the frame events) are no longer accessible, and subsequently modifiers are strictly confined to modifying proposition-like objects. Ultimately, this could lead to a reconstruction of ontologies relying on events, facts, propositions (compare, in the field of adverbial syntax, Ernst 2001) in terms of different sorts of events only.

4.3.2.4 To Recluster or not to Recluster

What is the bottom line to the immediately preceding discussion? The emerging pattern is that reclustering must be assumed to distinguish one possible analysis (with reclustering) of a sentence from another (without reclustering). Without it, many ambiguities could not arise, and some constraints on construable models could not be imposed at all, i.e. certain meanings could not be expressed.

However, the motivation for a hearer to assume a reclustered analysis cannot come from semantics alone, since the simpler analysis without reclustering is always well-formed and interpretable. I propose that it is pragmatics which forces interpretations involving

[29] A step which in turn was necessitated by the implementation of the idea that quantification could be encoded in event structures.

reclustering. Assume an analysis without reclustering does strongly contradict either world-knowledge or the previous discourse. In this situation, **consistency constraints** on interpretation can force reclustering to rescue the sentence. When such forces are not present, however, the simple analysis is forced by economy constraints.

On the other hand, assume that some potentially scopal constituent has been moved out of its unmarked position by a speaker. In cases where the marked linear order only makes a difference in interpretation if reclustering is assumed in addition to the relocation, then there will also be a high pragmatic indication for reclustering.

4.3.3 Frame Events and Alternatives

Finally, I want to add a remark on frames and alternatives as introduced in section 4.2.2 in view of the concept of frame event introduced in the last sections.

In cases where reclustering occurs, we have two options of alternative formation: below and above reclustering. The question is whether and how reclustering affects the formation and the interpretation of alternatives under the assumption that we do not want to change any of the formal mechanisms introduced. It is clear that a principled account is one which produces primary or frame events (of the same order) in both the primary value and the alternative value, since it would not make sense comparing frames and non-frames in terms of primary and alternative value.

Since frame events are in fact not distinguishable from events ontologically, application of focus operators *above* reclustering does not deserve special attention. With plain focus, the frame events in the primary denotation are asserted, and the alternative value will be some complement of those frame events.

I will however examine sentence (65) under the assumptions that reclustering applies in both coordinates of the tuple, and reclustering occurs in between application of the focus operator and below reclustering. This analysis is given in (66).

(65) Scooter often MENTIONED his uncle.

(66) $\langle \mathbf{often}(\dot{\mathbf{R}}(\mathbf{scooter}^{AG}(\mathbf{his.uncle}^{TH}(\mathbf{mention})))),$
$\mathbf{often}(\dot{\mathbf{R}}(\mathbf{scooter}^{AG}(\mathbf{his.uncle}^{TH}(\mathbf{Cmp}(\mathbf{mention})))))\rangle$

The primary denotation is a set of sets of positive frame events which encode that arbitrary clusters of positive primary events where Scooter mentions his uncle are in the model, and the clusters (as wholes) are in an *often* distribution. The alternative denotation is a set of sets of positive frame events which encode that arbitrary clusters of positive primary events where Scooter performs *any* action involving his uncle (as internal role bearer) except mentioning him are in an often-like distribution.

This is the desired result because with or without reclustering the contrast set to (65) should clearly be about what other things Scooter might often do involving his uncle. With or without reclustering, the alternatives are very similar to the alternatives in a Roothian framework (but without the need to address sets of propositions).

This concludes the introduction of the core concepts of GOA with Quantification, Alternatives, and (some) scope phenomena. The next chapter is devoted to a formalization of the theory.

Chapter 5

Formalization

5.1 Preliminaries

Based on the argumentation in the previous chapters, I now provide a formalization of the theory advocated so far: the specification of the syntax and interpretation of the representation language $\mathscr{L}_{\mathsf{GOA}}$. Section 5.2 defines the types and 5.3 defines the expressions of the representation language. In section 5.4, I define the model against which sentences are interpreted. Section 5.4.2 details the two-step interpretation procedure leading from sentence interpretation to knowledge and discourse representation in a non-monotonic fashion, before 5.5 deomnstrates a first theory of inferences and 5.6 provides some (purely) semantic derivations. These derivations are *purely semantic* in as much as they do not take into account some intricacies of natural-language surface form.

To facilitate the reader's understanding of the formalization, I want to point out again that, in order to fully detach the semantic representation of the verb from that of its arguments (in an Event Semantics) and to develop an Event Semantics system without event arguments (i.e., event variables which have to be bound and quantified over), some standard assumptions of model-theoretic semantics had to be given up, some others were added:

1. Sentences are interpreted against an abstract model $\mathfrak{M}$. It contains all object individuals and all conceivable events and, by virtue of being compatible with every bit of linguistically expressible information, it is fully contradictory. In a predicate-logical setting, this model would make **every sentence** true, including contradictions.

2. For two language users which share exactly the same language, $\mathfrak{M}$ is identically specified.

3. In the set-theoretic formalization used here, sentences are not primarily evaluated as true or false (since, given the previous point, every sentence would be true anyway), but they are interpreted as a certain collection (a set of sets) of events, which means they have type $\wp\wp\mathbf{Ev}$. In a parallel predicate-logical analysis, this could be expressed by attributing the type $\langle\langle event, t\rangle, t\rangle$ (in Montague notation).

4. These denotations are used to form a set of secondary models $\mathscr{M}$ which represent the knowledge state of a language user. The secondary model formation is a process which constructs all possible unions of sets of events of all known sentence denotata, then removing those sets where contradiction between at least two events would arise. The domain of each secondary model $\mathscr{M}$ is a subset of the abstract model $\mathfrak{M}$.

5. Nothing is said about how these models relate to the real world. The secondary models can be seen as the *theories of the real world* entertained by the language user. Truth means non-contradiction (or unifiability) with a previous state of knowledge for a single language user. If a language user receives contradictory information in the form of a sentence denotatum on the one hand and non-linguistic sensory perception on the other hand, one of the two must be discarded to form a consistent knowledge base. This is not essentialy different from the case where two contradicting sentence denotata are presented to the language user.

6. Specifying the last point further, it must be stressed that the events of this theory are also not "real world" events but those which are denotable by the expressions of a specific language. They are the events which speakers can distinguish by means of natural language. There might well be events in the real world which some speaker cannot distinguish, and there might be events in the real world which are distinguished in more detail by language than by, for example, human visual perception. In the vein of chapter 2, any *buy*/*sell* situation is a case where the English language is equipped to describe *two* events (one *selling* and one *buying*), but it is difficult to define in terms of visual perception (or probably any more advanced physical definition of events, if there is any) what distinguishes one event from the other. Consequently, one could easily define a language which does not allow talk about *buy* and *sell* events but only about either *buy* or *sell* events or something like *buysell* events.

7. As an interesting fact, it can be shown that if a sentence denotation has been added to the set of denotations which define the set of secondary models, there

must always be a model among these secondary models which can serve to render the sentence true in a classical model-theoretic way.

8. Negation is rendered by introducing events with negative polarity. The simplest case of contradiction is then given as the opposition between two events which are equally specified except for polarity.

9. To deal with certain scope phenomena, additional structure (frame formation or reclustering in chapter 4) has to be assumed in the models. Special rules have to be given for the process of generating secondary models from denotations containing such frames (positive and negative).

Some technical matters are handled in a slightly different manner here compared to the previous chapters and later chapters. For example, main event types (denotations of constants like **walk**, etc.) are introduced as simple sets of events which have to be raised to sets of sets of events by a special (raise-to-verb) function. These factors are treated differently in the other chapters for reasons of simplicity, and the switch from the more detailed version to the simplified one (and back) should be easy.

5.2 Types

1. $\mathbf{Obj}, \mathbf{Ev}, \mathbf{Per}, \mathbf{Loc} \in SType$ (individual types of object, event, period, and location individuals).

2. $\wp\tau \in SType$ iff $\tau \in SType$ (set types).

3. Nothing else is in *SType*.

4. $SType \subset Type$.

5. If $\sigma, \tau \in Type$ then $(\sigma \rightarrow \tau) \in Type$ (functional types).

6. Nothing else is in *Type*.

5.3 Expressions

5.3.1 Simple Expressions

1. The set of constants of $\mathscr{L}_{\mathsf{GOA}}$ is constructed as follows:

   (a) $\mathbf{Con}_\tau = \{c_n^\tau | n \in \omega\}$

(b) $\textbf{Con} = \bigcup_{\tau \in Type} \textbf{Con}_\tau$

2. There is a number of finite sets of constants and single constants which are written with pretty-print aliases (like **walk**) and which receive special names (or class names in the case of sets of constants). Note: The fact that a class name alludes to a category of natural language syntax like "adjectival constants" does not necessarily imply that any actual expression (e.g., an adjective) of English or any other language be directly translatable as such a constant. See section 5.6 for concrete translations of expressions of English into $\mathscr{L}_{\mathsf{GOA}}$. Some of these never occur as (or within) the direct translation of an expression of natural language in this study, which is inelegant but not fatal. It makes the formulation of some axioms easier.[1]

   (a) individual constants: $C_{ind} = \{\textbf{kermit}', \textbf{piggy}', \ldots\}$[2]
   where $\forall c \in C_{ind}[Ty[c] = \textbf{Obj}]$

   (b) name constants: $C_{name} = \{\textbf{kermit}, \textbf{piggy}, \ldots\}$
   where $\forall c \in C_{name}[Ty[c] = \wp\wp\textbf{Obj}]$

   (c) noun constants: $C_{noun} = \{\textbf{frog}, \textbf{pig}, \ldots\}$
   where $\forall c \in C_{noun}[Ty[c] = \wp\textbf{Obj}]$

   (d) adjectival constants: $C_{adj} = \{\textbf{red}', \textbf{intelligent}', \ldots\}$
   where $\forall c \in C_{adj}[Ty[c] = \wp\textbf{Obj}]$

   (e) intersector constants: $C_{inters} = \{\textbf{red}, \textbf{intelligent}, \ldots\}$
   where $\forall c \in C_{inters}[Ty[c] = (\wp\textbf{Obj} \rightarrow \wp\textbf{Obj})]$

   (f) determiner operators: $C_{det} = \{\textbf{all}, \textbf{some}, \ldots\}$
   where $\forall c \in C_{det}[Ty[c] = (\wp\textbf{Obj} \rightarrow \wp\wp\textbf{Obj})]$

   (g) event type constants: $C_{etype} = \{\textbf{hit}, \textbf{run}, \ldots\}$
   where $\forall c \in C_{etype}[Ty[c] = \wp\textbf{Ev}]$

   (h) event property constants: $C_{eprop} = \{\textbf{quick}, \textbf{slow}, \ldots\}$
   where $\forall c \in C_{eprop}[Ty[c] = \wp\textbf{Ev}]$

   (i) subset operators: $C_{subset} = \{\textbf{quickly}, \textbf{slowly}, \ldots\}$
   where $\forall c \in C_{subset}[Ty[c] = (\wp\textbf{Ev} \rightarrow \wp\textbf{Ev})]$

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[1] The definition of $Ty[\cdot]$ is found in section 5.3.1.1/2.

[2] Although these sets are given as open enumerations with "…" here, they are assumed to be finite for any concrete, fully specified grammar.

(j) role functors: $C_{role} = \{\mathbf{ext}, \mathbf{int_1}, \mathbf{int_2}, \mathbf{int_3}\}$[3]
where $\forall c \in C_{role}[Ty[c] = (\mathbf{Ev} \to \mathbf{Obj})]$

(k) thematic operators: $C_{theta} = \{\mathbf{Ext}, \mathbf{Int_1}, \mathbf{Int_2}, \mathbf{Int_3}\}$
where $\forall c \in C_{theta}[Ty[c] = (\wp\wp\mathbf{Obj} \to (\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev}))]$

(l) prepositional operators: $C_{prep} = \{\mathbf{to}, \mathbf{in}, \ldots\}$
where $\forall c \in C_{prep}[Ty[c] = (\wp\wp\mathbf{Obj} \to (\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev}))]$

(m) raise-to-verb operator: **Verb**
where $Ty[\mathbf{Verb}] = (\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev})$

(n) polarity constants: **pos**, **neg**
where $Ty[\mathbf{pos}] = Ty[\mathbf{neg}] = \wp\mathbf{Ev}$

(o) identity operator (polymorphic): **Id**
where $Ty[\mathbf{Id}] = (\tau \to \tau)$ for $\tau \in Type$

(p) low polarity operator: $\overline{\mathbf{p}}$
where $Ty[\overline{\mathbf{p}}] = (\wp\mathbf{Ev} \to \wp\mathbf{Ev})$

(q) high polarity operator: $\overline{\mathbf{P}}$
where $Ty[\overline{\mathbf{P}}] = (\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev})$

(r) complementation operator (polymorphic): **Cmp**
where $Ty[\mathbf{Cmp}] = (\wp\tau \to \wp\tau)$ for $\tau \in Type$

(s) period functor: **Peri**
where $Ty[\mathbf{Peri}] = (\mathbf{Ev} \to \mathbf{Per})$

(t) location functor: **Locat**
where $Ty[\mathbf{Locat}] = (\alpha \to \mathbf{Loc})$ with $\alpha \in \{\mathbf{Obj}, \mathbf{Ev}\}$[4]

(u) low reclustering operator: $\dot{\mathbf{r}}$
where $Ty[\dot{\mathbf{r}}] = (\wp\mathbf{Ev} \to \mathbf{Ev})$

(v) high reclustering operator: $\dot{\mathbf{R}}$
where $Ty[\dot{\mathbf{R}}] = (\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev})$

[3] The number of thematic roles should probably be assumed to be finite. For the sake of simplicity, I limit it to four here without any implied empirical claim that four is actually enough.

[4] We will not use this functor a lot in the current study. Otherwise, one would maybe have to make it $(\alpha \to \wp\mathbf{Loc})$ to account for objects and events taking up sets of points in space, and even $(\mathbf{Per} \to (\mathbf{Ev} \to \wp\mathbf{Loc}))$ to account for objects and events located in specific spatial areas during certain periods. In general, the theory of time and space used here is kept minimalistic to account only for some basic facts.

5.3.1.1 Complex Expressions

1. The set **Exp** of expressions of $\mathscr{L}_{\mathsf{GOA}}$ is the smallest set such that:

   (a) **Con** $\subset$ **Exp**

   (b) For any $\alpha, \beta \in$ **Exp** and $\sigma, \tau \in Type$: If $Ty[\alpha] = (\tau \to \sigma)$ and $Ty[\beta] = \tau$ then $\alpha(\beta) \in$ **Exp** and $Ty[\alpha(\beta)] = \sigma$.

2. $Ty[\cdot]$ is a function in the meta-language from **Exp** into *Type*.

5.4 The Model

5.4.1 Abstract Models

5.4.1.1 Basic Definition

1. The abstract model $\mathfrak{M} = \langle \mathfrak{Dom}, [\![\cdot]\!] \rangle$ (a domain and an interpretation function).

2. For each $\tau \in Type$ there is a domain $\mathfrak{Dom}_\tau$, and $\mathfrak{Dom} = \bigcup_{\tau \in Type} \mathfrak{Dom}_\tau \cup \{\bot\}$, such that:

   (a) $\mathfrak{Dom}_{\mathbf{Obj}}$ is a non-empty domain of object individuals.

   (b) $\mathfrak{Dom}_{\mathbf{Ev}}$ is a non-empty domain of event individuals.

   (c) $\mathfrak{Dom}_{\mathbf{Per}}$ is a non-empty domain of temporal period individuals (closed intervals).

   (d) $\mathfrak{Dom}_{\mathbf{Loc}}$ is a non-empty domain of location (or spatial area) individuals.

   (e) $\bot \in \mathfrak{Dom}$ and $\bot \notin \mathfrak{Dom}_{\mathbf{Obj}} \cup \mathfrak{Dom}_{\mathbf{Ev}} \cup \mathfrak{Dom}_{\mathbf{Per}} \cup \mathfrak{Dom}_{\mathbf{Loc}}$ (the undefined object which is in no subdomain).

   (f) $\mathfrak{Dom}_{\mathbf{Obj}} \cap \mathfrak{Dom}_{\mathbf{Ev}} = \{\}$, $\mathfrak{Dom}_{\mathbf{Obj}} \cap \mathfrak{Dom}_{\mathbf{Per}} = \{\}$, $\mathfrak{Dom}_{\mathbf{Obj}} \cap \mathfrak{Dom}_{\mathbf{Loc}} = \{\}$, $\mathfrak{Dom}_{\mathbf{Ev}} \cap \mathfrak{Dom}_{\mathbf{Per}} = \{\}$, $\mathfrak{Dom}_{\mathbf{Ev}} \cap \mathfrak{Dom}_{\mathbf{Loc}} = \{\}$, $\mathfrak{Dom}_{\mathbf{Per}} \cap \mathfrak{Dom}_{\mathbf{Loc}} = \{\}$.

   (g) $\mathfrak{Dom}_{\wp\tau} = \wp\mathfrak{Dom}_\tau$ (domains of sets of τ objects), where $\wp$ is used here as the power set operator in the meta-language and as a type constructor for the representation language.

   (h) $\mathfrak{Dom}_{\tau \mapsto \sigma} \subset (\mathfrak{Dom}_\sigma \cup \{\bot\})^{\mathfrak{Dom}_\tau}$ for $\sigma \in SType$ (possibly empty domains of partial functions from τ objects to σ objects). The inclusion of the undefined object into the range (as $\mathfrak{Dom}_\sigma \cup \{\bot\}$) allows us to define quasi-partial functions as functions which map some objects from their range to the undefined object.

Notice that $\mathfrak{Dom}_{\tau\mapsto\sigma}$ is only subset to the set of all possible functions with the specified domain and range. This is because, althought we explicitly have functional domains (and thus functions as first-class citizens), we strictly contemplate only explicitly defined functions (cf. 5.4.1.3) as is customary in many approaches to model-theoretic semantics. Only in some models for the λ-calculus, one sometimes needs all functional domains to provide denotations for all anonymous λ-functions (Carpenter, 1997:45).
[*Definition*]
The largest subset of $\mathfrak{Dom}_{\tau\mapsto\sigma}$ which contains only functions in $\mathfrak{Dom}_{\sigma}^{\mathfrak{Dom}_{\tau}}$ is called the *total functions* from τ objects to σ objects, and the subset of $\mathfrak{Dom}_{\tau\mapsto\sigma}$ which map at least one object from the domain $\mathfrak{Dom}_{\tau}$ to $\perp$ is called *truly partial functions* from τ objects to σ objects. We say that some function $f \in \mathfrak{Dom}_{\tau\mapsto\sigma}$ is *undefined for some* $x \in \mathfrak{Dom}_{\tau}$ if $f(x) = \perp$

3. $[\![\cdot]\!]$ is the interpretation function from **Exp** into $\mathfrak{Dom}$.

Note: Since set types are defined recursively, and since the definition of domains in (2g) depends on these type definitions, (2g) recursively defines set domains. The undefined object is not in any subdomain like $\mathfrak{Dom}_{\mathbf{Obj}}$ to avoid it being included in set domains, which would (among other things) be problematic for the account of quantification (cf. also Landman, 2000:44 who handles $\perp$ in a similar fashion for the same reasons.).

5.4.1.2 Structure

The term *parameter c* (or *c-parameter*) $\mathcal{P}_c$ is used here as an abbreviation for "member of $\mathfrak{Dom}_{\wp\mathbf{Ev}}$ characterized by constant c". Sometimes, "characterized by" means that a constant directly denotes the relevant set, sometimes the constant's denotation is related in a more complicated fashion to the set. The definition of $[\![\cdot]\!]$ later makes explicit which of these two options is the case.
For example: *event type (constant) parameters* are the members of $\mathfrak{Dom}_{\wp\mathbf{Ev}}$ denoted by the event type constants C_{etype}. The following axioms provide restrictions on the model, often in terms of parameters in this abbreviatory sense. The axioms are provided so as to make sure that for every expression of $\mathscr{L}_{\mathsf{GOA}}$, there are appropriate objects to refer to, which is non-trivial here mostly for event-denoting expressions, since the domain of events is constructed on the basis of the available expressions in a non-trivial fashion.
Note: The definition of $\mathfrak{Dom}_{\mathbf{Ev}}$ starts off with the fine-grained (cf. chapter 2) denotations of event type constants (cf. 4a below). Even though the interpretation of such constants (cf. definition of $[\![\cdot]\!]$ in 5.4.1.3) is then trivial, the definition is not circular or

void. It is important that there be a parameter for each event type constant which *in addition fulfills the other axioms*. These conditions are thus *general* in as much as it doesn't matter which or how many such event type constants there are in the representation language for any concrete natural language.

1. $\mathfrak{Dom}_{\mathbf{Obj}}$, $\mathfrak{Dom}_{\mathbf{Loc}}$ are arbitrary but fixed.

2. $\mathfrak{Dom}_{\mathbf{Per}}$ is the fixed set of temporal periods (closed intervals) defined over the real numbers, including the ususal properties of reals like being totally ordered by the $\leq$ relation, being dense (cf. Partee, ter Meulen and Wall, 1990:51), etc. Cf. Carpenter (1997:487) for a similarly compact introduction of time.

3. [*Defintion*]
   There are four functions in $\mathfrak{Dom}_{\mathbf{Obj}}^{\mathfrak{Dom}_{\mathbf{Ev}}}$ which we call role functions: $\mathcal{ext}$, $\mathcal{int}_1$, $\mathcal{int}_2$, $\mathcal{int}_3$, and which are denoted by **ext**, $\mathbf{int_1}$, $\mathbf{int_2}$, $\mathbf{int_3}$.
   [*Axiom*]
   Every role function is truly partial in the sense of 5.4.1.1/2h. For every role function r and every $\mathcal{P}_c$ with $c \in C_{etype}$, r is either defined for all members of $\mathcal{P}_c$, or r is defined for no member of $\mathcal{P}_c$.
   [*Elaboration*]
   It is a matter of lexical specification of any concrete natural language for which $\mathscr{L}_{\mathsf{GOA}}$ provides a translation whether for some $c \in C_{etype}$ r is defined for all members of $\mathcal{P}_c$ or whether it is undefined for all of them (Role Specification). The axiom is to make sure that there is no role funtion which for some event type is sometimes defined and sometimes not defined (this is similar to Landman, 2000:44).

4. The further axiomatization of $\mathfrak{Dom}_{\mathbf{Ev}}$ is split into two halves, where this list item and its subitems define a subset of $\mathfrak{Dom}_{\mathbf{Ev}}$ called $\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$ (where $\mathfrak{Dom}_{\wp\mathbf{Ev}}^{bas}$ is the subset of $\mathfrak{Dom}_{\wp\mathbf{Ev}}$ which is defined by $\wp\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$, etc.), which is the set of non-frame events. The second part can be found below in 5 and is concerned with the definition of frame events. $\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$ is the minimal set fulfilling these requirements:

   (a) [*Definition*]
   There is a finite number of non-empty sets in $\mathfrak{Dom}_{\wp\mathbf{Ev}}^{bas}$ called **event type (constant) parameters** or $\mathcal{P}_c^{bas}$ (one for each event type constant $c \in C_{etype}$); for example $\mathcal{P}_{\mathbf{run}}^{bas}$.
   [*Axiom*]

For any two such sets $\mathcal{P}^{bas}_{c_1}$, $\mathcal{P}^{bas}_{c_2}$: $\mathcal{P}^{bas}_{c_1} \cap \mathcal{P}^{bas}_{c_2} = \{\}$, and for the set C_{etype} of event type (constant)s c_3: $\mathfrak{Dom}^{bas}_{\mathbf{Ev}} = \bigcup_{c_3 \in C_{etype}} \mathcal{P}^{bas}_{c_3}$. The event type (constant) parameters are thus required to form a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$.

(b) [*Definition*]
There is a finite number of non-empty sets in $\mathfrak{Dom}^{bas}_{\wp\mathbf{Ev}}$ called **event property (constant) parameters** or $\mathcal{P}^{bas}_{c}$ (for each event property constant $c \in C_{eprop}$); for example $\mathcal{P}^{bas}_{\mathbf{quick}}$.

(c) [*Definition*]
There are two non-empty sets in $\mathfrak{Dom}^{bas}_{\wp\mathbf{Ev}}$ called the **positive and negative polarity (constant) parameter**, respectively, or $\mathcal{P}^{bas}_{+}$ and $\mathcal{P}^{bas}_{-}$ (denoted by **pos** and **neg**).
[*Axiom*]
$\mathcal{P}^{bas}_{+} \cap \mathcal{P}^{bas}_{-} = \{\}$ and $\mathfrak{Dom}^{bas}_{\mathbf{Ev}} = \mathcal{P}^{bas}_{+} \cup \mathcal{P}^{bas}_{-}$ and $Card(\mathcal{P}^{bas}_{+}) = Card(\mathcal{P}^{bas}_{-})$, where $Card$ is a function in the meta-language from sets into ω, giving the cardinality of a set. The positive and negative polarity constant parameters are thus required to form a partition with two equally sized cells on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$.

(d) [*Axiom*]
$\forall c \in C_{etype}[Card(\mathcal{P}^{bas}_{c} \cap \mathcal{P}^{bas}_{+}) = Card(\mathcal{P}^{bas}_{c} \cap \mathcal{P}^{bas}_{-})]$

(e) [*Theorem*]
$*S = \{S | \exists \mathcal{P}^{bas}_{pol} \in \{\mathcal{P}^{bas}_{-}, \mathcal{P}^{bas}_{+}\}[\exists c \in C_{etype}[S = \mathcal{P}^{bas}_{pol} \cap \mathcal{P}^{bas}_{c}]]\}$ is a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$.
[*Proof*]
The first condition of a partition $*T$ on some set T is that $\bigcup_{*T} = T$, which is given by the axioms in 4a and 4c.
As for the second condition: $\neg\exists T', T'' \in *T[T' \cap T'' \neq \{\}]$. Assume $*S$ ist not a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$. Then $\exists e[e \in S_1 \wedge e \in S_2]$ where $S_1, S_2 \in *S$. The sets $\mathcal{P}^{bas}_{+}$ and $\mathcal{P}^{bas}_{-}$ are required to form a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ by 4c, and thus $\neg\exists e[e \in \mathcal{P}^{bas}_{+} \wedge e \in \mathcal{P}^{bas}_{-}]$. The task thus reduces to showing that $\exists e'[e' \in S'_1 \wedge e' \in S'_2]$ where $S'_1, S'_2 \in *S'$ and $*S' = \{S' | \exists c \in C_{etype}[S' = \mathcal{P}^{bas}_{-} \cap \mathcal{P}^{bas}_{c}]\}$ (or the same for $\mathcal{P}^{bas}_{+}$ instead of $\mathcal{P}^{bas}_{-}$ in the definition of $*S'$). $*S'$ is a set of intersections of cells of a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ (because the event type parameters form a partition on $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ by 4b) with some subset $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ (namely $\mathcal{P}^{bas}_{-}$ or $\mathcal{P}^{bas}_{+}$, respectively), thus all sets in $*S'$ (including S'_1 and S'_2) must be (by the definition of intersection) subset or equal to some cell of a partition of $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$, which falsifies the assumption $\exists e'[e' \in S'_1 \wedge e' \in S'_2]$,

thus falsifying the inital assumption and thereby proving the theorem. □

(f) [*Definition 1*]
$peri$ is a total function in $\mathfrak{Dom}_{\mathbf{Per}}^{\mathfrak{Dom}_{\mathbf{Ev}}}$ denoted by **Peri**.
[*Definition 2 (Differentiation by temporal periods)*]
With the partition $*S$ as defined in 4e: $**S =$
$\{S'|\exists S \in *S[S' \subset S \wedge \exists p \in \mathfrak{Dom}_{\mathbf{Per}}[\forall e \in S[peri(e) = p \leftrightarrow e \in S']]]\}$

(g) [*Theorem*]
$**S$ is a partition on $\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$.
[*Proof*]
Assume $**S$ is not a partition on $\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$. Then $\exists e[e \in S_1 \wedge e \in S_2]$ where $S_1, S_2 \in **S$. Since all $S \in *S$ are disjoint by virtue of $*S$ being a partition (cf. 4e), we can restrict our search to two subsets S'_1, S'_2 of some $S \in *S$ where $S'_1, S'_2 \in **S$. Then, by the definition of $**S$, there must be two $p_1, p_2 \in \mathfrak{Dom}_{\mathbf{Per}}$ for some e such that $peri(e) = p_1 \wedge peri(e) = p_2$ so that $e \in S_1 \wedge e \in S_2$, which is impossible since $peri$ is a function by definition. This proves the theorem by contradiction. □

(h) [*Definition 1*]
$locat$ is a total function in $\mathfrak{Dom}_{\mathbf{Loc}}^{\mathfrak{Dom}_{\mathbf{Ev}}}$ denoted by **Locat**.
[*Definition 2 (Differentiation by spatial locations)*]
With the partition $**S$ as defined in 4f: $***S =$
$\{S'|\exists S \in **S[S' \subset S \wedge \exists l \in \mathfrak{Dom}_{\mathbf{Loc}}[\forall e \in S[locat(e) = l \leftrightarrow e \in S']]]\}$

(i) [*Theorem/Proof*]
$***S$ is a partition on $\mathfrak{Dom}_{\mathbf{Ev}}^{bas}$. The proof is parallel to the one in 4g.

(j) [*Definition (Differentiation for external participance)*]
With the partition $***S$ as defined in 4h: $*^4S =$
$\{S'|\exists S \in ***S[S' \subset S \wedge \exists o \in \mathfrak{Dom}_{\mathbf{Obj}}[\forall e \in S[ext(e) = o \leftrightarrow e \in S']]]\}$

(k) [*Definition (Differentiation for first internal participance)*]
With the partition $*^4S$ as defined in 4j: $*^5S =$
$\{S'|\exists S \in *^4S[S' \subset S \wedge \exists o \in \mathfrak{Dom}_{\mathbf{Obj}}[\forall e \in S[int_1(e) = o \leftrightarrow e \in S']]]\}$

(l) [*Definition (Differentiation for second internal participance)*]
With the partition $*^5S$ as defined in 4k: $*^6S =$
$\{S'|\exists S \in *^5S[S' \subset S \wedge \exists o \in \mathfrak{Dom}_{\mathbf{Obj}}[\forall e \in S[int_2(e) = o \leftrightarrow e \in S']]]\}$

(m) [*Definition (Differentiation for third internal participance)*]
With the partition $*^6S$ as defined in 4l: $*^7S =$
$\{S'|\exists S \in *^6S[S' \subset S \wedge \exists o \in \mathfrak{Dom}_{\mathbf{Obj}}[\forall e \in S[int_3(e) = o \leftrightarrow e \in S']]]\}$

(n) [*Theorem/Proof*]

$*^7 S$ is a partition on $\mathfrak{Dom}_{\mathbf{Ev}}$. The proof (to be conducted recursively for 4j through 4m) is parallel to the one in 4i.

(o) [*Definition*]

$*\mathcal{P}_{eprop} = \{\mathcal{P}_c | c \in C_{eprop}\}$

[*Axiom*] (Construction of event properties)

With the definition of $*^7 S$ as in 4m, for all models $\mathfrak{M}$ of $\mathscr{L}_{\mathsf{GOA}}$:

$$\forall S \in *^7 S[\forall \mathcal{P}' \in (\wp(*\mathcal{P}_{eprop}) - \{\})$$
$$[\exists e \in ((\bigcap \mathcal{P}') \cap S)[\forall Q \in *\mathcal{P}_{eprop}[Q \notin \mathcal{P}' \leftrightarrow e \notin ((\bigcap \mathcal{P}') \cap S \cap Q)]]]]$$

[*Notes*]

I overload $\bigcap$ here for reasons of notational compactness. Applied to a set of sets S, $\bigcap S$ is meant to resolve to: $\bigcap_{s \in S} s$.

Event property sets are different from the previously introduced sets (which all formed partitions) because they can overlap. To make sure that $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ contains all events which are discernable by event property constants, we need to make sure that for each cell in the partition given by $*^7 S$, and for each possible intersection I of event property sets with that cell, there is one event which is not contained in any set defined by intersecting I with an additional event property set. This axiom is to make sure that this is the case.

5. We now introduce frame events into $\mathfrak{Dom}_{\mathbf{Ev}}$ by cyclic formation of frames of n-th order. Some readers might be inclined to think that these could be better introduced via a mereological account. The fact that every frame formation involves a positive and a negative frame event, and the fact that frames can be formed recursively make it not feasible to use a standard mereological formulation. If any, frames would be more like groups in the sense of Link (1983) or Landman (2000), but in a manner that there would have to be groups of groups. The primary argument against frames as sums, however, is that in a sum structure (like the part-of structures of Landman, 2000:96-105), if a is a part of b, and b is a part of c, then a is also a part of c. In such a mereological structure, we would lose relevant structure of frames, a fact which should become clear in section 5.4.2 in the definitions of contradiction in models when frames are involved.

   (a) [*Definition*]

   To allow for a more general formulation, we introduce an alias for $\mathfrak{Dom}^{bas}_{\mathbf{Ev}}$ (and similarly all set and function domains specified using the exponent *bas*): $\mathfrak{Dom}_{\mathbf{Ev}}^{fra_0} = \mathfrak{Dom}_{\mathbf{Ev}}^{bas}$.

(b) [*Definition*]
Generally, domains of frame events are specified as $\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$ with $n \in \omega$. We call $\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$ the set of frames of n-th order.
[*Axiom*]
$\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n} \subset \mathfrak{Dom}_{\mathbf{Ev}}$ and $\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n} \cap \mathfrak{Dom}_{\mathbf{Ev}}^{fra_{n+1}} = \{\}$. Even more generally: for all $n, m \in \omega$, if $n \neq m$ then $\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n} \cap \mathfrak{Dom}_{\mathbf{Ev}}^{fra_m} = \{\}$.

(c) [*Axiom*]
The two **framing functions** $\boxplus$ and $\boxminus$ in $\mathfrak{Dom}_{\mathbf{Ev}}^{\mathfrak{Dom}_{\wp\mathbf{Ev}}}$ are defined for every $E \in \mathfrak{Dom}_{\wp\mathbf{Ev}}^{fra_n}$ (with $n \in \omega$), s.t. $\boxplus E \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_{n+1}}$ (similarly, for every $E \in \mathfrak{Dom}_{\wp\mathbf{Ev}}^{fra_n}$, $\boxminus E \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_{n+1}}$). Furthermore, for every such E, it is the case that $\boxplus E \in \mathcal{P}_+$ and $\boxminus E \in \mathcal{P}_-$.

(d) [*Axiom*]
$\mathfrak{Dom}_{\mathbf{Ev}} = \bigcup_{n \in \omega} \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$.

(e) [*Definition*]
Given $\boxplus$ and $\boxminus$, the **frame inclusion relation** $\boxdot$ is defined: $e_1 \boxdot e_2$ iff for some E, $e_1 \in E$ and $[e_2 = \boxplus E$ or $e_2 = \boxminus E]$.[5] We require that $\boxdot$ is asymmetric, and especially that it is intransitive, i.e. if $a \boxdot b$ and $b \boxdot c$, then necessarily not $a \boxdot c$.

(f) [*Axiom*]
$\forall n, m \in \omega[(n < m) \leftrightarrow (\neg \exists e \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_m}[\exists e' \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}[e \boxdot e']])]$

(g) [*Definition*]
The **canvas function** $\boxed{\boxdot}$: For $e_1 \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$ with $n \geq 1$: $\boxed{\boxdot} e_1 = \{e_2 \in \mathfrak{Dom}^{fra_{n-1}} | e_2 \boxdot e_1\}$.

(h) [*Axiom*]
For all role functions r (where $r \in \{\mathfrak{ext}, int_1, int_2, int_3\}$), for every $E \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$ such that for all $e \in E$, $r(e) = o$: $r(\boxplus E) = r(\boxminus E) = o$. Otherwise, $r(\boxplus E) = r(\boxminus E) = \perp$.

(i) [*Definition*]
Let $\mathfrak{lep}$ be the function which gives the left endpoint (a real number) of a time period, and $\mathfrak{rep}$ the function which gives its right endpoint.

(j) [*Axiom*]
For every frame $\mathfrak{e} = \boxplus(E)$ for some set of events E (or $\mathfrak{e} = \boxminus(E)$): $\mathfrak{peri}(\mathfrak{e}) = [i, j]$ where $i = min\{k | \exists e \in E[k = \mathfrak{lep}(e)]\}$ and $j = max\{k | \exists e \in E[k = \mathfrak{rep}(e)]\}$.

[5] Brackets indicate that the *or*-term is the second argument of the *and*-term.

(k) [*Axiom*]
For all functions with domain and range in $\mathfrak{Dom}_{\mathbf{Ev}}$ (or any set domain constructed from $\mathfrak{Dom}_{\mathbf{Ev}}$), domain and range are required to respect frame order, i.e. they map from (sets of) frames of n-th order to (sets of) frames of n-th order *unless explicitly stated otherwise*. In fact, the only functions which do not respect frame order are $\boxplus$ and $\boxminus$.

6. [*Axiom*]
For every $e \in \mathfrak{Dom}_{\mathbf{Ev}}^{fro_0}$ the **polarity mirror function** $\varobar$ in $(\mathfrak{Dom}_{\mathbf{Ev}}^{fra_0})^{(\mathfrak{Dom}_{\mathbf{Ev}}^{fra_0})}$ is defined. Furthermore, $\varobar$ is a bijection between $\mathcal{P}_+^{fra_0}$ and $\mathcal{P}_-^{fra_0}$ which gives for every e an otherwise identically specified event.
[*Elaboration*]
Constructively: With $*\mathcal{P}_{etype} = \{\mathcal{P} | \exists c \in C_{etype}[\mathcal{P} = \mathcal{P}_c]\}$ and $*\mathcal{P}_{eprop} = \{\mathcal{P} | \exists c \in C_{eprop}[\mathcal{P} = \mathcal{P}_c]\}$: For $e, e' \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_0}$:

$$
\begin{aligned}
& e = \varobar e' \text{ and } e' = \varobar e \text{ iff} \\
& \quad (e \in \mathcal{P}_+ \leftrightarrow e' \in \mathcal{P}_-) \wedge (e \in \mathcal{P}_- \leftrightarrow e' \in \mathcal{P}_+) \\
& \quad \wedge (peri(e) = peri(e')) \wedge (locat(e) = locat(e')) \\
& \quad \wedge (\forall \mathcal{P}_1 \in *\mathcal{P}_{etype}[e \in \mathcal{P}_1 \leftrightarrow e' \in \mathcal{P}_1]) \\
& \quad \wedge (\forall \mathcal{P}_2 \in *\mathcal{P}_{eprop}[e \in \mathcal{P}_2 \leftrightarrow e' \in \mathcal{P}_2]) \\
& \quad \wedge (ext(e) = ext(e')) \wedge (int_1(e) = int_1(e')) \\
& \quad \wedge (int_2(e) = int_2(e')) \wedge (int_3(e) = int_3(e'))
\end{aligned}
$$

[*Definition*]
For e and e', we also write e and $\bar{e}$ to indicate that $e = \varobar \bar{e}$ and $\bar{e} \in \mathcal{P}_-$.

7. [*Axiom*]
For every $e \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$ where $n \geq 1$, the polarity mirror function $\varobar$ is defined in $(\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n})^{(\mathfrak{Dom}_{\mathbf{Ev}}^{fra_n})}$. For every $\mathcal{P}_-^{fra_n}$ and $\mathcal{P}_-^{fra_n}$, $\varobar$ is a bijection between them. Furthermore, for every $e, e' \in \mathfrak{Dom}_{\mathbf{Ev}}^{fra_n}$: $e = \varobar e'$ and $e' = \varobar e$ iff $(\boxbox e = \boxbox e') \wedge (e \in \mathcal{P}_+ \leftrightarrow e' \in \mathcal{P}_-)$.

5.4.1.3 Interpretation

$[\![\cdot]\!]$ is defined:

1. For all c where $Ty[c] \in SType$, $[\![c]\!]$ is the object denoted by c.

2. For every individual constant $c_{ind_i} \in C_{ind}$ there is exactly one name constant in $c_{name_i} \in C_{name}$ such that if $[\![c_{ind_i}]\!] = o$, then $[\![c_{name_i}]\!] = \{\{o\}\}$.

3. For every noun constant $c_{noun_i} \in C_{noun}$, $[\![c_{noun_i}]\!]$ is the set of i-objects (like frogs, pigs, or jokes).

4. For every adjectival constant $c_{adj_i} \in C_{adj}$ there is exactly one intersector constant $c_{inters_i} \in C_{inters}$ such that if $[\![c_{adj_i}]\!] = S$, then $[\![c_{inters_i}]\!] = f$ where f is exactly the function in $\mathfrak{Dom}_{\wp\mathbf{Obj}}^{\mathfrak{Dom}_{\wp\mathbf{Obj}}}$ such that for every set $T \in \mathfrak{Dom}_{\wp\mathbf{Obj}}$, $f(T) = T \cap S$.

5. Determiner operators $c_{det_i} \in C_{det}$ are interpreted $[\![c_{det_i}]\!] = f_{c_{det_i}}$ where $f_{c_{det_i}}$ is a function in $\mathfrak{Dom}_{\wp\wp\mathbf{Obj}}^{\mathfrak{Dom}_{\wp\mathbf{Obj}}}$, such that for every $S \in \mathfrak{Dom}_{\wp\mathbf{Obj}}$:

   (a) $f_{\mathbf{all}}(S) = \{T \in \wp S | T = S\} = \{S\}$

   (b) $f_{\mathbf{some}}(S) = \{T \in \wp S | T \neq \{\}\} = \wp S - \{\}$

   (c) $f_{\mathbf{3}}(S) = \{T \in \wp S | Card(T) \geq 3\}$

   (d) $f_{\mathbf{3!}}(S) = \{T \in \wp S | Card(T) = 3\}$

   (e) $f_{\mathbf{most}}(S) = \{T \in \wp S | Card(T) > Card(S - T)\}$ etc.

6. For every event type constant $c_{etype_i} \in C_{etype}$, $[\![c_{etype_i}]\!] = \mathcal{P}^{bas}_{etype_i} \cap \mathcal{P}^{bas}_{+}$.

7. For every event property constant $c_{eprop_i} \in C_{eprop}$, $[\![c_{eprop_i}]\!] = \mathcal{P}^{bas}_{eprop_i} \cap \mathcal{P}^{bas}_{+}$.

8. For every event property constant $c_{eprop_i} \in C_{eprop}$ there is exactly one subset operator $c_{subset_i} \in C_{subset}$ such that if $[\![c_{eprop_i}]\!] = S$ then $[\![c_{subset_i}]\!] = f$ where f is exactly the function in $\mathfrak{Dom}_{\wp\mathbf{Ev}}^{\mathfrak{Dom}_{\wp\mathbf{Ev}}}$ such that for every set $T \in \mathfrak{Dom}_{\wp\mathbf{Ev}}$, $f(T) = T \cap S$.

9. For each role functor $c_{role_i} \in C_{role}$ there is exactly one thematic operator $c_{theta_i} \in C_{theta}$ (**Ext** for **ext**, $\mathbf{Int_1}$ for $\mathbf{int_1}$, etc.) such that if $[\![c_{role_i}]\!] = f$, where f is a function in $\mathfrak{Dom}_{\mathbf{Obj}}^{\mathfrak{Dom}_{\mathbf{Ev}}}$ (from events to participant objects), then $[\![c_{theta_i}]\!] = g$, where g is exactly the function in $(\mathfrak{Dom}_{\wp\wp\mathbf{Ev}}^{\mathfrak{Dom}_{\wp\wp\mathbf{Ev}}})^{\mathfrak{Dom}_{\wp\wp\mathbf{Obj}}}$ such that for every $S \in \mathfrak{Dom}_{\wp\wp\mathbf{Obj}}$ and every $T \in \mathfrak{Dom}_{\wp\wp\mathbf{Ev}}$:
   $g(S)(T) =$
   $$\{U | \exists O \in S[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[f(e) = o]]] \wedge$$
   $$\forall o \in O[\exists E'' \in E[\forall e' \in E''[f(e') = o]]]]]\}$$
   [*Note*]
   I overload $\bigcup$ here for reasons of notational compactness. Applied to a set of sets S, $\bigcup S$ is meant to resolve to: $\bigcup_{s \in S} s$.

10. Prepositional operators always depend on a specific function or relation between events and other individuals (like times, spaces, and non-event objects) to express

that some event happens *in* some place(s), *at* a certain temporal interval, *with the aid of* some object, or similar. This function is not predictable, but a matter of lexical specification (possibly requiring extensions to the models of $\mathscr{L}_{\mathsf{GOA}}$).[6] Therefore, given that the interpretation of prepositional operators is otherwise similar to that of thematic operators, I here provide merely an *ad hoc* sample definition of a prepositional operator **at** with $[\![\mathbf{at}]\!] = \mathit{at}$ such that:

$$\mathit{at}(S)(T) =$$
$$\{U|\exists L \in S[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists l \in L[\forall e \in E'[\mathit{locat}(e) = l]]] \wedge \forall l \in L[\exists E'' \in E[\forall e' \in E''[\mathit{locat}(e') = l]]]]]\}$$

11. The raise-to-verb operator **Verb** is interpreted: $[\![\mathbf{Verb}]\!] = f$ where f is the function in $\mathfrak{Dom}_{\wp\wp\mathbf{Ev}}^{\mathfrak{Dom}_{\wp\mathbf{Ev}}}$ such that for every $S \in \mathfrak{Dom}_{\wp\mathbf{Ev}}$, $f(S) = \wp S$.

12. The polarity constants **pos** and **neg** are interpreted: $[\![\mathbf{pos}]\!] = \mathcal{P}_+$ and $[\![\mathbf{neg}]\!] = \mathcal{P}_-$.

13. The interpretation of the identity operator: $[\![\mathbf{Id}]\!] = f$ such that for any $A \in \mathfrak{Dom}$, $f(A) = A$.

14. $[\![\overline{\mathbf{p}}]\!] = f$ where f is the function in $\mathfrak{Dom}_{\wp\mathbf{Ev}}^{\mathfrak{Dom}_{\wp\mathbf{Ev}}}$ such that for every $S \in \mathfrak{Dom}_{\wp\mathbf{Ev}}$: $f(S) = \{e|\exists e' \in S[e = \Phi e']\}$.

15. Given the interpretation of the low polarity operator $[\![\overline{\mathbf{p}}]\!] = f$, the high polarity operator $\overline{\mathbf{P}}$ is interpreted $[\![\overline{\mathbf{P}}]\!] = g$ where g is the function such that for every $S \in \mathfrak{Dom}_{\wp\wp\mathbf{Ev}}$: $g(S) = \{U|\exists T \in S[U = f(T)]\}$.

16. For the complementation operator **Cmp**, $[\![\mathbf{Cmp}]\!] = f$ such that for any $A \in \mathfrak{Dom}_A$, $f(A) = \mathfrak{Dom}_A - A$. For practical application, one must almost always assume that the complementation operator is interpreted as a derived function f' which takes a contextually salient subset $C_A \subset \mathfrak{Dom}_A$ and that $f'(A) = C_A - A$ (especially for huge domains).

17. For the interpretation of the period functor **Peri** and the location functor **Locat**, see 5.4.1.2/4f and 5.4.1.2/4h, respectively.

18. $[\![\dot{\mathbf{r}}]\!] = \boxplus$

[6] A general merger of thematic operators and prepositional operators might be considered, reducing all argument and adjunct semantics to the notion of *role*. However, many prepositional terms can (or rather *could*, in a richer fragment) modify event- and object-denoting expressions, which is usually not true for agent or other core role-encoding terms. This is the reason I kept both kinds of operators apart.

19. $[\![\dot{\mathbf{R}}]\!] = f$ where f is the function in $(\mathfrak{Dom}^{fra_n}_{\wp\wp\mathbf{Ev}})^{\mathfrak{Dom}^{fra_{n-1}}_{\wp\wp\mathbf{Ev}}}$ such that for all $E \in \mathfrak{Dom}^{fra_{n-1}}_{\wp\wp\mathbf{Ev}}$, $f(E) = \wp\{\mathfrak{e} | \exists E' \in E[\mathfrak{e} = \boxplus(E')]\}$.

5.4.2 Secondary Models and Discourse Construction

1. The abstract model $\mathfrak{M}$ is identically specified for all speakers. We refer to the interpretation function specified above for $\mathfrak{M}$ as $[\![\cdot]\!]^{\mathfrak{M}}$.

2. A **secondary model** derived from $\mathfrak{M}$ is $\mathscr{M} = \mathbf{Dom}$ where $\mathbf{Dom} = \mathbf{Dom_{Obj}} \cup \mathbf{Dom_{Ev}} \cup \mathbf{Dom_{Per}} \cup \mathbf{Dom_{Loc}}$ and $\mathbf{Dom_{Obj}} = \mathfrak{Dom}_{\mathbf{Obj}}$, $\mathbf{Dom_{Per}} = \mathfrak{Dom}_{\mathbf{Per}}$, $\mathbf{Dom_{Loc}} = \mathfrak{Dom}_{\mathbf{Loc}}$ and $\mathbf{Dom_{Ev}} \subseteq \mathfrak{Dom}_{\mathbf{Ev}}$.
   Note: It is for convenience that secondary models are called "models" here. They merely represent static knowledge about object, period, and location individuals (called "static" because they are identical with the domains of $\mathfrak{M}$) and (non-static) knowledge about events. Compared to both standard models and the abstract model defined here, they lack an interpretation function.

3. A **discourse** D of affirmative statements[7] perceived by a hearer is a tuple $D = \langle I, K \rangle$ of a list (n-tuple) of sentences $I = \langle \alpha_1, .., \alpha_n \rangle$ and a set of assumable mental models $K = \{\mathscr{M}_1, .., \mathscr{M}_m\}$.[8]

4. A **stage of a discourse** is characterized by there being n sentences in I. We speak of *stage n* of discourse D: $D_n = \langle I_n, K_n \rangle$.

5. For every discourse D, the **initial stage** D_0 is the stage where no sentence has been uttered: $D_0 = \langle \langle \rangle, \{\} \rangle$.

6. An **update** from stage n consists in appending a sentence α_{n+1} to I: $D_{n+1} = \langle \langle I_n, \alpha_{n+1} \rangle, K_{n+1} \rangle$.

7. At any stage n (prototypically after an update), the **consistency** of the discourse can be determined because K_n is defined via I_n by **secondary model formation**, a process by which all states of affairs compatible with the knowledge transmitted in the discourse are calculated. The states of affairs compatible with the knowledge transmitted are represented by the set of construable mental models K_n.

[7] We only contemplate discourses which are constructed from simple affirmative statements in this study.

[8] This is the simplest possible structure. For a more advanced modeling, I might be better conceived as a tree or heap structure, for example.

8. K_n is a **set of secondary models** which represent (in terms of events) what can be assumed to the case given a certain collection of informative sentences. All subdomains are taken over from $\mathfrak{M}$, except $\mathbf{Dom_{Ev}}$. Therefore, with:
$$E'_n = \{E|(\exists E_1 \in [\![\alpha_1]\!]^{\mathfrak{M}})(\exists E_2 \in [\![\alpha_2]\!]^{\mathfrak{M}})..(\exists E_n \in [\![\alpha_n]\!]^{\mathfrak{M}})[E = \bigcup_{m=1}^{n} E_m])\}$$
K_n is specified:
$$K_n = \{\mathscr{M}|\exists E \in E'_n[\mathscr{M} = \mathfrak{Dom}_{\mathbf{Obj}} \cup \mathfrak{Dom}_{\mathbf{Per}} \cup \mathfrak{Dom}_{\mathbf{Loc}} \cup E]\}$$
By interpreting each sentence in the abstract model, we get the sets of sets of events it can possibly denote, which is a specification of what information the sentence conveys. By forming the union of every possible permuation of denotata of all sentences perceived so far, the totality of information about events which was transmitted can be calculated.
Negation complicates the picture by its exhaustivity. More on this exhaustivity requirement is said in 5.5.2.1.

9. The interpretations of any sequence of n sentences (with $n \in \omega$ and $n > 0$) can be modified by an interpretation condition Σ before the update. If some interpretation condition Σ is applicable for $\alpha_1,..,\alpha_n$, we write $\Sigma(\alpha_1,..,\alpha_n)$. We write $\langle\alpha_1,..,\alpha_n\rangle \overset{IC}{\Longrightarrow} \Sigma(\alpha_1,..,\alpha_n)$ to indicate that a sequence α_1 through α_n of sentences is interpreted not directly in $\mathfrak{M}$, but by applying inerpretation condition Σ. Some of these interpretation conditions are introduced in 5.5.2.1 and later.

10. In a coherent discourse, there is either no contradictory information, or conflict between bits of information must be resolved in some way. We resolve contradiction by removing models from K_n. First, we proceed to a definition of contradiction:[9]

    (a) For any $\mathscr{M}_m \in K_n$ (where $\mathbf{Dom_{Ev}}_m$ is the domain of events in $\mathscr{M}_m$), $\mathscr{M}_m$ is contradictory if $\exists e_1, e_2 \in \mathbf{Dom_{Ev}}_m[e_1 = \oplus e_2]$.

    (b) For any $\mathscr{M}_m \in K_n$, $\mathscr{M}_m$ is contradictory if $\exists \mathfrak{e}_1 \in \mathbf{Dom_{Ev}}_m[(\mathfrak{e}_1 \in \mathscr{P}_+) \wedge (\exists e_2 \in \mathfrak{Dom}_{\mathbf{Ev}}[\exists e_3 \in \mathbf{Dom_{Ev}}_m[(e_2 \boxdot \mathfrak{e}_1) \wedge (e_2 = \oplus e_3)]])]$.

    (c) For any $\mathscr{M}_m \in K_n$, $\mathscr{M}_m$ is contradictory if $\exists \mathfrak{e}_1 \in \mathbf{Dom_{Ev}}_m[(\mathfrak{e}_1 \in \mathscr{P}_-) \wedge (\boxdot \mathfrak{e}_1 \subseteq \mathbf{Dom_{Ev}}_m)]$.

    (d) For any $\mathscr{M}_m \in K_n$, $\mathscr{M}_m$ is contradictory if any lexical-conceptual constraint (roughly: a meaning postulate) specifies that for some $e_1, e_2 \in \mathbf{Dom_{Ev}}_m$ it

[9] Readers should not take this notion of contradiction as too closely related to the logical notion of contradiction. If any, classical cases of contradiction are rather cases of *full contradiction* here, and they will be discussed further in 5.5.

is impossible to co-occur in a mental model. Such constraints involve, for example, ones which state that one object cannot run at one temporal period and sleep at an overlapping temporal period, that one individual cannot run on Mars and run on the Earth at overlapping temporal periods, or even that no individual can ever run on the Moon (because running is impossible under the weak gravitational force of the Moon) etc.

11. Contradictory models are removed from K_n on secondary model formation. As will be shown in 5.5, removing contradictory models is the standard process by which the information state becomes more specific. It is not in itself a non-monotonic behavior.

12. **Full contradiction**: An utterance α_{n+1} fully contradicts a non-empty and possibly singleton set of utterances I_n iff for stage $D_n = \langle I_n, K_n \rangle$, $K_n \neq \{\}$ and for the updated stage $D_{n+1} = \langle \langle I_n, \alpha_{n+1} \rangle, K_{n+1} \rangle$, $K_{n+1} = \{\}$.

13. In the case of full contradiction at stage $n+1$, removal of utterances from I_{n+1} is required, which is either **rejection** of the newly acquired utterance α_{n+1}, or it is a truly **non-monotonic** update if a non-empty set of sentences α_m with $m \leq n$ is removed.

14. Which sentences are removed cannot be predicted in a fully automatic fashion, because the decision depends on many factors, especially plausibility judgements by the respective language user. As a general default, it can be assumed that the smallest set of sentences is removed which resolves the case of full contradiction.

5.5 Inference and Coherence

In this section, I show what it means for a sentence to imply and to not imply another sentence in the framework presented here (5.5.1). Also, cases of full contradiction will be discussed further (5.5.2), and it will be shown how negation interacts with sentential conjunction and disjunction (5.5.2.2). Finally, a sketch of how implication can be handled is provided in 5.5.2.4.

5.5.1 Consequence

5.5.1.1 Necessary Consequences

5.5.1.1.1 Definition A semantic theory should predict which conclusions from one sentence to another sentence have the status of being trivial. These include the following ones, for example:

(1) Kermit walks. ⊩ Someone walks.

(2) Three frogs walk. ⊩ Some frog walks.

(3) Miss Piggy walks quicky. ⊩ Miss Piggy walks.

To deal with cases like (1) through (3), a formal definition of what a necessary consequence is is required. Intuitively, sentence α_2 is a consequence of sentence α_1 iff sentence α_1 provides more specific information than sentence α_2, which is the case in all three examples. In terms of sentence denotations for $\mathscr{L}_{\mathsf{GOA}}$, this can be captured formally as follows.

Consequence α_2 is a consequence of α_1 (written $\alpha_1 \Vdash \alpha_2$) iff for all models of $\mathscr{L}_{\mathsf{GOA}}$: $[\![\alpha_1]\!]^{\mathfrak{M}} \subseteq [\![\alpha_2]\!]^{\mathfrak{M}}$.

Note: The models of $\mathscr{L}_{\mathsf{GOA}}$ can be distinct by virtue of containing differing sets of objects, locations and temporal intervals. Given these domains, the possible events of some model of $\mathscr{L}_{\mathsf{GOA}}$ are fixed mechanically.
This definition captures the fact that, if every possible set of event in the denotation of the more specific sentence is also in the denotation of the more general sentence, then the states of affairs described by the more specific sentence (α_1) are completely contained in the states of affairs described by the less specific sentence (α_2).
Remember that every single set of events in a sentence's denotation, if found in the "real world", would render the sentence true in a classical predicate-logic-based setting. This insight might help to understand why the definition of consequence given here is adequate: If the sets which make one sentence α_1 true are the same as or just less than those which make some other sentence α_2 true, then α_1 clearly only describes circumstances which also make α_1 true.
The simplest case is self-consequence. Is, according to the above definition, every sentence a necessary consequence of itself? This is of course trivially the case since $[\![\alpha_n]\!]^{\mathfrak{M}} = [\![\alpha_n]\!]^{\mathfrak{M}}$.

5.5.1.1.2 Specific Individuals and *something* I now take the above definition to demonstrate how (4) turns out as a consequence.

(4) Kermit walks. ⊩ Someone walks.

The final translation of (4) into $\mathscr{L}_{\mathsf{GOA}}$ is given in (5). Please cf. 5.6 for a more thorough demonstration of how such translations are derived, and how the lexical entries are specified. We assume here that *walk* assigns the external theta role, and we decompose *someone* as *some creature* (which would probably be replaced by *some human* in a less Jim-Henson-ish world).

(5) $\textbf{Ext}(\textbf{kermit})(\textbf{Verb}(\textbf{walk})) \Vdash \textbf{Ext}(\textbf{some}(\textbf{creature}))(\textbf{Verb}(\textbf{walk}))$

The two denotations can be derived as specified in (6) and (7). I use syncategorematic interpretations of operators where such interpretations were defined to keep the derivation shorter and more compact. Also notice that I assume that the individual *Kermit the Frog* exists in $\mathfrak{Dom}_{\textbf{Obj}}$ by virtue of there being a constant denoting it.

(6)
1. $[\![\textbf{walk}]\!]^{\mathfrak{M}} = \mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+}$ by 5.4.1.3/6)
2. $[\![\textbf{Verb}(\textbf{walk})]\!]^{\mathfrak{M}} = \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$ (by 5.4.1.3/11)
3. $[\![\textbf{kermit}]\!]^{\mathfrak{M}} = \{\{k\}\}$ (where k is Kermit the Frog, by 5.4.1.3/2)
4. $[\![\textbf{Ext}(\textbf{kermit})(\textbf{Verb}(\textbf{walk}))]\!]^{\mathfrak{M}} = \ldots$
   $\{U|\exists O \in \{\{k\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$
   $[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$
   $\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$
   (by 5.4.1.3/9 and the previous steps)

(7)
1. $[\![\textbf{walk}]\!]^{\mathfrak{M}} = \mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+}$ by 5.4.1.3/6)
2. $[\![\textbf{Verb}(\textbf{walk})]\!]^{\mathfrak{M}} = \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$ (by 5.4.1.3/11)
3. $[\![\textbf{creature}]\!] = C$ where C is the set of creature-objects (by 5.4.1.3/3)
4. $[\![\textbf{some}(\textbf{creature})]\!] = \{T \in \wp C | T \neq \{\}\} = \wp C - \{\}$ (by 5.4.1.3/5)
5. $[\![\textbf{Ext}(\textbf{some}(\textbf{creature}))(\textbf{Verb}(\textbf{walk}))]\!]^{\mathfrak{M}} =$
   $\{U|\exists O \in (\wp C - \{\})[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$
   $[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$
   $\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$
   (by 5.4.1.3/9 and the previous steps)

Assuming that $k \in C$ is part of the model specification, we can be sure that $\{\{k\}\} \subseteq \wp C - \{\}$ by the definition of $\wp$. Given that, since the interpretations of the formulae (6.4) and (7.5) define the sets of sets U such that there is some set in $\{\{k\}\}$ and $\wp C - \{\}$, respectively, for which the other conditions hold, we can be sure that whenever the conditions hold for $\{k\}$, they hold for at least one member in $\wp C - \{\}$ (namely $\{k\}$). This is sufficient to prove (5) under our definition of $\Vdash$.

This generalizes to any creature-denoting constant (similar to **kermit**, such as **piggy**). Also, it generalizes to the similar case of any object-denoting (instead of creature-denoting) constant $c \in C_{ind}$ and the constant $\textbf{object} \in C_{noun}$ (where $[\![\textbf{object}]\!] = \mathfrak{Dom}_{\textbf{Obj}}$), assuming $\textbf{some}(\textbf{object})$ as the $\mathscr{L}_{\mathsf{GOA}}$ translation of *something*.

5.5.1.1.3 Numeral Determiners Can (9) be proven, given the $\mathscr{L}_{\mathsf{GOA}}$ translations in (8)?

(8) Three frogs walk. ⊩ Some frog walks.

(9) $\mathbf{Ext}(\mathbf{3}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk})) \Vdash \mathbf{Ext}(\mathbf{some}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))$

I provide here only the interpretations of the full formulae directly, since they are compositionally built up exactly like (7). The interpretations are given in (10) and (11)

(10) $[\![\mathbf{Ext}(\mathbf{3}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}} =$
$$\{U|\exists O \in \{T \in \wp F|Card(T) \geq 3\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$$
where F is the set of frog-objects

(11) $[\![\mathbf{Ext}(\mathbf{some}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}} =$
$$\{U|\exists O \in \wp F - \{\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$$
where F is the set of frog-objects

It is again sufficient to concentrate on the existential condition after the set constructor in the interpretations of the two formulae. From the definition of $\wp$, it can be concluded that $\{T \in \wp F|Card(T) \geq 3\} \subset \wp F - \{\}$, because $\{T \in \wp F|Card(T) \geq 3\}$ is $\wp F$ with all sets removed which have less than three (including zero) members. This is again enough to prove that (11) is a consequence of (10) under our definition of consequence. This generalizes to cases with any two non-strict numeral determiners where the encoded cardinalities are not equal (i.e., one cardinality is higher than the other). It also generalizes to all formulae containing strict numeral determiners (!**3** corresponding to English *exactly three*, etc.) which imply the formula with the corresponding non-strict determiner, since $[\![!\mathbf{3}(\mathbf{frog})]\!]^{\mathfrak{M}} \subset [\![\mathbf{3}(\mathbf{frog})]\!]^{\mathfrak{M}}$, etc.
For the special case that there are less than three (or generally: n) relevant objects (frogs, in the above example) in $\mathfrak{M}$, we get $[\![\alpha_1]\!]^{\mathfrak{M}} \subseteq [\![\alpha_2]\!]^{\mathfrak{M}} \rightsquigarrow \{\} \subseteq S$ where S is a possibly empty set of sets of events denoted by α_2. This is always true since the empty set is subset to any set by definition.

5.5.1.2 Contingent Cases

One usually distinguishes cases which are *contingent on the model* (in a predicate-logical setting). One such case is the one in (12), translated as (13):

(12) Every frog walks. $\nVdash$ Three frogs walk.

(13) $\mathbf{Ext}(\mathbf{every}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk})) \nVdash \mathbf{Ext}(\mathbf{three}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))$

Classically speaking, if there are less than three frog objects in $\mathfrak{Dom}_{\mathbf{Obj}}$, then the consequence in (12)) does not hold, because the antecedent is non-empty and the consequent is empty. (12) is not a necessary consequence. I now show how this notion transports to the current framework, i.e. how it is not a consequence in all models of $\mathscr{L}_{\mathsf{GOA}}$.
Assume $Card([\![\mathbf{frog}]\!]^{\mathfrak{M}'}) = n-1$, where $n > 1$, then $[\![\mathbf{n}(\mathbf{frog})]\!]^{\mathfrak{M}'} = \{\{\}\}$ (where $\mathbf{n}$ is the numeral determiner constant encoding a cardinality of n) by 5.4.1.3/5c. This results in the interpretation given in (14), building on (10).

(14) $[\![\mathbf{Ext}(\mathbf{n}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'} =$

$$\{U | \exists O \in \{\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\}$$

Since the primary quantification after the set constructor is $\exists O \in \{\}$, which can never be satisfied by the definition of $\exists$, it follows that $[\![\mathbf{Ext}(\mathbf{n}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'} = \{\}$ (since no U can meet even the primary condition).
However, $[\![\mathbf{Ext}(\mathbf{every}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'}$ is non-empty, as demonstrated in (15).

(15) $[\![\mathbf{Ext}(\mathbf{every}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'} =$

$$\{U | \exists O \in \{\{f_1, .., f_{n-1}\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\} =$$
$$\{U | \exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in \{f_1, .., f_{n-1}\}[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in \{f_1, .., f_{n-1}\}[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]\}$$

where $\{f_1, .., f_{n-1}\}$ are the $n-1$ frog objects in $\mathfrak{M}'$.

Since the models of $\mathscr{L}_{\mathsf{GOA}}$ are specified so as to provide distinct events of any type for each individual-as-participant at any temporal interval, any location, and with any additional event property, (15) cannot be empty.
For the definition of $\Vdash$ to hold, it must be that $[\![\mathbf{Ext}(\mathbf{every}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'} \subseteq [\![\mathbf{Ext}(\mathbf{n}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'}$. Since $[\![\mathbf{Ext}(\mathbf{n}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'}$ was just shown to be empty for the models under discussion, this cannot be the case (notice that $[\![\mathbf{Ext}(\mathbf{every}(\mathbf{frog}))(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}'}$ was shown to be non-empty). Thus, (13) falls out. *Every* is clearly not a general sub-case of n, and no necessary consequence can therefore be established.

5.5.1.3 Subset Modifiers

Subset modifiers, as argued for in chapter 2, invite certain inferences along the lines of (16), repeated here from (3).

(16) a. Miss Piggy walks quicky. ⊩ Miss Piggy walks.

b. $\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{quickly}(\mathbf{walk}))) \Vdash \mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{walk}))$

I now argue that these are cases of what I have called necessary consequence in the previous subsections. First, I provide interpretations of the $\mathscr{L}_{\mathsf{GOA}}$-translations in (17) and (18).

(17) 1. $[\![\mathbf{walk}]\!]^{\mathfrak{M}} = \mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+}$ (by 5.4.1.3/6)

2. $[\![\mathbf{quickly}(\mathbf{walk})]\!]^{\mathfrak{M}} = \mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap \mathcal{P}^{fra_0}_{\mathbf{quick}}$ (by 5.4.1.3/8)

3. $[\![\mathbf{Verb}(\mathbf{quickly}(\mathbf{walk}))]\!]^{\mathfrak{M}} = \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap \mathcal{P}^{fra_0}_{\mathbf{quick}})$ (by 5.4.1.3/11)

4. $[\![\mathbf{piggy}]\!]^{\mathfrak{M}} = \{\{p\}\}$ (where p is Miss Piggy, by 5.4.1.3/2)

5. $[\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{quickly}(\mathbf{walk})))]\!]^{\mathfrak{M}} =$
$\{U | \exists O \in \{\{p\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap \mathcal{P}^{fra_0}_{\mathbf{quick}})$
$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$
$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$
(by 5.4.1.3/9 and the previous steps)

(18) 1. $[\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}} =$
$\{U | \exists O \in \{\{p\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$
$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$
$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$

To prove that the denotations as calculated make (18) a consequence of (17) under our definition, simply consider what sets of events are collected in both cases.[10] The set generated in (18) contains sets of events U such that for the set $\{p\}$ (notice that there is only one set in $\{\{p\}\}$), U is a union of an arbitrary subset of sets from $\wp(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+})$ which meets some additional conditions. Now, in (17) we encode exactly the same formation of unions of sets of events (with the same conditions), but from subsets of $\wp(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+} \cap \mathcal{P}^{fra_n}_{\mathbf{quick}})$ instead of $\wp(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+})$. By the definition of $\cap$: $(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+} \cap \mathcal{P}^{fra_n}_{\mathbf{quick}}) \subseteq (\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+})$, and thus, by the definition of $\wp$: $\wp(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+} \cap \mathcal{P}^{fra_n}_{\mathbf{quick}}) \subseteq \wp(\mathcal{P}^{fra_n}_{\mathbf{walk}} \cap \mathcal{P}^{fra_n}_{+})$. This means that every U in (17) is a union of some

[10] I again stress the fact that the objection *"But what if Piggy doesn't walk quickly in the given model?"* is not applicable here since the interpretation is achieved in the abstract domain of possible events. The axiomatization of the abstract model makes sure that there are always enough events of Piggy walking in any possible kind of way.

sets from a subset of the sets of which the U in (18) are unions, and thus (concluding the reasoning): $[\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{quickly}(\mathbf{walk})))]\!]^{\mathfrak{M}} \subseteq [\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}}$
This generalizes to any case where two $\mathscr{L}_{\mathsf{GOA}}$ formulas differ only by the presence of some subset operator applied to the main event type constant, since the interpretations of the two will always be equal except for the additional intersection in the interpretation of the formula including subset modification.
Subsection 5.5.2.1 is devoted to the discussion of how the involvement of negation affects the picture.

5.5.1.4 Subset Modifiers and Elaboration

Elaborating on the last section, I now show how a sequence such as the one in (19), taken as one discourse where both sentences are uttered in the order as given here, is processed:

(19) a. Kermit walked onto the stage at the beginning of the second show of the third season.
b. Kermit *quickly* walked onto the stage at the beginning of the second show of the third season.

In many a discourse situation the version in (20) would be enough to achieve a similar effect, where location and time are inferred to be the same using infomation from the previous discourse, or where connectors like *actually* (shown in brackets) provide a clue that the second sentence specifies the first further:

(20) a. Piggy walked.
b. (Actually/In fact,) Piggy walked quickly.

It should be clear from the previous subsection that in these cases, the first sentence is a consequence of the second sentence. Additionally, in the case of (19) time and location parameters are fixed explicitly, and in (20), the discourse context seems to fix them to arbitrary but the *same* time and space coordinates. This identity of time and space coordinates (and especially the connector *actually* in (20)) makes the second sentence appear as an *elaboration* of the first.
First, let me examine how the update procedure (defined in 5.4.2) proceeds in such cases, assuming that the identification of time and space is taken care of. More specifically: Does the update with the second sentence automatically narrow down the set of possible mental models?
To see whether this is so, we look again at (22) and (21).

(21) $[\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}} =$
$$\{U|\exists O \in \{\{p\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$$

(22) $[\![\mathbf{Ext}(\mathbf{piggy})(\mathbf{Verb}(\mathbf{quickly}(\mathbf{walk})))]\!]^{\mathfrak{M}} =$
$$\{U|\exists O \in \{\{p\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap \mathcal{P}^{fra_0}_{\mathbf{quick}})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathfrak{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathfrak{ext}(e') = o]]]]]\}$$

To see how these two sentences, uttered in sequence, affect the discourse knowledge base, think about how the discourse stages in (23) is interpreted (where I use the English sentences the translations of which we are contemplating for reasons of better readability).

(23) a. $D_n = \langle \textit{Piggy walks}, K_n \rangle$

b. $D_{n+1} = \langle \langle \textit{Piggy walks}, \textit{Piggy walks quickly} \rangle, K_{n+1} \rangle$

I repeat in (24) the definition of the update in shortened form from 5.4.2/8.

(24) K_n is a set of secondary models. All subdomains are taken over from $\mathfrak{M}$, except $\mathbf{Dom_{Ev}}$. Therefore, with:
$$E'_n = \{E|(\exists E_1 \in [\![\alpha_1]\!]^{\mathfrak{M}})(\exists E_2 \in [\![\alpha_2]\!]^{\mathfrak{M}})..(\exists E_n \in [\![\alpha_n]\!]^{\mathfrak{M}})[E = \bigcup_{m=1}^{n} E_m])\}$$
K_n is specified:
$$K_n = \{\mathscr{M}|\exists E \in E'_n[\mathscr{M} = \mathfrak{Dom}_{\mathbf{Obj}} \cup \mathfrak{Dom}_{\mathbf{Per}} \cup \mathfrak{Dom}_{\mathbf{Loc}} \cup E]\}$$

According to (24), the event domains of secondary models are all possible unions of some set in the denotation of a sentence with some set from each of the denotations of the previously uttered sentences. This means that after updating some discourse (empty or not) with (21), the event domain of every possible model contains at least one event which is in $\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap E_p$, where $E_p = \{e|Ext(e) = p\}$. This is so because $[\![\textit{Piggy walks}]\!]$ strictly contains only sets of events formed from this basic intersection of sets of events, and thus unions of these sets with other sets will always contain at least one event so specified. Of course, there is no restriction to *quick* walkings (or any other additional property of events), and consequently there secondary are event domains which do not contain quick walking events with the given specification, but only *slow* or *frantic* ones, for example. We can actually be sure that this is so, because, as the reader might remember, we have made sure in the axiomatization of the abstract event domain $\mathfrak{Dom}_{\mathbf{Ev}}$ in 5.4.1.2/4 (especially 4o) that for every permutation of event properties, there is at least one event (for every configuration of participants and every possible spatio-temporal coordinate) which is in the intersection of all these

event-property parameters, but not in any subset which is obtained by intersection with any other additional event property parameter. In the case at hand, this means that the interpretation of the first sentence (for some specific location and point in time fixed by the context or by world-knowledge, and with Miss Piggy being the agent) contains sets containing distinct walking events which are arbitrarily specified for event properties.
Since the denotation of the second sentence (22) draws its events from $\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+} \cap \mathcal{P}^{fra_0}_{\mathbf{quick}} \cap E_p$, however, updating with it will result in new a situation where every secondary model after the update contains **at least one** *quick* walking with the given additional specification, simply because the sentence only denotes sets of quick walkings, and every event domain of a secondary model after an update with this sentence must be the union of a set from its denotation and other sets, thus containing at least one quick walking (by Piggy, etc.).
The assumed elaboration relation between the two sentences in (20) is thus only relevant to fix time and location as equal between the two sentences, and the additional knowledge contributed by the second sentence is then calculated as normal by the update procedure. Also, there might be world-knowledge constraints (5.4.2/10d) removing models where for the same time period and the same location Piggy walks quickly and slowly or quickly and leisurely, etc., but these are clearly not part of the (in fact: any) core logic.

5.5.2 Partial and Full Contradiction

5.5.2.1 Contradiction

Let me now verify how certain positive and negative sentences lead to full contradiction. I examine (25) (taken as subsequent contributions to a discourse).

(25) a. $\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk}))$ (Kermit walks.)

b. $\bar{\mathbf{P}}(\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk})))$ (Kermit doesn't walk.)

We clearly wish these formulae/sentences to be contradictory. If Kermit doesn't walk at all at some point in time, then he does not walk at the same time. The interpretation is given in (26), in slightly shorter form since the conventions (like k for Kermit and W for the set of walkings, etc.) can be guessed by now. I omit the additional parameters which fix the sets of events to those taking place at the speech time interval, but I assume that such a restriction is in place.

(26) a. $[\![\mathbf{kermit}]\!]^{\mathfrak{M}} = k$

b. $[\![\mathbf{walk}]\!]^{\mathfrak{M}} = W$

c. $[\![\mathbf{Verb}(\mathbf{walk})]\!]^{\mathfrak{M}} = \wp W$

d. $[\![\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk}))]\!]^{\mathfrak{M}} =$

$$\{U|\exists O \in \{\{k\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\}$$

e. $[\![\overline{\mathbf{P}}(\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk})))]\!]^{\mathfrak{M}} =$

$$\{V|\exists W \in$$
$$\{U|\exists O \in \{\{k\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\mathbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\}$$
$$[V = \{e''|\exists e''' \in W[e'' = \oplus e''']\}$$

The non-negated sentence denotes a set of sets U of events as specified in the interpretation. The otherwise parallel interpretation of the negated sentence also denotes a set of sets V of events, which are formed by picking each set U and switching the polarity of all events in it.

In absence of special discourse-level interpretation instructions (some of which also feature in 5.5.2.2), negation must be interpreted as exhaustive, i.e., we remove all non-maximal sets from the denotation of the negative sentence before performing the discourse update. For this, we introduce the default interpretation condition EXH in (27).

(27) **Exhaustivity IC**: For any formula α_1: If $\forall S \in [\![\alpha_1]\!]^{\mathfrak{M}}[\forall e \in S[e \in \mathit{neg}]]$, then $\alpha_1 \overset{IC}{\Longrightarrow} EXH(\alpha_1)$ where $[\![EXH(\alpha_1)]\!]^{\mathfrak{M}} = \{\bigcup [\![\alpha_1]\!]^{\mathfrak{M}}\}$.

The interpretation of the negated formula without the IC was said above to be a negative mirror of the denotation of the non-negated sentence in that it contains for every set from the positive sentence's denotation a set which contains the negative mirrors of the events in the set from the postive denotation. The Exhaustivity IC now takes all these sets and forms their generalized union (which is equivalent to the largest set among its members). This union thus contains all possible negative events of Kermit walking. We can now determine how the discourse in (28) is processed, i.e., what K_2 turns out to be.

(28) $\langle\langle\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk})), EXH(\overline{\mathbf{P}}(\mathbf{Ext}(\mathbf{kermit})(\mathbf{Verb}(\mathbf{walk}))))\rangle, K_2\rangle$

By the definition of the update procedure, the event domains for the secondary models in K_2 are calculated as in (30).

(29) $K_2 = \{\mathscr{M}|\exists E \in F_2[\mathscr{M} = \mathfrak{Dom}_{\mathbf{Obj}} \cup \mathfrak{Dom}_{\mathbf{Per}} \cup \mathfrak{Dom}_{\mathbf{Loc}} \cup F_2]\}$ where:

(30) $F_2 = \{E|$
$$(\exists E_1 \in$$
$$\{U|\exists O \in \{\{k\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\})$$
$$(\exists E_2 \in$$
$$\{\bigcup$$
$$\{V|\exists W \in$$
$$\{U|\exists O \in \{\{k\}\}[\exists E \subseteq \wp(\mathcal{P}^{fra_0}_{\textbf{walk}} \cap \mathcal{P}^{fra_0}_{+})$$
$$[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[\mathit{ext}(e) = o]]]$$
$$\wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[\mathit{ext}(e') = o]]]]]\}$$
$$[V = \{e''|\exists e''' \in W[e'' = \oplus e''']\}$$
$$\})$$
$$[E = E_1 \cup E_2]\}$$

Given (30), which secondary models in K_2 have to be removed by the contradiction conditions in 5.4.2/10? There is only one E_2, viz. the huge set of all negative events of Kermit walking. Forming unions of this set with the E_1 sets from the interpretation of the positive sentence (positive events of Kermit walking) will *always* lead to contradiction, and therefore to the subsequent removal of the model. Since this is the case for all models formed with E_1 sets, this is a case of full contradiction.
It should be clear from previous examples that the interpretation of (31) is subset to the interpretation of (25a).

(31) a. **Ext**(**kermit**)(**Verb**(**quickly**(**walk**))) (Kermit walks quickly.)

Put in a discourse with (25b), the same full contradiction therefore arises.

5.5.2.2 Negation and *and* or *or*

5.5.2.2.1 Conjunction In this section, I show how negation interacts with conjunction and disjunction. I only treat cases of *sentential* conjunction and disjunction, and I treat them as contributing information on how to update models. Although the update instructions as discussed here and in the next two subsections are probably best seen as actual procedural instructions, I provide representational definitions where possible to stay within the set-theoretical framework used in this study.
Let me first turn to a simple case of conjunction like the one in (32), which, as the accompanying rendering in a standard Event Semantics shows, is a contradiction.

(32) a. Kermit walks and Kermit doesn't walk.

b. $(\exists e[\textbf{walk}(e) \wedge \textbf{agent}(e) = x]) \wedge (\neg \exists e[\textbf{walk}(e) \wedge \textbf{agent}(e) = x])$

We have already shown that the discourse in (28), which is composed of the two formulae which enter into the conjunction in (32), is a case of full contradiction even without sentential *and*. I suggest that we interpret the default sentential *and* as a discourse marker which makes explicit what the standard update requires anyway: Update the secondary models with the interpretations of both sentences!
Formally, the IC *AND* is defined in (33).

(33) **Conjunctivity IC**: For any two fomulae α_1, α_2:
$[\![AND(\alpha_1)(\alpha_2)]\!] = [\![AND(\alpha_2)(\alpha_1)]\!] = \{E | \exists E_1 \in [\![\alpha_1]\!][\exists E_2 \in [\![\alpha_2]\!][E = E_1 \cup E_2]]\}$.

Thus, rendering cases like (32) as in the scheme in (34), it should be obvious that the contradiction arises in the same way as in (28).

(34) $AND(\alpha_1)(EXH(\overline{\mathbf{P}}(\alpha_1)))$

The status of a logical contradiction like $p \wedge \neg p$ is thus reintroduced as a discourse-level model-theoretic notion: Every update with a formulae like (34) will lead to full contradiction, which is the definition of logical contradiction.

5.5.2.2.2 Disjunction

A similar treatment of disjunction by introducing an IC *OR* suggests itself. However, there is no simple set theoretic formulation as for *AND*, and I resort to the ad hoc introduction of a disjunctive set

(35) **Disjunctivity IC**: For any two fomulae α_1, α_2:
$[\![OR(\alpha_1)(\alpha_2)]\!] = [\![OR(\alpha_2)(\alpha_1)]\!] = [\![\{\alpha_1 \vee \alpha_2\}]\!]$, where $\{a \vee b\}$ is a disjunctive set which can be instantiated as either *a* or *b*.[11]

So, encountering a logical representation of the scheme $OR(\alpha_1)(\alpha_2)$, an update can be performed with either α_1 or α_2.
What about apparent tautologies as in (36)?

(36) Kermit walks or Kermit doesn't walk.

The logical translation of (35) is of the form $OR(\alpha_1)(EXH(\overline{\mathbf{P}}(\alpha_1)))$. While simple logical contradiction was characterized as the impossibility of updating a discourse with some formula without triggering full contradiction, such tautological formulae are trivially successful updates. If all models from the previous stage of the discourse contain

[11] Similar constructs feature in belief revision theory, a classic paper on which is Alchourròn, Gärdenfors and Makinson (1985). There are also apparent similarities to the representation of disjunctive information in database theory, cf. Minker (1989).

positive α_1 events, then update with $EXH(\bar{\mathbf{P}}(\alpha_1))$ must lead to full contradiction (because its denotation is a set of just one large set of all negative α_1 events). If that is *not* the case, however, an update with just α_1 can be performed (by the definition of *OR*).

5.5.2.3 Nobody and specific individuals

Here, I add a demonstration of why certain expressions with negative determiners (the simplest case: *no*) lead to contradiction with statements about specific individuals. The account is based on a decomposition of *no* into sentential negation and *every*.

(37) a. No being walks.

b. $\bar{\mathbf{P}}(\mathbf{Ext}(\mathbf{every}(\mathbf{being}))(\mathbf{Verb}(\mathbf{walk})))$

(38) a. Kermit walks.

b. $\mathbf{Ext}(\mathbf{kermit}(\mathbf{Verb}(\mathbf{walk})))$

First of all, notice that, as argued for earlier, by the definition of **every**, $[\![\mathbf{Ext}(\mathbf{every}(\mathbf{being}))(\mathbf{Verb}(\mathbf{walk}))]\!]$ is a singleton set (containing a set), and that therefore (39) is the case.

(39) $[\![\bar{\mathbf{P}}(\mathbf{Ext}(\mathbf{every}(\mathbf{being}))(\mathbf{Verb}(\mathbf{walk})))]\!] =$
$[\![EXH(\bar{\mathbf{P}}(\mathbf{Ext}(\mathbf{every}(\mathbf{being}))(\mathbf{Verb}(\mathbf{walk}))))]\!]$

Furthermore, even without providing step-by-step calculations of the denotation of (37), it should be clear that it contains the set of all possible events of some being-object walking. If we assume that Kermit is a being-object, the denotation of (38) contains exclusively sets of events of some being-object (viz., Kermit) walking. This suffices to cause full contradiction, thus demonstrating how (37) and (38) turn out as contradictory.

5.5.2.4 Conditionals

In this section, I do not show in a fully formal fashion how *conditionals* are treated in the present framework. However, a short word is in order, since many classical rules of inference from first-order logic (like Modus Ponens or Hypothetical Syllogism) involve conditionals.

Think about Modus Ponens, given here in (40).

(40) $P \to Q, P \vdash Q$

I suggest that in terms of the logic of $\mathscr{L}_{\mathsf{GOA}}$, this rule can be reconstructed if an IC is introduced which renders conditionals as conditional updates on a discourse. Instead of falling under the standard update procedure, a conditional involving the IC

IF introduces a function which itself performs a conditional update on any discourse interpretation.

(41) **Conditional IC**: $IF(\alpha_1)(\alpha_2) = F$ where F is a function on a set of sets of events $K_i^{\mathbf{Dom_{Ev}}}$ (the set of event domains of the secondary models at stage i).
Define $K_i^{\mathbf{Dom_{Ev}}} = E$, $[\![\alpha_1]\!] = A_1$, $[\![\alpha_2]\!] = A_2$, then:
$F(E) = \{S|\exists E' \in E[\exists A'_1 \in A_1[(A'_1 \subseteq E') \wedge (\exists A'_2 \in A_2[S = A'_2 \cup E'])]]\}$
$\cup\{S|S \in E \wedge \neg\exists A'_1 \in A_1[A'_1 \subseteq S]\}$

The first set in the definition of $F(E)$ contains for every pre-update event domain E' which is superset or equal to some set A'_1 from the denotation A_1 of the antecedent of the conditional some set $A'_2 \cup E'$, where A'_2 is in the denotation A_2 of the consequent. The second set just adds all sets from E which are not superset or equal to some set from A_1.
Looking at the simplest case of a discourse to demonstrate an application of Modus Ponens $D_2 = \langle\langle\alpha_1, IF(\alpha_1)(\alpha_2)\rangle, K_2\rangle$, it can be shown how K_2 warrants the consequence α_2. By the definition of IF, since the pre-update event domains are identical to the antecedent of the conditional ($[\![\alpha_1]\!]$), the first half of the definition of IF is relevant: The post-update domains are all possible unions of some sets from $[\![\alpha_1]\!]$ and some set from $[\![\alpha_2]\!]$, cf. (42).

(42) With $D_2 = \langle\langle\alpha_1, IF(\alpha_1)(\alpha_2)\rangle, K_2\rangle$, $K_2^{\mathbf{Dom_{Ev}}} =$
$\{E|\exists E' \in [\![\alpha_1]\!][\exists E'' \in [\![\alpha_2]\!][E = E' \cup E'']]\}$
(where again $K_2^{\mathbf{Dom_{Ev}}}$ is the set of the event domains of all models in K_2).

Since this is the same as the update procedure (according to 5.4.2/8) would produce for a discourse $D'_2 = \langle\langle\alpha_1, \alpha_2\rangle, K'_2\rangle$, we can safely say that discourses which model $\langle\alpha_1, IF(\alpha_1)(\alpha_2)\rangle$ also model α_2.
Far from explaining natural language conditionals in even remotely adequate subtlety, this analysis gives at least a hint how (40) and similar inferences go through in the present framework.

5.5.3 Undefined Subjects

Albeit slightly misplaced at this point, I now add a word about what is traditionally called undefined subjects. When a definite NP like “the present king of France” is not defined, in truth-functional semantics one has the choice to either making a sentence containing the aforementioned NP false by some postulate, or to introduce a three-valued logic, assigning the third truth-value to such sentences.
I suggest that in GOA, we can implement a Strawsonian treatment of definite singular

NPs without making any further adaptations to the logic. As a formal manifestation of the Strawsonian approach, I introduce a form of the ι operator suited to the present framework.

(43) a. $[\![\mathbf{the_{sg}}]\!] = \iota$

b. ι is a function in $\mathfrak{Dom}_{\wp\wp\mathbf{Obj}}^{\mathfrak{Dom}_{\wp\mathbf{Obj}}}$ such that for every $O \in \mathfrak{Dom}_{\wp\mathbf{Obj}}$

$$\iota(O) = \begin{cases} \{\{o\}\} & \text{if } o \in O \wedge \forall o'[o' \in O \leftrightarrow o = o'] \\ \{\{\}\} & \text{otherwise} \end{cases}$$

With this definition, any undefined NP functioning as the first argument to a thematic operator, will trigger an interpretation like the one in (44).

(44) $[\![\mathbf{Ext}(\mathbf{the_{sg}}(\mathbf{kingoffrance}))(\mathbf{Verb})(\mathbf{walks})]\!] =$

$$\{U | \exists O \in \{\{\}\}[\exists E \subseteq \wp(\mathcal{P}_{\mathbf{walk}}^{fra_0} \cap \mathcal{P}_{+}^{fra_0})[\ldots]]\} = \{\{\}\}$$

(with $[\![\mathbf{the_{sg}}(\mathbf{kingoffrance})]\!] = \{\{\}\}$)

In other words, the denotation of the sentence will simply be empty and thus **uninformative**. I see this as a welcome result, which comes absolutely free with the theory advocated here.

5.6 Sample Derivations

5.6.1 Lexicalization

In this section, I present some lexicalization of expressions of English, i.e. I define a lexicalization relation $\overset{Lex}{\Rightarrow}$ between expressions of English and their representation in $\mathscr{L}_{\mathsf{GOA}}$(possibly complex expressions and tuples of (complex) expressions), given as $exp :: t$ where $t \in Type$ and $exp \in \mathbf{Exp}$.

1. *Miss Piggy* $\overset{Lex}{\Rightarrow}$ **piggy** :: $\wp\wp\mathbf{Obj}$

2. *Kermit the Frog* $\overset{Lex}{\Rightarrow}$ **kermit** :: $\wp\wp\mathbf{Obj}$

3. *Fozzie Bear* $\overset{Lex}{\Rightarrow}$ **fozzie** :: $\wp\wp\mathbf{Obj}$

4. *pig* $\overset{Lex}{\Rightarrow}$ **pig** :: $\wp\mathbf{Obj}$

5. *frog* $\overset{Lex}{\Rightarrow}$ **frog** :: $\wp\mathbf{Obj}$

6. *bear* $\overset{Lex}{\Rightarrow}$ **bear** :: $\wp\mathbf{Obj}$

7. *happy* $\overset{Lex}{\Rightarrow}$ **happy** :: $(\wp\mathbf{Obj} \rightarrow \wp\mathbf{Obj})$

8. *some, a* $\overset{Lex}{\Rightarrow}$ $\textbf{some} :: (\wp\textbf{Obj} \to \wp\wp\textbf{Obj})$

9. *every* $\overset{Lex}{\Rightarrow}$ $\textbf{every} :: (\wp\textbf{Obj} \to \wp\wp\textbf{Obj})$

10. *someone* $\overset{Lex}{\Rightarrow}$ $\textbf{some}(\textbf{being}) :: \wp\wp\textbf{Obj}$

11. *something* $\overset{Lex}{\Rightarrow}$ $\textbf{some}(\textbf{object}) :: \wp\wp\textbf{Obj}$

12. *nothing* $\overset{Lex}{\Rightarrow}$ $\langle\overline{\textbf{P}} :: (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{every}(\textbf{object}) :: \wp\wp\textbf{Obj}\rangle$

13. *walk(s)* $\overset{Lex}{\Rightarrow}$ $\langle\textbf{Ext} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Verb} :: (\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{walk} :: \wp\textbf{Ev}\rangle$

14. *talk(s)* $\overset{Lex}{\Rightarrow}$ $\langle\textbf{Ext} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Verb} :: (\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{talk} :: \wp\textbf{Ev}\rangle$

15. *love(s)* $\overset{Lex}{\Rightarrow}$ $\langle\textbf{Ext} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Verb} :: (\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{walk} :: \wp\textbf{Ev},$
$\textbf{Int}_\textbf{1} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev}))\rangle$

16. *give(s)*$_1$ $\overset{Lex}{\Rightarrow}$ $\langle\textbf{Ext} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Verb} :: (\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{give} :: \wp\textbf{Ev},$
$\textbf{Int}_\textbf{2} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Int}_\textbf{1} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev}))\rangle$

17. *give(s)*$_2$ $\overset{Lex}{\Rightarrow}$ $\langle\textbf{Ext} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{Verb} :: (\wp\textbf{Ev} \to \wp\wp\textbf{Ev}),$
$\textbf{give} :: \wp\textbf{Ev},$
$\textbf{Int}_\textbf{1} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})),$
$\textbf{to} :: (\wp\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev}))\rangle$

18. *quickly* $\overset{Lex}{\Rightarrow}$ $\textbf{quickly} :: (\wp\textbf{Ev} \to \wp\textbf{Ev})$

19. *passionately* $\overset{Lex}{\Rightarrow}$ $\textbf{passionately} :: (\wp\textbf{Ev} \to \wp\textbf{Ev})$

20. *does not, it is not the case that* $\overset{Lex}{\Rightarrow}$ $\overline{\textbf{P}} :: (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})$

21. $\overset{Lex}{\Rightarrow}$ $\dot{\textbf{R}} :: (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev})$

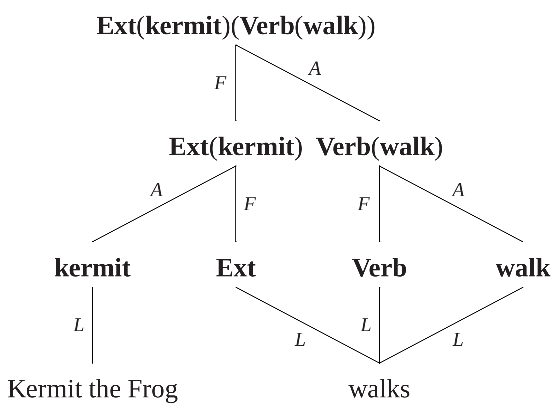
5.6.2 Logical Forms

Finally, in this section, I provide some derivations based on the lexicalizations provided in 5.6.1. I completely ignore problems of surface syntax, though. A mechanism of dealing with them is described in the later chapters.
The sentences derived are given in (45).

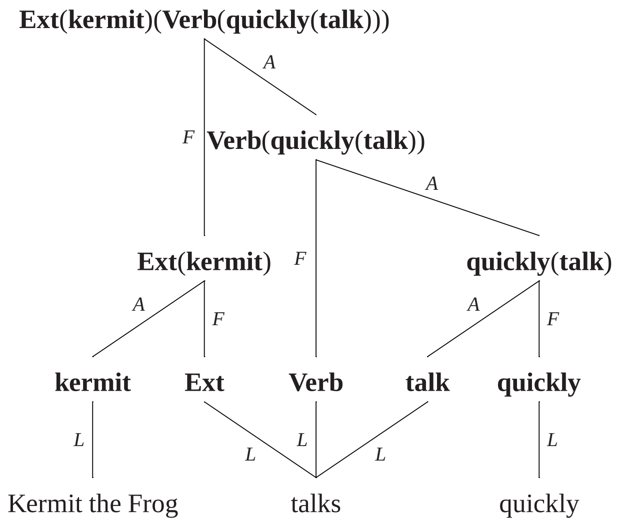
(45) a. Kermit the Frog walks.
b. Kermit the Frog talks quickly.
c. Miss Piggy loves some frog.
d. Miss Piggy gives Kermit a happy bear.
e. Some pig loves every frog. (both readings)
f. i. Every bear doesn't talk. (∀¬ reading)
ii. It is not the case that every bear talks. (¬∀ reading)

The derivations are provided in (46)–(51), where *L* labels lexicalizations, and *F* and *A* label functor and argument in function application structures. Again, I want to point out that English surface word order is sometimes ignored, leading to crossing *L*-branches.

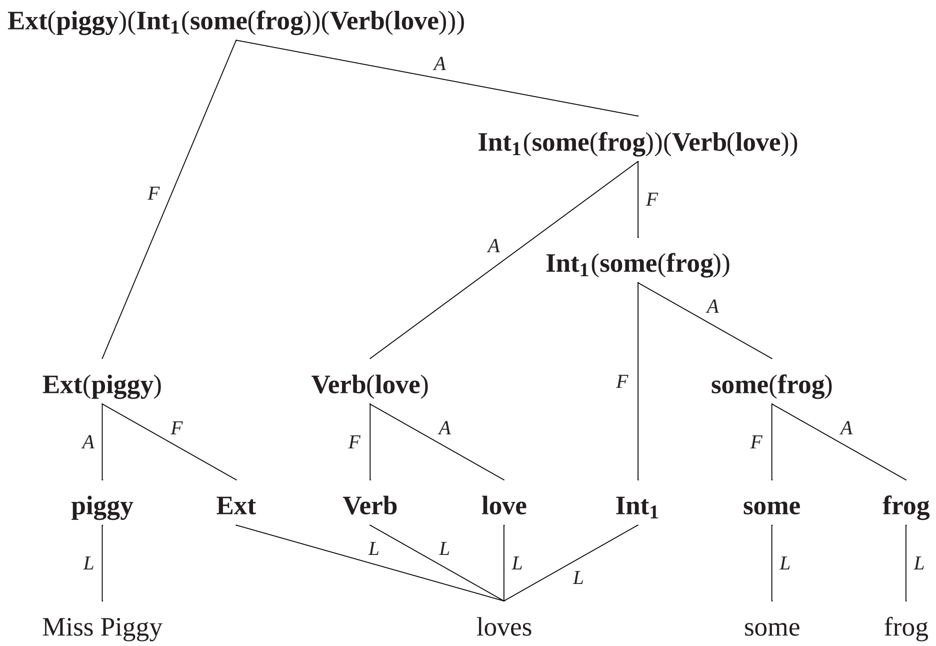
(46)



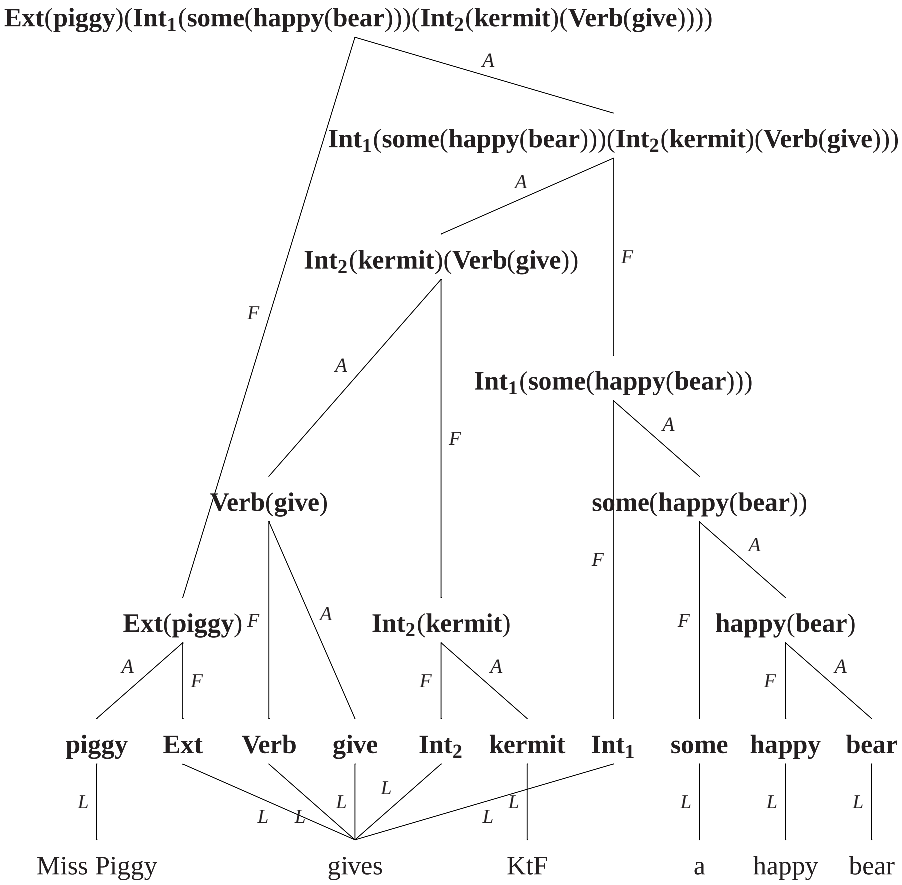
(47)


Ext(kermit)(Verb(quickly(talk)))
A
F
Verb(quickly(talk))
A
Ext(kermit)
F
quickly(talk)
A
F
A
F
kermit
Ext
Verb
talk
quickly
L
L
L
L
L
Kermit the Frog
talks
quickly

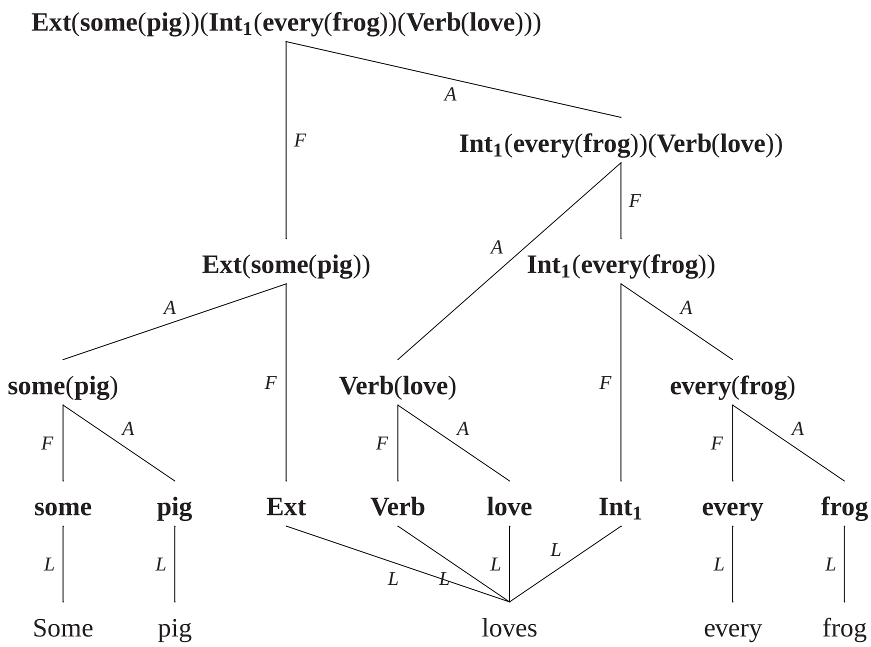
(48)


Ext(piggy)(Int1(some(frog))(Verb(love)))
A
Int1(some(frog))(Verb(love))
F
F
A
Int1(some(frog))
A
Ext(piggy)
Verb(love)
F
some(frog)
A
F
F
A
F
A
piggy
Ext
Verb
love
Int1
some
frog
L
L
L
L
L
L
L
Miss Piggy
loves
some
frog

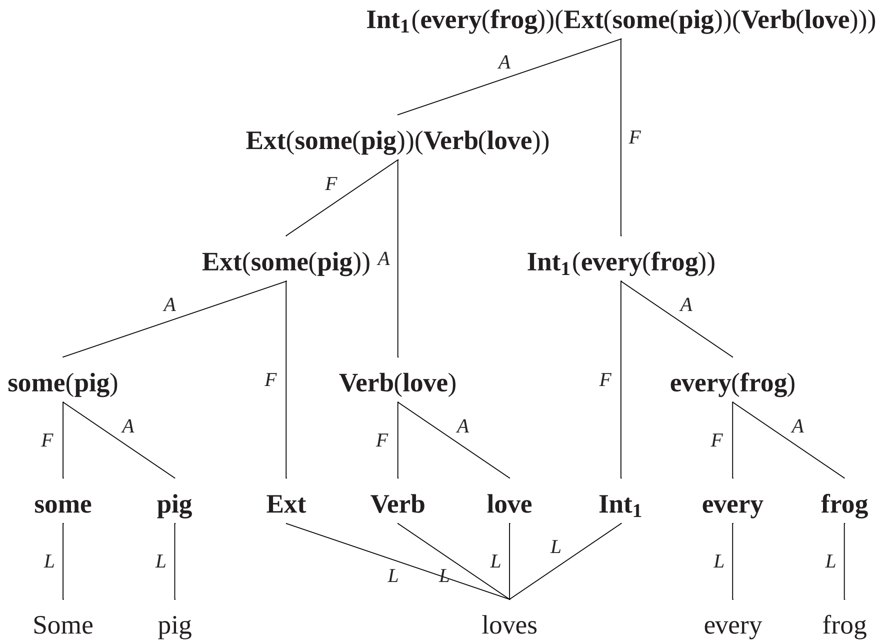
(49)



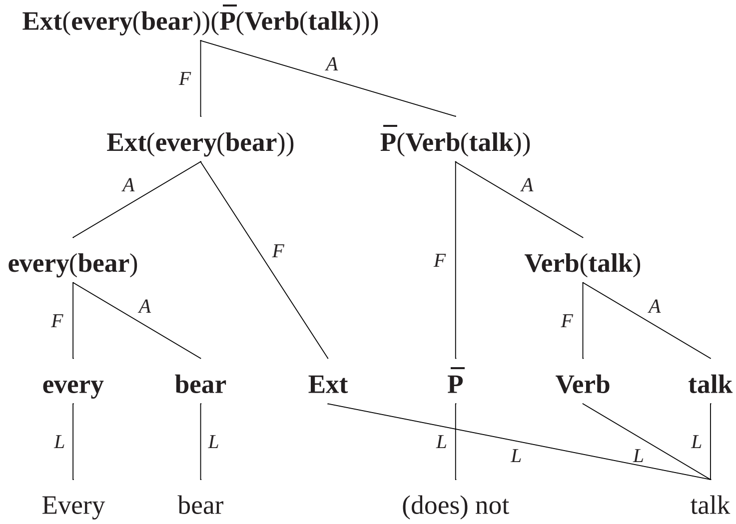
(50) a. ∃∀ reading:



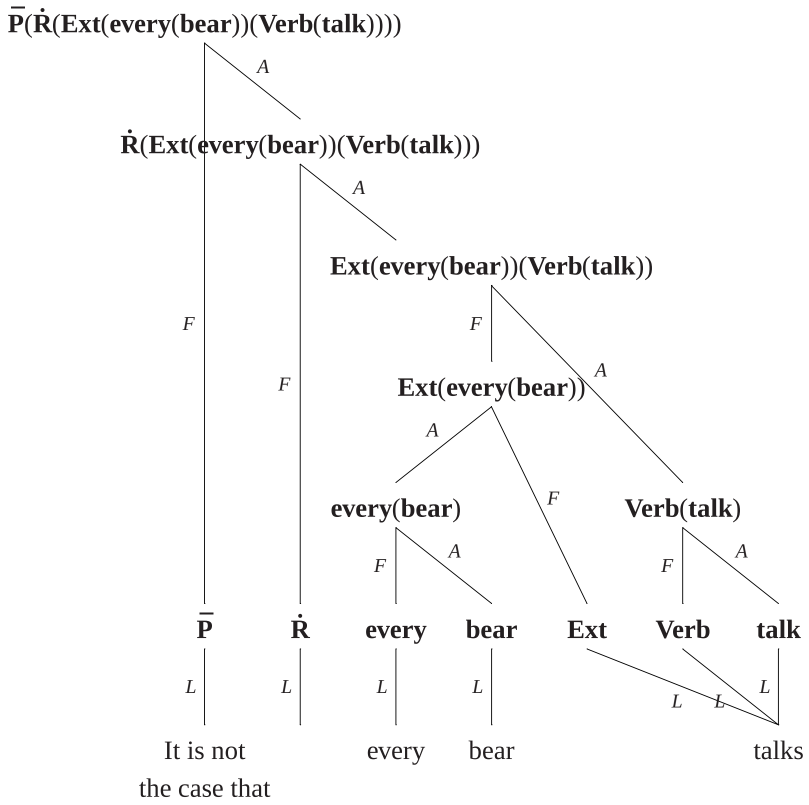
b. ∀∃ reading:


Int1(every(frog))(Ext(some(pig))(Verb(love)))
Ext(some(pig))(Verb(love))
Ext(some(pig))
Int1(every(frog))
some(pig)
Verb(love)
every(frog)
some
pig
Ext
Verb
love
Int1
every
frog
Some
pig
loves
every
frog

(51) a. ∀¬ reading:


Ext(every(bear))(P̄(Verb(talk)))
Ext(every(bear))
P̄(Verb(talk))
every(bear)
Verb(talk)
every
bear
Ext
P̄
Verb
talk
Every
bear
(does) not
talk

b. ¬∀ reading:[12]



[12] The assumption of the reclustering operator is necessary to distinguish this reading from the previously derived one semantically.

Chapter 6

Distributivity and Collectivity

All quantificational readings generated so far by the theory presented here are strictly distributive, i.e., sentence (1a) can only be understood as specified in (1b).

(1) a. Three dogs played two songs on the piano.

b. Dog 1 played song 1, dog 1 played song 2, dog 2 played song 3, dog 2 played song 4,…

The songs might be fully or partially identical between the dogs who played them, to the effect that there might be 2 to 6 distinct songs which could be involved in circumstances making the sentence true. But, in terms of events, there always have to be six distinct events of a dog playing a song. However, (1a) can naturally refer to a situation where two dogs together played two songs (four-handedly), and one other dog played some other (possibly) identical tunes or to one where the dogs played the songs together in a total of two events. So far, my theory cannot render this reading, and this chapter redeems this situation.

This chapter should be seen as an appendix to chapter 2 through chapter 5. The appendixal character is due mostly to the fact that I do not provide a full formal treatment of the phenomena discussed here, and that I allow myself to leave certain problems unsolved for the time being. Instead, I show in a general fashion how mereological structures in the domains of events and objects can be introduced in my framework, following the classical literature on the subject: Scha (1981), Link (1983), Krifka (1989), Wyner (1994), Landman (2000). Excluded from this study are also questions of aspectual types of verbs, aktionsart and grammatical aspect, which have also been analyzed in terms of mereological event structures.

I will introduce sum ontologies in section 6.2 and provide a short discussion of distributivity, collectivity, and the readings of some universal (or *totalic*) quantifiers (namely *all*, *every*, *each*, and *the*). Finally, it should be noted that, because the update procedure does not play much of a role for the problems discussed here, and because the theory of sums as indicated here works also in classical frameworks, I do not refer to the abstract model here, but rather use standard truth-functional parlance.

6.1 Sums and Groups

The concept of sum formation and plural logic was introduced into linguistics by Scha (1981) and Link (1983), and extended to event ontologies by Krifka (1989), Landman (2000), and others. I loosely follow the these works here.

The essential idea is to close the domains of events and objects under the join operation, turn it into a join-semi-lattice structure, and define for every two individuals *a* and *b* (called *atoms*) the sum (join) of them both $a \sqcup b$, a pluralic individual which can be involved in events just as any other individual can. The logical expression corresponding to the join of *a* and *b* is constructed by the sum operator $\oplus$, such that $[\![\mathbf{a} \oplus \mathbf{b}]\!] = a \sqcup b$, although sometimes one finds $[\![\mathbf{a} \oplus \mathbf{b}]\!] = a \oplus b$. It is assumed that plural morphology is a good indicator for pluralic reference.

The simplest reference to a plural individual would be a conjoined noun phrase, as in (2).

(2) Scooter and Fozzie performed the “Telephone Pole” sketch.

(3) Scooter performed the “Telephone Pole” sketch.

Under a non-distributive collective reading, the individual which performed the sketch clearly is the unity of Scooter and Fozzie, and none of the two can be claimed to have performed the sketch, i.e., in the same situation were (2) is true, (3) is not true (unless at some other occasion Scooter actually performed the sketch alone, which can be assumed impossible given the nature of the sketch).

The difference between distributive and collective predicates is simply whether they allow us to infer that the predicate also holds for the atoms of a sum when it predicates over sums. Take a strictly collective predicate as in (4), where the inference to (5) is not licensed. The sentence is actually ungrammatical, because strictly collective predicates always require a sum (or *group*, see below) subject.

(4) Kermit and Fozzie met at the old Sleezo Cafe.

(5) * Kermit met at the old Sleezo Cafe.

A *group*, on the other hand, is a sum reinterpreted as an atomic individual. The notion of group is required because there are simplex singular terms referring to plural individuals, and there is never a license for distributive inferences with such individuals as subject referents. In (6), the singular term *the cast of the Muppet Show* refers to the group individual, which must be ontologically plural (because *meet* is strictly collective).

(6) The cast of the Muppet Show met in the first Muppet movie.

But even predicates which allow a distributive reading like *carry a piano upstairs*, never have any such reading with group-denoting subjects. This can be shown by (7), which never (i.e., independently of concrete models) allows the inference to (8), even if we know that Rowlf is a member of the cast of the Muppet Show.

(7) The cast of the Muppet Show carried a piano upstairs.

(8) Rowlf carried a piano upstairs.

To demonstrate a typical case where the distinction between sums and groups is crucial, I would like to cite an example from Link (1983) in (9), which leads to the false inference to (10) if the coordinated NPs are interpreted as sums.

(9) The cards below 7 and the cards above 7 are separated.

(10) The cards below 10 and the cards above 10 are separated.

Why is this so? If we take *the cards below 7* and the other NPs which enter into the two conjunctions as sums, they can be interpreted as in (11), with c_1 etc. standing in for *card 1*, etc.

(11) a. $\sqcup\{c_1, c_2, \ldots, c_6\}$

b. $\sqcup\{c_7, c_8, \ldots, c_{32}\}$

c. $\sqcup\{c_1, c_2, \ldots, c_9\}$

d. $\sqcup\{c_{10}, c_{11}, \ldots, c_{32}\}$

It should be immediately obvious that in both (9) and (10), the coordinated NP denotes the sum in (12).

(12) $\sqcup\{c_1, c_2, \ldots, c_{32}\}$

Clearly, if both sentences thus receive the same model-theoretic interpretation, then in any sound logic, they should both be true or false. If (9) is true, however, then (10) is explicitly not true. Group formation in the conjuncts helps to keep the ontological constructs of the two piles of cards distinct when the sum of both piles is formed. This demonstrates the need for two plural structures, traditionally called sums and groups.

The process of group formation is usually formalized by introducing a one-to-one function from the domain of sum individuals into the domain of atoms which is denoted by

$\uparrow$, i.e. $\uparrow(a \oplus b)$ denotes the group containing $[\![a]\!]$ and $[\![b]\!]$. The reverse function from group atoms into sums is $\downarrow$, such that $[\![\downarrow\uparrow(a \oplus b)]\!] = a \sqcup b$.
If there are plural objects, then there must also be complex "sum" properties which distribute their component properties among the atoms of a pluralic subject, cf. (13).

(13) Die 27 und 30 Jahre alten Männer wurden von der Polizei bereits gestern verhaftet.
the 27 and 30 years old men were by the police already yesterday arrested
The 27 and 30 year old men were arrested by the police already yesterday.

The information that there are at least two men involved and that at least one of them is 27 and the other 30 years of age is mostly encoded in the adjectival predicate. It is the adjective which requires the N-bar term to denote a 2-sum, which means there must be some way of generalizing conjunction from individual expressions to predicates.
In this study, predicates are reified as events and states, which means they are addressed as individuals in their own right, which in turn means they can be summed up. Sum formation of events and states will also be crucial for simple verb phrase conjunction as in (14).

(14) Gonzo blew the trumpet and fell off the stage.

A similar phenomenon as in (13) can be created by pluralizing the noun phrase as in (15), when it is read as (16).

(15) Gonzo and Camilla blew the trumpet and fell off the stage.

(16) Gonzo and Camilla blew the trumpet and fell off the stage, respectively.

This sentence leaves open the question of whether Gonzo and his hen friend performed both actions together (as a sum taking part in two events total), or whether there were up to four events: Gonzo blowing the trumpet, Camilla blowing the trumpet, etc.
It appears natural to assume under the strongly event-based theory advanced here, that coordinated verb phrases are interpreted as sets of sets of sums of events. Once such an interpretation is in place, it is a mere matter of defining conditions on 'how distributive' certain predicates and noun phrases can or must be.
This is exactly what the next sections are about. I argue that we need to make available a third kind of reading besides distributive and collective readings, viz. cover or partition readings, which are neither collective nor distributive. However, collectivity and distributivity are extreme cases of this third reading, to the effect that there is essentially just one reading.

6.2 Quantifiers, Collectivity, and Distributivity

This section has two subsections. In the first one, section 6.2.1, I discuss the general classes of sentences where distributivity, collectivity, etc. have to be distinguished. The second one, section 6.2.2, is devoted to the four maximal quantifiers in natural language English: *all*, *every*, *each*, and plural definites. I argue that they have different preferred readings with respect to the distributive/cumulative/collective/partitioned distinction discussed here.

6.2.1 All Sorts of Readings

6.2.1.1 Distributive Readings

As was already said, distributive readings are all the theory generates so far. For non-coordinated quantificational noun phrases, this means that we can calculate the minimal number of suitable events required to be in the model based on the quantificational information encoded in the noun phrases. The minimal number of events n_e in the sets in the denotation of the sentence can be calculated as in (17), where $NP_1,..,NP_n$ are the quantificational noun phrases.

(17) $n_e \geq \min_{E_1 \in [\![NP_1]\!]} Card(E_1) \times \min_{E_2 \in [\![NP_2]\!]} Card(E_2) \times \cdots \times \min_{E_n \in [\![NP_n]\!]} Card(E_n)$

This is so because of the definition of quantifiers as "collectors" of sets (as we called them informally). Under the distributive reading, every quantifier requires that for at least one (e.g., the smallest) set in its denotation, there be a set in the denotation of the verbal projection which has for each element of that one set from the quantifier one event, and those events are "collected" in the output sets. Since this happens with every quantificational NP, the multiplication effect arises and gives us the minimal number of events.

For example, (18) denotes, if true, a set containing at least one set containing at least $2 \times 3 \times 4 = 24$ events by (17).

(18) Two Muppets gave three guests four bunches of flowers.

Other cases of distributivity are those with collective-distributive predicates, as I call them. Look at (19), a sentence where a plural definite and a collective-distributive predicate lead to clear inferences regarding the singing activities of the single frogs.

(19) The frogs sang.

We have not defined the function of the definite determiner yet, even for singular nouns. In singular NPs, it is reasonable to define the denotation of the definite determiner as the

ι (*iota*) operator. In plural NPs, I will follow the Scha (1981), Link (1983), Landman (2000) tradition and assume that $\mathbf{the_{pl}}$ is an operator which selects the join of the set denoted by the noun, for (19), see (20).

(20) $[\![\mathbf{the_{pl}}(\mathbf{frogs})]\!] = \{\{\sqcup[\![\mathbf{frog}]\!]\}\}$

While this is intuitively what the NP seems to refer to (the totality of frogs), such NPs (or rather such sentences) can be read distributively, or at least there is a distributive inference with some (or even all) predicates. Look at (21), which seems to convey that the totality of frogs crossed the bridge in the swamp, but it also requires every single frog to have crossed the swamp (to have been the agent in a swamp-crossing event).

(21) The frogs crossed the bridge in the swamp.

(22) is even stronger in its ambiguity, since we have a clear intuition that the event of *the frogs* singing the song together is distinct from the singing of the song performed by each frog, but that the single singing events are necessary for there to be the larger event.

(22) The frogs sang the song.

This suggests that such sentences involve predicates which describe single atomic (*large*) events which have sum (or group) subjects. That the large event and the single smaller events are distinct can be tested by adding modifying adjuncts. In a model where Kermit was among the frogs who sang the song, (23) and (24) can both be true at the same time and referring to the same real-life event.

(23) Kermit sang the song badly.

(24) The frogs sang the song beautifully.

Scha assumes that for certain predicates (like the ones in (21) and (22)), we can assume meaning postulates hard-wiring the inferences just mentioned, because he is convinced that only some predicates force distribution when they take a plural definite as their argument. However, Roberts (1990), based on her 1987 dissertation, argues that any sentence containing plural definites can receive a distributive interpretation, even though in examples like (25), the collective reading might be much preferred (especially because of the indefinite object NP).

(25) The women from Boxborough brought a salad.

I agree that under the right circumstances, (25) can very well mean that each woman from Boxborough brought one salad, just as much as (22) can mean that the frogs didn't even sing the song together, but at different places and points in time.

These facts only show that the phenomena discussed here are is less a question of logical properties of classes of predicates, but rather a question of how far a model allows the "inferences" to individual events when such predicates are used. The answer lies in lexical knowledge and world/context knowledge.
Now, we have already touched on the question of what distinguishes distributivity and collectivity, taking as an example the special case of plural definites. In the next section, I will provide a model of how cumulativity/collectivity is an effect of a specific distribution of sum objects and atomic objects in the NP denotation, in conspiracy with certain (world/model-knowledge) relations between atomic events. Plural definites will then again be under discussion in section 6.2.2.

6.2.1.2 Collective Readings and Ambiguity

From the discussion which closed the immediately preceding subsection, we have seen that even predicates which seem to suggest a cumulative reading with plural definites can have a distributive interpretation under the right circumstances. It is only strictly collective predicates like *meet* which force a non-distributive interpretation, cf. (26).

(26) The Muppets met.

I will call such predicates recipro-collective from now on. Since section 6.2.2 is devoted to plural definites in a larger context of maximal (or universal) quantifiers, this present section only looks at other determiners (except numeral quantifiers, which are discussed in 6.2.1.3).
It seems like the meaning of sentences containing the quantifiers in question (and most sentences with plural definites and, as I am going to argue, sentences with numeral quantifiers) is underdetermined with respect to the degree of distributivity of the respective sentences. For example, look at (27). Cearly, the sentence does not specify whether the many bears told one joke together (as one sum), whether they all told a joke separately (strictly as atoms), or whether there were intermediately sized sums of bear sums and bear atoms (the total number of atoms amounting to *many*) who told a joke.

(27) Many bears told a bad joke.

In my terminology, these sentences have multiple readings (not analyses). Multiple readings which are common to one analysis are assumed to be truly ambiguous. This, in turn, means that they must all be represented in the set-theoretic object as which a specific analysis of the sentence is interpreted.
In other words, I will try to account for distributivity/collectivity phenomena by en-

riching the denotations of sentences (containing quantifiers), and leave the question of how language-users decide which specific reading is intended completely open. The fact that natural language expressions are ambiguous with regard to the degree of distributivity of most predicates is indicative of a hypothesized fact that language-users normally don't need to decide upon a specific reading. Section 6.2.2 tries to find some tendencies for maximal quantifiers, however.

I now simply present my technical solution to implement cumulativity when needed. The idea is that the definition of base quantifiers can simply be modified to impose constraints only on the number of the *atoms* in the sets it contains, ignoring possible sum formations involving these atoms. Thus, all sets in $[\![\textbf{many}(\textbf{bears})]\!]$ would have to contain a large enough number of bear atoms to warrant calling it *many*, no matter whether these are organized in sums or not. By way of example, (28) would then arise as a proper interpretation in a model where three is a large enough number for bears to warrant calling them *many* (and there are only three of them). In this case *many bears* coincides with *three bears*.

(28) $[\![\textbf{many}(\textbf{bears})]\!] = \{\{b_1, b_2, b_3\}, \{b_1 \sqcup b_2, b_3\}, \{b_1, b_2 \sqcup b_3\}, \{b_1 \sqcup b_3, b_2\}, \{b_1 \sqcup b_2 \sqcup b_3\}\}$

This is a handy solution, because now this NP can combine successfully with any event-denoting expression the denotation of which either

(29) a. exclusively contains events which have atomic role bearers (called here **micro-events**),

b. contains events which have appropriate sums of bears as role bearer (while still being atomic events) (called **macro-events**) and possibly other events which have bear atom role bearers (as long as every bear atom occurs once in such a sum or as an atom),

c. exclusively contains only one macro event which has as its role bearer the maximal sum of bears (here: $b_1 \sqcup b_2 \sqcup b_3$) as its role bearer.

Under current assumptions, where the event domain is also closed under summation, there arises a certain redundancy. Even if (continuing with example (28)) b_1, b_2 and b_3 were involved in three distinct events with a right main parameter specification (no macro-events), these events e_{b_1}, e_{b_2}, and e_{b_3} would be available in sums. The sum $e_{b_1} \oplus e_{b_2}$ would be available, and the set $\{e_{b_1} \oplus e_{b_2}, e_{b_3}\}$ would be in the verb's denotation. This would lead to both $\{e_{b_1} \oplus e_{b_2}, e_{b_3}\}$ and $\{e_{b_1}, e_{b_2}, e_{b_3}\}$ redundantly (among a total of five equally redundant sets) being in the final denotation. Since redundancy might be ugly but not dangerous, I leave this matter as it is.

The most attractive aspect of this analysis is that (29) gives us the distinction between **distributive**, **partitioned** and **collective** readings for free in an ambiguitiy located within the quantificational noun phrase. It's the distribution of micro- and macro-events semantically corresponding to sums and atoms in the NP denotation which creates all relevant effects.

Finally, I now turn to a discussion of those predicates which are exclusively collective (labeled recipro-collective, ex. (26)) and those which warrant entailments to a distributive reading even under a collective interpretation (labelled collective-distributive), although these effects only occur with a restricted set of quantifiers.

Collective-distributive predicates (like *sing a song* or *cross the swamp*) are treated by Scha in terms of meaning postulates which hard-wire the inferences from a macro-event to micro-events for all atoms of the sum which is the role bearer of the macro-event. This is, in my view, the correct solution, given that meaning postulates in essence capture in the logic some knowledge about necessary states of affairs in certain types of models, making logical formulae always true correspondingly.

The fact that for some types of events, if they are performed by a sum object, there are corresponding micro-events (having the same main parameter specification) for every atom of the sum appear not to be an effect of the grammar, but of knowledge about the world or rather knowledge about models. Hence, whenever there are such inferences, I assume that language-users simply have the knowledge that if the macro-event is in the model, there must be the relevant micro-events. Since the problem is therefore no longer related to the core grammar, I leave the problem as it is.

Recipro-collective predicates are those like *meet* which, at least if used intransitively, require the subject to be a plural structure, like a sum or a group. Also, they denote only macro-events, and there are never any inferences from the macro-event to any potential micro-events. Again, I do not see that there needs to be a grammatical solution. The fact that such predicates strictly require pluralic structures in the denotations of their subjects can be captured by a constraint on the model, informally (31). The same goes for the fact that there are never inferences to micro-events, informally (32).

(30) * Kermit met.

(31) Events with main parameter *meet*,… always have sums or groups as external role bearers (i.e., they are always macro-events).

(32) For (macro-)events with main parameter *meet*,… there never are collocated micro-events for atoms in the sum which is the external role bearer.

6.2.1.3 Cumulative Readings and Numeral Quantifiers

Cumulative readings are (as Fred Landman puts it) non-scopal readings of sentences involving more than one numeral quantifiers. What is meant by that in terms of my distinction between analysis and reading is that no matter which scopal *analysis* one adopts, the sentences will always have the same range of *readings*. Furthermore, this reading is relational and encodes a relation about non-differentiated collections of objects. An example is (33).

(33) Ten Muppets sang 27 songs.

Prototypically, such sentences are felt to be about certain portions of objects which are involved in a certain number of events, but the question of which sums of objects or single objects are involved in which of the single events doesn't matter at all. In other words, (33) tells us that ten Muppets were involved in 27 songs being sung, and nothing more.

To make sure that sentences like (33) are true/false in the right event-based models, however, we must make sure that they can in principle denote all kinds of event configurations (as quirky and marginal as they might be) which make them true. This means that in any model where there are nine Muppets who sang a song (in nine events) and one Muppet who sang 26 songs (in 26 events), then the sentence should be true.

As I see it, we can adopt either one of two possible strategies, using (33) as an example:

1. We turn the whole real-life events which were involved in the singing of 27 songs by ten objects in twelve shows into one atomic macro-event which has a sum of 27 objects as theme, a ten-sum as agent and a twelve-sum as location.

2. We redefine the formation of NP quantifiers so that it requires only a certain number of atoms to be in the sets it denotes, be they bound in sums or not (as we have already done in (29)).

Since the generalized interpretation of pluralic noun phrases as sets of sum/atom partitions is already in place, and since I don't see an easy way of formulating the constraints on models which would be required to link the macro event to the relevant micro-(or meso-)events in case one adopts the first solution, I opt for the second solution. Also, it contains the first solution as an extreme case.

This means that in any situation where there is an atom/sum partition of Muppets (totalling ten Muppet atoms) and an atom/sum partition of songs (totalling 27 song atoms) which were involved (bearing their respective roles) in an adequate number of singing events, then the sentence will be true. The adequate number of events here depends totally on the concrete atom/sum partitioning of the objects in as much as the highest number of objects (atoms or sums) in any of the NP denotations is the minimal number of events possible.

An example corresponding to (33): If the only relevant partition of Muppets is as in (34), then the number of singing events must not be less than four (one micro-event, three macro-events).

(34) $\{m_1 \sqcup m_2 \sqcup m_3, m_4, m_5 \sqcup m_6, m_7 \sqcup m_8 \sqcup m_9 \sqcup m_9 \sqcup m_{10}\}$

This configuration of Muppet objects could for example have been involved in eight events in a manner visualized in figure 6.1, resulting in eight events.

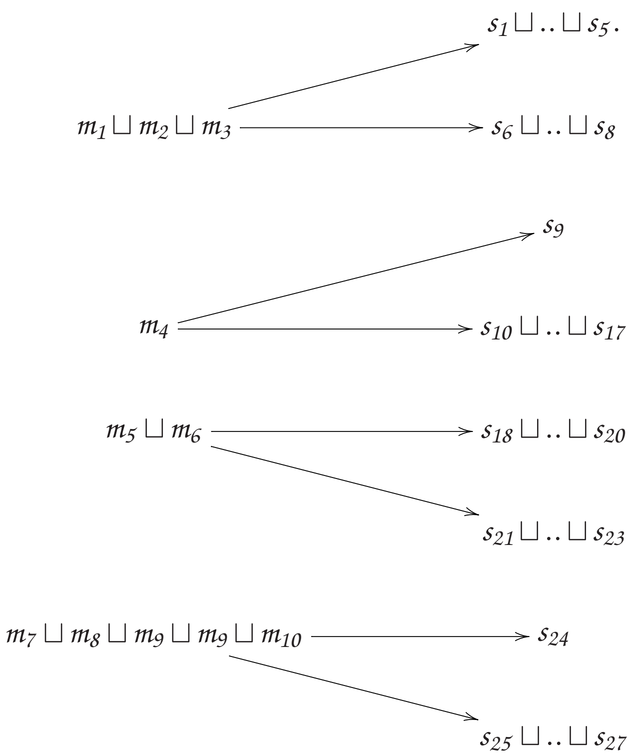


Figure 6.1: Illustration of (33) and (34)

I have now shown how atom/sum partitions of quantifiers can account for the truth of sentences in distributive, collective, and partitioned cases. It was generally assumed that quantifiers are ambiguous with regard to the partitioning, and that only the number of total atoms in the sets denoted by the quantifiers is checked. Fully collective and fully distributive readings are thus just extreme cases of the general case.

Furthermore, I have argued that the number of events involved is intimately related to the partition structures in the nominal quantifiers, and that the interpretations of certain event descriptions (verbs) might be subject to constraints on models requiring them to be only micro-events or macro-events (e.g., recipro-collectives), or to be macro-events which always allow language-users to additionally assume specific micro-events (collective-distributive). In the remainder of this section, I will take a look at the effects of the maximal quantifiers *all*, *every*, *each*, and plural *the*.

6.2.2 All, Every, and Each, and The Plurals

This final subsection on cumulativity, distributivity, and their subtleties argues for the hypothesis that there is a clear division of labor between the maximal quantifiers of English: *all*, *every*, *each*, and plural *the*. They are called "maximal" here, because they all involve in some way all objects from the denotation of the noun which they take as their argument. Some of the results in this section are derivative of the seminal Vendler (1962).

6.2.2.1 Pluralic vs. Atomic

In (35)–(37), all four cases are exemplified. In (35), they occur with a (prototypically) distributive predicate, in (36) with a recipro-collective predicate, and in (37) with a collective-distributive predicate.

(35) a. Each bear loves a joke.
b. Every bear loves a joke.
c. All bears love a joke.
d. The bears love a joke.

(36) a. * Each bear gathers on stage.
b. * Every bear gathers on stage.
c. All bears gather on stage.
d. The bears gather on stage.

(37) a. Each bear crossed the samp.
b. Every bear crossed the swamp.
c. All bears crossed the swamp.
d. The bears crossed the swamp.

The ungrammaticality of (36a) and (36b) is very clear and leads us to detecting the first split in the functions of the four determiners. Under our current assumptions, the ungrammaticality leads to the conclusion that NPs with the determiners *each* and *every* don't denote sum structures, because we said above that recipro-collectives are fine with sum objects as subject denotations, and absolutely incompatible with atomic objects. Let us therefore say for a start that *each* and *every* are strictly non-collective and always pair atomic micro-events with object atoms. This is also in line with the intuitions about sentences with *each* and *every*. For *each*, full distributivity is a defining criterion, and for *every*, it also seems impossible to conjure up collective interpretations.[1]

Since both *all* and *the* are fine with recipro-collectives, we can conclude further that these two make claims about the totality of objects the noun denotes. So, even if there are standard inferences to micro-events as in (37c) and (37d), sentences containing them might describe undifferentiated macro-events with maximal sum subjects.

6.2.2.2 *The* and *All*

I now give what is mainly a reformulation of ideas from Heim (1982), Link (1983), and Landman (2000) in the current framework.

The question is: What is the difference between *all* and *the*? We could suspect that the distinction is somehow related to degrees of definiteness brought about by the two different determiners. These determiners are strong both in the sense of Milsark (1977) and the sense of Barwise and Cooper (1981), and they both lead to ungrammaticality in the coda of existential *there* sentences. But definiteness does not always overlap with the strong/weak distinction (cf. also Abbott 2006), and an account along the lines of the familiarity theory of definiteness (Heim 1982 being the most cited source, although the idea dates back to Christophersen 1939) might be helpful in the case of *all* and plural *the*.

Obviously, (38) is felicitous as a discourse-initial segment, and (39) is not (assuming that the initial sentences are uttered out of the blue, and that we can be sure the language-users have no reason to believe that they know which frogs are referred to).

(38) All frogs have a funny voice. They sing songs on the Muppet Show.

(39) # The frogs have a funny voice. They sing songs on the Muppet Show.

Considering that we said that both determiners create NPs which refer to the maximal sum of the objects the noun denotes, we could say that they both refer uniquely. In other words, the uniqueness condition in the sense of Russell (1905) should be vacuously fulfilled, because there can only be one maximal sum of a set of objects. Also, familiarity

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[1] Furthermore, Scha (1981) already suggests treating morphological plurals (of nouns) as marking the presence of sums in their denotation. Singulars should have entirely atomic denotations, and *every* takes singular nouns.

shouldn't actually matter, because the maximal sum of all known frogs should always be salient or at least accessible.

However, (39) still seems to require some specific structure of the previous discourse to be salient. I suggest in the spirit of Heim's theory that NPs with plural *the* require information which allows the hearer to (contextually) restrict the set of noun referents (frogs in this case) to some salient set which usually is not the total set of all referents of the noun which there are. On the other hand, *all* can default to denote the actual sum of all noun referents, and turn sentences like the first on in (38) into something like a generic statement about frogs.

If we add some prior information to the discourse in (39) which allows the restriction of the sum referred to by *the frogs* by some poset relation as in (40), or if such an information is reliably present through language-external factors, then the sentences become fine.

(40) I love all Muppets. The frogs have a funny voice. They sometimes sing songs on the show.

I thus see good evidence that the division of labor between *all* and plural *the* is that the former requires no familiarity-based embedding in a discourse (like indefinite *a*), but plural *the* does.

6.2.2.3 *Each* an *Every*

The differences between the two distributive universal quantifiers is subtle. First of all, there also seems to be a preference to use *each* in discourse contexts which support a poset relation, as (41) vs. (42), taken as discourse-initial, show. "#" here signals (almost) absolute infelicity, "?" signals that the sentence is mildly infelicitous.

(41) ? Every frog sang a song.

(42) # Each frog sang a song.

Like *all*, *every* seems to default to conveying information about universally every frog in (40), but it appears that the effect is less clear than in the case of the summative maximal quantifiers. It is slightly more noticeable with generic statements as in (43) and (44).

(43) Every frog is shorter than 12 inches.

(44) # Each frog is shorter than 12 inches.

However, this cannot be the whole story. Vendler (1962:148–150) already provides a solution, although of course not yet in terms of sum ontologies. Vendler argues that while *all* is strictly collective, and *each* is strictly distributive, *every* is sort of in between. By referring to examples like the ones in (45) through (47), he convincingly shows that while (45) is prototypically interpreted as saying that Rowlf took the apples *en bloc*, (47) requires that he did something to each apple (i.e., the sentence refers to a set of distinguishable events for each apple), whereas with (46) the speaker conveys his indifference towards the question of in which bulks of apples Rowlf arrived at finally having taken all of them.

(45) Rowlf took all apples.

(46) Rowlf took every apple.

(47) Rowlf took each apple.

It is not clear to me whether Vendler would say that differences in truth values arise. On page 148, he clearly classifies the distinction to be made between *each* and *every* as "*much too fine to be located by merely comparing truth-values*. However, if (47) requires there to be distinct events for each apple, and (46) does not, then there could be situations where one sentence would have to be classified as true, and the other one would sound very much false under the Vendlerian interpretation.
I would nevertheless opt for a solution which assigns the same denotations to (46) and (47), such that both require that for each object in (a set in the) denotation of *every N* and *each N* there be one micro-event of which it is the relevant role bearer. In addition, *each* introduces the pragmatic condition that for these micro-events there be *no* macro-event to which they are implicationally related by a meaning postulate. For *every*, however, any model which has the respective micro-events in or not in a consequence relation to macro events, makes the sentence felicitous.
This explains why (48) is not felicitous, or at least heavily dispreferred compared to an otherwise identical variant with *each*.

(48) # Rowlf ate every apple separately.

The version with *every apple* says that it doesn't matter whether Rowlf ate the apples one-by-one or in a bulk, as long as every apple ended up eaten by Rowlf. *separately* then says that the apple-eating events were explicitly *not* related through the presence of some macro-event. This should be, and apparently is, an inconsistent use of pragmatic means, especially since *each* is available. The same is the case in (49) with *every apple* and *one-by-one*.

(49) # Rowlf ate every apple one-by-one.

6.2.2.4 Summary

To summarize, the properties for maximal quantifiers argued for are.

(50) a. *all* and *the* strictly create NPs denoting total sum structures.

b. *each* and *every* strictly create NPs denoting atom structures.

c. *each* requires that the model does not contain macro-events related to any of the micro-events in which the object atoms denoted by the NP are involved, while *every* is indifferent towards such micro-macro relations. The pragmatic division of labour between the two will be clear and keep *every* from being used when the speaker knows that the events were distinct (by Gricean principles).

d. *all* is less definite (in the sense of familiarity theory) than plural *the*.

This concludes the short discussion of distributivity and collectivity in GOA. I have shown that, while conjunction is largely related to sum formation in the domain of events, plurality effects with certain quantifiers involve also sum formation in the domain of objects. It should be kept in mind that the major tool in the analysis of such plurality effects were relations between object atom/sum structures on the one hand and micro-events and macro-events on the other hand. Relations between micro-events and macro-events, however, are implemented only as constraints on the model, and would not enter into the "logic" of the language.

Chapter 7

Implementation within a Syntactic Framework

7.1 Introduction

In the development of the semantics framework presented in the previous chapters, I did not go into any details of how natural language syntax and the representation language $\mathscr{L}_{\mathsf{GOA}}$ could be mapped onto each other. This final chapter redeems this situation by providing an implementation of at least one foundational aspect of $\mathscr{L}_{\mathsf{GOA}}$ in a highly formalized theory of syntax, viz. Head-Driven Phrase Structure Grammar (HPSG, Pollard and Sag 1994). Primarily, I show how arguments receive their special interpretation as generalized operators, leaving many other aspects of $\mathscr{L}_{\mathsf{GOA}}$ unimplemented.
After a few introductory comments on HPSG in section 7.2, the definition of an HPSG representation format for applicative semantics follows in section 7.3. In section 7.4, a mechanism in shown by which NPs receive their $\mathscr{L}_{\mathsf{GOA}}$ interpretation, and how that mechanism can be extended to allow free scoping.

7.2 The HPSG Framework

I assume that the reader has introductory-level knowledge of HPSG, corresponding to roughly the first three chapters of Pollard and Sag 1994 or the first six chapters of Müller 2008. The proof-of-concept implementation of the $\mathscr{L}_{\mathsf{GOA}}$ syntax-semantics interface shown here is based on a simple grammar by Stefan Müller, corresponding to chapter 6 of his aforementioned introductory book.[1]

I assume standard HPSG constructs in the syntax, where subcategorization is encoded in a SUBCAT list of lexical heads (Müller 2008, 22). A version of the *Head Feature Principle* (Müller 2008, 34), the *Head Argument Schema* (Müller 2008, 60) and the *Valency Principle* (Müller 2008, 79) are assumed to be in place. Likewise, a MOD feature (of non-heads) (Müller 2008, 73) with a *Head Adjunct Schema* (Müller 2008, 78) take care of adjunct selection and the corresponding phrase structure construction. Since only a proof-of-concept implementation for the most basic concepts is intended, nothing is said about natural language word order, subordinate clauses and many other phenomena usually covered by larger HPSG fragments.

On top of this syntax, the following sections describe the implementation of the semantics, which is everything below the SYNSEM|LOC|CONT and SYNSEM|SCOPES (cf. section 7.4.6.2) nodes. First, an HPSG encoding for applicative semantics is given in section 7.3, and then the actual syntax-semantics interface is described in section 7.4.

7.3 Applicative Semantics in HPSG

The only compositional semantic operation needed to implement $\mathscr{L}_{\mathsf{GOA}}$ is function application, as follows from chapter 5, where no other such operation is defined. Encoding function application in HPSG can be easily achieved. As opposed to more complex syntax-semantics interfaces which involve function application as well as complex abstraction schemes (such as Sailer 2003, from which some inspiration was drawn for the encoding presented here), the simplicity of the $\mathscr{L}_{\mathsf{GOA}}$ interface makes it easy to encode the semantics of complex expressions in HPSG feature structures.

$\mathscr{L}_{\mathsf{GOA}}$ depends heavily on typed expressions, so first I am going to present an encoding of the $\mathscr{L}_{\mathsf{GOA}}$ type system in section 7.3.1, then an encoding of the semantic values of expressions in section 7.3.2, and finally a Semantics Principle, which defines how syntactic composition and compositional semantics interact.

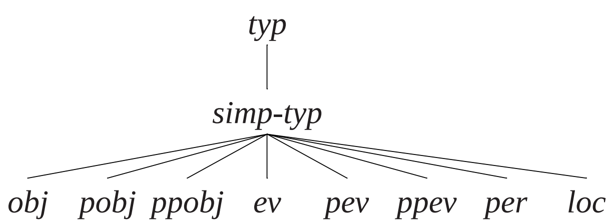
7.3.1 Semantic Types

First, we encode semantic types by mapping them onto an HPSG sort hierarchy. In $\mathscr{L}_{\mathsf{GOA}}$, simple types and complex types are defined, cf. section 5.2. Simple types are

[1] The grammar proposed in this chapter is implemented in the *Trale* system (Haji-Abdolhosseini and Penn 2003), and the source files can be downloaded from http://www.rolandschaefer.net/phd (permanent URL). Stefan Müller's implementations and a full *Trale* system are included with the print version of his book.

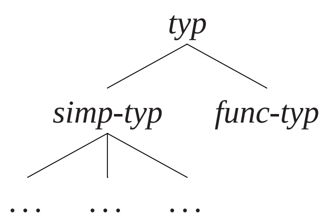
$\mathbf{Obj}, \mathbf{Ev}, \mathbf{Per}, \mathbf{Loc}$ and set types for these. The definition is recursive, in that every set type of a type is also a type, including arbitrary depths of set types of set types. Such a recursive definition cannot be easily achieved in an HPSG signature. Fortunately, the only set types ever used in $\mathscr{L}_{\mathsf{GOA}}$ are $\wp\mathbf{Obj}, \wp\mathbf{Ev}$ and $\wp\wp\mathbf{Obj}, \wp\wp\mathbf{Ev}$. It is therefore not actually necessary to encode the fully recursive definition, and the signature can be given simply as (1).

(1)



Functional types are recursively characterized as having an input and an output type. The input and output types can be any type, including functional types. Thus, it is only required to add one sort to the signature, namely *func-typ*, cf. (2).

(2)



Since any functional type (by the definition given in section 5.2) is characterized as having an input and an output-value, *func-typ* is given as in the feature declaration (3).

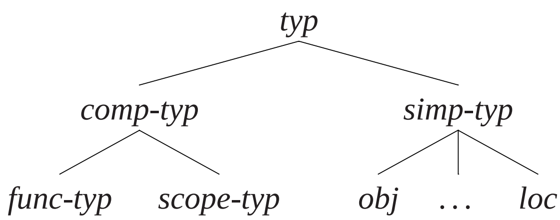
(3) $\textit{func-typ} : \begin{bmatrix} \textsc{in} & \textit{typ} \\ \textsc{out} & \textit{typ} \end{bmatrix}$

Given this type encoding, all $\mathscr{L}_{\mathsf{GOA}}$ types can be fully rendered. Taking the type of prepositions as an example, the encoding is presented in (4).

(4) $$\begin{bmatrix} \textit{func-typ} & \\ \textsc{in} & \textit{ppobj} \\ \textsc{out} & \begin{bmatrix} \textsc{in} & \textit{ppev} \\ \textsc{out} & \textit{ppev} \end{bmatrix} \end{bmatrix} \equiv (\wp\wp\mathbf{Obj} \to (\wp\wp\mathbf{Ev} \to \wp\wp\mathbf{Ev}))$$

Since it will be necessary (in section 7.4) to distinguish between functional types of scopal elements (delayed application) and ordinary functional types, a further distinction must be made between scopal functional types *scope-typ* and non-scopal functional types *func-typ*. They are made subsorts of one sort *comp-typ*, and the full hierarchy for the semantic type encoding looks like (5).

(5) a.



b. *comp-typ* : $\begin{bmatrix} \text{IN} & \textit{typ} \\ \text{OUT} & \textit{typ} \end{bmatrix}$

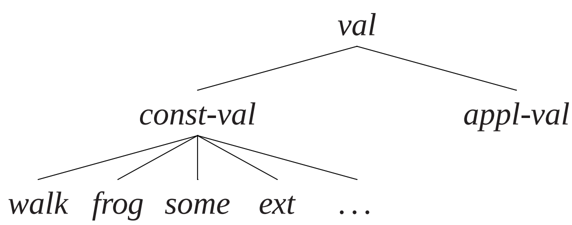
I now turn to the encoding of the semantic values, which is equally straightforward.

7.3.2 Semantic Values

7.3.2.1 Value Encoding

Semantic values in $\mathscr{L}_{\mathsf{GOA}}$ are individual or set constant symbols on the one hand and function symbols on the other hand. The value of any such symbol can be encoded directly in a simple HPSG sort, requiring an accompanying $\mathscr{L}_{\mathsf{GOA}}$ type encoding to make sure that the combinatorial mechanism has information as to how applicative structures can be built up. The result of a function application itself must be a complex structure, giving the result type and a specification of the functor and the argument. The Semantics Principle given in section 7.4 builds up applicative values appropriately, the (partial) signature and the feature declaration are given in (6).

(6) a.



b. *appl-val* : $\begin{bmatrix} \text{FUNC} & \textit{val} \\ \text{ARG} & \textit{val} \end{bmatrix}$

Consequently, (7) should be assumed.

(7) $\begin{bmatrix} \textit{appl-val} & \\ \text{FUNC} & \alpha \\ \text{ARG} & \beta \end{bmatrix} \equiv \alpha(\beta)$

7.3.2.2 Determiners and Thematic Operators Redefined

This section provides some additions to $\mathscr{L}_{\mathsf{GOA}}$, which will make it easier to integrate $\mathscr{L}_{\mathsf{GOA}}$ semantics with a standard HPSG syntax in section 7.4.3. I introduce an additional class of lexical semantic values by defining new operators based on other operators. Specifically, the $\mathscr{L}_{\mathsf{GOA}}$ idea of representing natural language predicates as tuples of constants (an event set constant plus an appropriate number of operators, which have a meaning similar to prepositions) could be rendered in HPSG only by introducing phonologically empty prepositions. The PPs formed by such prepositions would have to be subcategorized by the verb to the effect that no verb would actually select NPs, but just PPs. Using lexical rules is not a general solution in this case, because the generalized operator must be applied to a whole NP, which is in most cases not a lexical item (but see section 7.4.4).

The solution proposed here is therefore as follows:

1. The **Verb** operator (basically just power set formation) is dropped. Instead, verbs denote sets of sets of events directly. This effect could actually be achieved by a lexical rule, but in this fragment, we only need verbs which denote sets of sets of events, never the simpler variant denoting just sets of events. Thus, I implicitly assume that **Verb** has already applied to the verb meaning. Semantic values of verbs are of type $\wp\wp\mathbf{Ev}$.

2. New, more complex thematic operators, which lexically contribute both the effect of the generalized operator (such as **Ext**) and the effect of the quantifier (such as **all**), are defined. Simply speaking, instead of **Ext**(**all**(·)), there will now be **ExtAll**(·). For the closed class of determiners, this means that there must be at least three lexical variants explicitly defined (one for each role functor).

3. The original generalized operators such as **Ext** are still there, but they are only used in a lexical rule which makes proper names thematic, i.e., which applies a thematic operator to proper names. For this open class, such a solution is favorable because there is no need to define three lexical variants of each proper name.

The definition of the new, more complex functors, which are quantificational and thematic at the same time, is a simple task. First, I repeat section 5.4.1.3/5,9 as (8) and (9).

(8) Determiner operators $c_{det_i} \in C_{det}$ are interpreted $[\![c_{det_i}]\!] = f_{c_{det_i}}$ where $f_{c_{det_i}}$ is a function in $\mathfrak{Dom}_{\wp\wp\mathbf{Obj}}^{\mathfrak{Dom}_{\wp\mathbf{Obj}}}$, such that for every $S \in \mathfrak{Dom}_{\wp\mathbf{Obj}}$:

1. $f_{\mathbf{all}}(S) = \{T \in \wp S | T = S\} = \{S\}$
2. $f_{\mathbf{some}}(S) = \{T \in \wp S | T \neq \{\}\} = \wp S - \{\}$
3. $f_{\mathbf{3}}(S) = \{T \in \wp S | Card(T) \geq 3\}$
4. $f_{\mathbf{3!}}(S) = \{T \in \wp S | Card(T) = 3\}$

5. $f_{\textbf{most}}(S) = \{T \in \wp S | Card(T) > Card(S - T)\}$ etc.

(9) For each role functor $c_{role_i} \in C_{role}$ there is exactly one thematic operator $c_{theta_i} \in C_{theta}$ (**Ext** for **ext**, $\textbf{Int}_1$ for $\textbf{int}_1$, etc.) such that if $[\![c_{role_i}]\!] = f$, where f is a function in $\mathfrak{Dom}_{\textbf{Obj}}^{\mathfrak{Dom}_{\textbf{Ev}}}$ (from events to participant objects), then $[\![c_{theta_i}]\!] = g$, where g is exactly the function in $(\mathfrak{Dom}_{\wp\wp\textbf{Ev}}^{\mathfrak{Dom}_{\wp\wp\textbf{Ev}}})^{\mathfrak{Dom}_{\wp\wp\textbf{Obj}}}$ such that for every $S \in \mathfrak{Dom}_{\wp\wp\textbf{Obj}}$ and every $T \in \mathfrak{Dom}_{\wp\wp\textbf{Ev}}$:

$g(S)(T) =$

$$\{U | \exists O \in S[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[f(e) = o]]] \wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[f(e') = o]]]]]\}$$

The new operators are of type $(\wp\textbf{Obj} \to (\wp\wp\textbf{Ev} \to \wp\wp\textbf{Ev}))$. I define them on top of the existing definitions in (10) as an extension of $\mathscr{L}_{\mathsf{GOA}}$ as presented in chapter 5.

(10) For each determiner operator c_{det_i} and each thematic operator c_{theta_j} there is exactly one thematic determiner $c_{thdet_{(i,j)}}$ such that $[\![c_{thdet_{(i,j)}}]\!] = h$, where h is a function, $h \in (\mathfrak{Dom}_{\wp\wp\textbf{Ev}}^{\mathfrak{Dom}_{\wp\wp\textbf{Ev}}})^{\mathfrak{Dom}_{\wp\textbf{Obj}}}$ and with $k = [\![c_{det_i}]\!]$ and $f = [\![c_{role_j}]\!]$ and $V \in \mathfrak{Dom}_{\wp\textbf{Obj}}$ and $T \in \mathfrak{Dom}_{\wp\wp\textbf{Ev}}$: $h(V)(T) =$

$$\{U | \exists O \in k(V)[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[f(e) = o]]] \wedge \forall o \in O[\exists E'' \in E[\forall e' \in E''[f(e') = o]]]]]\}$$

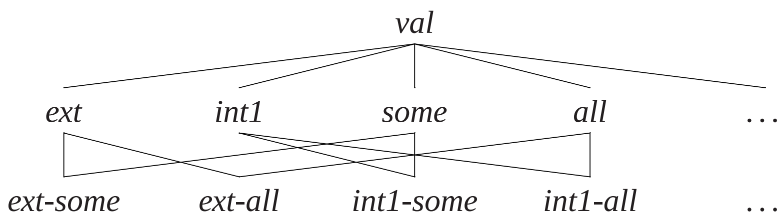
The thematic determiner is thus just a lexical pre-combination of the determiner and the thematic operator. Two examples follow in (11).

(11) a. $[\![\textbf{ExtAll}]\!](V)(T) = \{U | \exists O \in \{W \in \wp V | W = V\}$
$[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[ext(e) = o]]] \wedge$
$\forall o \in O[\exists E'' \in E[\forall e' \in E''[ext(e') = o]]]]]\}$

b. $[\![\textbf{Int}_1\textbf{Some}]\!](V)(T) = \{U | \exists O \in \{T \in \wp S | T \neq \{\}\}$
$[\exists E \subseteq T[U = \bigcup E \wedge \forall E' \in E[\exists o \in O[\forall e \in E'[int_1(e) = o]]] \wedge$
$\forall o \in O[\exists E'' \in E[\forall e' \in E''[int_1(e') = o]]]]]\}$

To make the HPSG signature reflect the functional connections between simple determiners, thematic operators, and the new thematic determiners, the thematic determiner value sorts are made subsorts of both determiner value and the thematic operator value sorts in the signature. Part of the hierarchy is shown for illustrative purposes in (12).

(12)



This completes the description of the HPSG signature required for the $\mathscr{L}_{\mathsf{GOA}}$ encoding. In the next section, I define the lexical entries and the relevant rules and constraints which add the encoding to an HPSG grammar.

7.4 Generalized Operator Semantics in HPSG

7.4.1 Lexical Entries

First of all, we need to redefine the SYNSEM|LOC|CONT feature of *sign*, which is where the meaning of expressions is standardly encoded to represent $\mathscr{L}_{\mathsf{GOA}}$ encodings. I thus just give a redefined feature declaration for *cont(ent)* in (13) (compare to, for example, Pollard and Sag, 1994:398).

(13) *cont(ent)* : $\left[\begin{array}{ll} \text{TYP} & \textit{typ} \\ \text{VAL} & \textit{val} \end{array}\right]$

A sample lexical entry would thus look as in (14).

(14) a.
$$\left[\begin{array}{ll} \text{PHON} & \textit{walks} \\ \text{SYNSEM}|\text{LOC} & \left[\begin{array}{ll} \text{CAT} & \left[\begin{array}{ll} \text{HEAD} & \textit{verb} \end{array}\right] \\ \text{CONT} & \left[\begin{array}{ll} \text{TYP} & \textit{ppev} \\ \text{VAL} & \textit{walk} \end{array}\right] \end{array}\right] \end{array}\right]$$

b.
$$\left[\begin{array}{ll} \text{PHON} & \textit{the} \\ \text{SYNSEM}|\text{LOC} & \left[\begin{array}{ll} \text{CAT} & \left[\begin{array}{ll} \text{HEAD} & \textit{det} \end{array}\right] \\ \text{CONT} & \left[\begin{array}{ll} \text{TYP} & \left[\begin{array}{ll} \text{IN} & \textit{pobj} \\ \text{OUT} & \left[\begin{array}{ll} \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{array}\right] \end{array}\right] \\ \text{VAL} & \textit{some} \end{array}\right] \end{array}\right] \end{array}\right]$$

7.4.2 Basic Composition

Function application takes place when constituents combine syntactically. For simplicity reasons, I assume a grammar which has maximally binary phrases, which are either a *head-argument-phrase* (Müller 2008, 53ff.) or a *head-adjunct-phrase* (Müller 2008, 73ff.).

What the CONT of a binary phrase is, is defined by the Semantics Principle given in (15).

(15) **Semantics Principle (preliminary version)**

binary-phrase $\rightarrow$

$$
\left[\begin{array}{ll}
\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{1}\\ \text{VAL} & \left[\begin{array}{ll}\text{FUNC} & \boxed{2}\\ \text{ARG} & \boxed{3}\end{array}\right]\end{array}\right]\\
\text{HEAD-DTR}\mid\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{4}\\ \text{VAL} & \boxed{3}\end{array}\right]\\
\text{NON-HEAD-DTR}\mid\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \left[\begin{array}{ll}\text{IN} & \boxed{4}\\ \text{OUT} & \boxed{1}\end{array}\right]\\ \text{VAL} & \boxed{2}\end{array}\right]
\end{array}\right] \vee
$$

$$
\left[\begin{array}{ll}
\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{1}\\ \text{VAL} & \left[\begin{array}{ll}\text{FUNC} & \boxed{2}\\ \text{ARG} & \boxed{3}\end{array}\right]\end{array}\right]\\
\text{HEAD-DTR}\mid\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \left[\begin{array}{ll}\text{IN} & \boxed{4}\\ \text{OUT} & \boxed{1}\end{array}\right]\\ \text{VAL} & \boxed{2}\end{array}\right]\\
\text{NON-HEAD-DTR}\mid\text{SYNSEM}\mid\text{LOC}\mid\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{4}\\ \text{VAL} & \boxed{3}\end{array}\right]
\end{array}\right]
$$

The two cases covered by this disjunction are those where the non-head is the functor, and where the head is the functor. Since neither can be excluded, the disjunction is entirely justified. The result of the combination (the phrase) is characterized by having as its TYP the TYP|OUT value of the functor daughter. Furthermore, the VAL of the phrase is an applicative structure with the VAL of the functor daughter as VAL|FUNC and the VAL of the non-functor daughter as VAL|ARG.

An example is (16), where only PHON and SYNSEM|LOC|CONT are shown and paths are abbreviated accordingly. Generally, structure sharing of PHON values will not be indicated throughout this chapter.

$$
(16)\quad
\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{head-argument-phrase}}\\
\text{PHON} & \textit{some frog}\\
\text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{1}\,\textit{ppobj}\\ \text{VAL} & \left[\begin{array}{ll}\text{FUNC} & \boxed{2}\,\textit{some}\\ \text{ARG} & \boxed{3}\,\textit{frog}\end{array}\right]\end{array}\right]\\
\text{HEAD-DTR} & \left[\begin{array}{ll}\text{PHON} & \textit{frog}\\ \text{CONT} & \left[\begin{array}{ll}\text{TYP} & \boxed{4}\,\textit{pobj}\\ \text{VAL} & \boxed{3}\,\textit{frog}\end{array}\right]\end{array}\right]\\
\text{NON-HEAD-DTR} & \left[\begin{array}{ll}\text{PHON} & \textit{some}\\ \text{CONT} & \left[\begin{array}{ll}\text{TYP} & \left[\begin{array}{ll}\text{IN} & \boxed{4}\,\textit{pobj}\\ \text{OUT} & \boxed{1}\,\textit{ppobj}\end{array}\right]\\ \text{VAL} & \boxed{2}\,\textit{some}\end{array}\right]\end{array}\right]
\end{array}\right]
$$

7.4.3 Subcategorized NPs

When developing the semantic framework in the earlier chapters, I postulated thematic operators as something like phonologically empty elements, which have to be lexically co-selected with each verb. In order to avoid empty elements in the HPSG grammar, I defined thematic determiners earlier in this chapter (cf. section 7.3.2.2). These thematic determiners combine the effect of the determiner and the thematic operator.
In the HPSG syntax, we can control their selection in a simple way:

1. Thematic determiners behave syntactically like determiners and are subcategorized by the noun (Müller 2008, 67ff.).

2. Verbs specify on their SUBCAT list that the NP arguments which they require should have a CONT|VAL|FUNC value that is of the required thematic type: *ext*, *int1* or *int2*. This has the effect that only the right version of the thematic determiner will lead to a successful unification, since all semantic values of thematic determiners are subsorts of one of the aforementioned thematic types.

Sample verbs are given in (17). Again, the SYNSEM|LOC part of paths is omitted for reasons of compactness, and it will be omitted for the remainder of this chapter.

(17) a.
$$\begin{bmatrix} \text{PHON} & \textit{walks} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{SUBCAT} & \left\langle \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{CASE} & \textit{nom} \\ \text{NUM} & \textit{sg} \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{VAL} & \begin{bmatrix} \text{FUNC} & \textit{ext} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{PHON} & \textit{loves} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{SUBCAT} & \left\langle \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{CASE} & \textit{nom} \\ \text{NUM} & \textit{sg} \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{VAL} & \begin{bmatrix} \text{FUNC} & \textit{ext} \end{bmatrix} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{CASE} & \textit{acc} \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{VAL} & \begin{bmatrix} \text{FUNC} & \textit{int1} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

Given the Semantics Principle and such SUBCAT lists, a simple sentence can be represented as in (18) with the usual abbreviations and HD-DTR and NHD-DTR standing in for HEAD-DAUGHTER and NON-HEAD-DAUGHTER, respectively.

(18)

$$\begin{bmatrix} \textit{head-argument-phrase} & \\ \text{PHON} & \textit{some frog walks} \\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{verb}\\ \text{SUBCAT} & \langle\rangle\end{bmatrix} \\ \text{CONT} & \begin{bmatrix}\text{TYP} & \boxed{6}\ \textit{ppev} \\ \text{VAL} & \begin{bmatrix} \text{FUNC} & \boxed{4}\begin{bmatrix}\text{FUNC} & \boxed{2}\ \textit{ext-some}\\ \text{ARG} & \boxed{3}\ \textit{frog}\end{bmatrix}\\ \text{ARG} & \boxed{5}\ \textit{walk}\end{bmatrix}\end{bmatrix}\\ \text{HD-DTR} & \begin{bmatrix}\text{PHON} & \textit{walks}\\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{verb}\\ \text{SUBCAT} & \langle\boxed{7}\rangle\end{bmatrix}\\ \text{CONT} & \begin{bmatrix}\text{TYP} & \boxed{9}\ \textit{ppev}\\ \text{VAL} & \boxed{5}\ \textit{walk}\end{bmatrix}\end{bmatrix}\\ \boxed{7}\ \text{NHD-DTR} & \begin{bmatrix} \textit{head-argument-phrase} & \\ \text{PHON} & \textit{some frog}\\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{noun}\\ \text{SUBCAT} & \langle\rangle\end{bmatrix}\\ \text{CONT} & \begin{bmatrix}\text{TYP} & \boxed{1}\begin{bmatrix}\text{IN} & \boxed{9}\ \textit{ppev}\\ \text{OUT} & \boxed{6}\ \textit{ppev}\end{bmatrix}\\ \text{VAL} & \boxed{4}\begin{bmatrix}\text{FUNC} & \boxed{2}\ \textit{ext-some}\\ \text{ARG} & \boxed{3}\ \textit{frog}\end{bmatrix}\end{bmatrix}\\ \text{HD-DTR} & \begin{bmatrix}\text{PHON} & \textit{frog}\\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{noun}\\ \text{SUBCAT} & \langle\boxed{8}\rangle\end{bmatrix}\\ \text{CONT} & \begin{bmatrix}\text{TYP} & \boxed{10}\ \textit{pobj}\\ \text{VAL} & \boxed{3}\ \textit{frog}\end{bmatrix}\end{bmatrix}\\ \boxed{8}\ \text{NHD-DTR} & \begin{bmatrix}\text{PHON} & \textit{some}\\ \text{CAT}|\text{HEAD} & \textit{det}\\ \text{CONT} & \begin{bmatrix}\text{TYP} & \begin{bmatrix}\text{IN} & \boxed{10}\ \textit{pobj}\\ \text{OUT} & \boxed{1}\begin{bmatrix}\text{IN} & \boxed{9}\ \textit{ppev}\\ \text{OUT} & \boxed{6}\ \textit{ppev}\end{bmatrix}\end{bmatrix}\\ \text{VAL} & \boxed{2}\ \textit{ext-some}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

A parallel example with a verb which requires more than one argument could be easily constructed. Notice that in the actual syntactic structure in (18), the determiners with the appropriate specific values (e.g., *ext-some*) are instantiated, whereas the lexical entries for verbs in (17) specifiy only the supersorts *ext*, *int1*, etc. for the CONT|VAL|FUNC. Since there are no determiners which have as their value the supersort *ext*, etc., this will always be the case.

7.4.4 Proper Names

Proper names like *Kermit* and *Piggy* are in fact much simpler. They are NP-valued lexical items, and they can be made the argument of a thematic operator which is introduced by a lexical rule. Thus, proper names are handled exactly as in the earlier chapters on semantics, except that the lexical rules make phonologically empty thematic operators dispensable.

The entry for *Piggy* is given in (19). Notice that the semantic type is $\wp\wp$**Obj**, just as in chapter 5.

(19)
$$\begin{bmatrix} \textsc{phon} & \textit{piggy} \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{noun} \\ \textsc{subcat} & \langle\rangle \end{bmatrix} \\ \textsc{cont} & \begin{bmatrix} \textsc{typ} & \textit{ppobj} \\ \textsc{val} & \textit{piggy} \end{bmatrix} \end{bmatrix}$$

The three lexical rules for external, first internal, and second internal participant are simple and provided in (20).

(20) **Proper Name Thema Rule(s) (PNTR)**

$$\begin{bmatrix} \textsc{cat}|\textsc{head} & \textit{noun} \\ \textsc{cont} & \begin{bmatrix} \textsc{typ} & \textit{ppobj} \\ \textsc{val} & \boxed{1} \end{bmatrix} \end{bmatrix} \Rightarrow \begin{bmatrix} \textsc{cont} & \begin{bmatrix} \textsc{typ} & \begin{bmatrix} \textsc{in} & \textit{ppev} \\ \textsc{out} & \textit{ppev} \end{bmatrix} \\ \textsc{val} & \begin{bmatrix} \textsc{func} & \textit{ext-op} \\ \textsc{arg} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(The definition is parallel for *int1* and *int2*.)

The values *ext-op*, *int1-op* and *int2-op* (the pure thematic operators) must be added to the signature as subsorts of *ext*, etc., as in (21).

(21) a. Partition of *ext*: *ext-op*, *ext-some*, *ext-all*, . . .

b. Partition of *int1*: *int1-op*, *int1-some*, . . .

c. Partition of *some*: *some-pure*, *ext-some*, *int1-some*, . . .

d. Partition of *all*: *all-pure*, *ext-all*, *int1-all*, . . .

An application of the rules yields an output such as (22).

(22)
$$\begin{bmatrix} \textsc{phon} & \textit{piggy} \\ \textsc{cat} & \begin{bmatrix} \textsc{head} & \textit{noun} \\ \textsc{subcat} & \langle\rangle \end{bmatrix} \\ \textsc{cont} & \begin{bmatrix} \textsc{typ} & \begin{bmatrix} \textsc{in} & \textit{ppev} \\ \textsc{out} & \textit{ppev} \end{bmatrix} \\ \textsc{val} & \begin{bmatrix} \textsc{func} & \textit{ext-op} \\ \textsc{arg} & \textit{piggy} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

7.4.5 Prepositions and Adverbs

Finally, representations for prepositions and adverbs shall now be given. An adverb is always of the generalized operator type $(\wp\wp\mathbf{Ev} \rightarrow \wp\wp\mathbf{Ev})$, and thus the representation is trivial. A simple example is given in (23).

(23)
$$\begin{bmatrix} \text{PHON} & \textit{probably} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{adv} & \\ \text{MOD}|\text{CAT}|\text{HEAD} & \textit{verb} \end{bmatrix} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \\ \text{VAL} & \textit{probably} \end{bmatrix} \end{bmatrix}$$

Prepositions can also be rendered without any further adaptations, cf. (24). However, it becomes clear that non-thematic versions of the determiners (*all-pure*, *some-pure*, etc.) must still be available (and not just thematic determiners as defined earlier in this chapter), cf. (25).

(24)
$$\begin{bmatrix} \text{PHON} & \textit{with} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{prep} \\ \text{SUBCAT} & \left\langle \text{NP} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \textit{ppobj} \\ \text{OUT} & \begin{bmatrix} \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \textit{with} \end{bmatrix} \end{bmatrix}$$

(25)
$$\begin{bmatrix} \text{PHON} & \textit{some} \\ \text{CAT}|\text{HEAD} & \textit{det} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \textit{pobj} \\ \text{OUT} & \textit{ppobj} \end{bmatrix} \\ \text{VAL} & \textit{some-pure} \end{bmatrix} \end{bmatrix}$$

The semantic value of prepositions can be some specific function (like **with**, as assumed in the example), or it could be one of the thematic operators *ext-op*, *int1-op* or *int2-op* for argument-marking prepositions.

We can now form regular and well-formed PPs as in (26), where all syntactic features have been omitted for clarity.

(26)

$$\begin{bmatrix} \textit{head-argument-phrase} & \\ \text{PHON} & \textit{with some pig} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{6}\begin{bmatrix} \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{FUNC} & \boxed{5}\,\textit{with} \\ \text{ARG} & \boxed{7}\begin{bmatrix} \text{FUNC} & \boxed{3}\,\textit{some-pure} \\ \text{ARG} & \boxed{4}\,\textit{pig} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{PHON} & \textit{with} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \boxed{1}\,\textit{ppobj} \\ \text{OUT} & \boxed{6}\begin{bmatrix} \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \boxed{5}\,\textit{with} \end{bmatrix} \end{bmatrix} \\ \text{NHD-DTR} & \begin{bmatrix} \textit{head-argument-phrase} & \\ \text{PHON} & \textit{some pig} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{1}\,\textit{ppobj} \\ \text{VAL} & \boxed{7}\begin{bmatrix} \text{FUNC} & \boxed{3}\,\textit{some-pure} \\ \text{ARG} & \boxed{4}\,\textit{pig} \end{bmatrix} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{PHON} & \textit{pig} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{2}\,\textit{pobj} \\ \text{VAL} & \boxed{4}\,\textit{pig} \end{bmatrix} \end{bmatrix} \\ \text{NHD-DTR} & \begin{bmatrix} \text{PHON} & \textit{some} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \boxed{2}\,\textit{pobj} \\ \text{OUT} & \boxed{1}\,\textit{ppobj} \end{bmatrix} \\ \text{VAL} & \boxed{3}\,\textit{some-pure} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

This completes the first simple HPSG fragment for $\mathscr{L}_{\mathsf{GOA}}$. The next and final section is devoted to implementing a simple scoping mechanism.

7.4.6 Scoping

This final section is in fact not intended as a theory of scope in general, but merely as a proof-of-concept implementation of free scoping. The fragment only demonstrates how scopal arguments of a verb and scopal adverbials which modify the same verb can be combined semantically in a way such that their scope order is not determined by the order of syntactic combination. This is achieved by a storage mechanism, which is – for the sake of simplicity – constructed to only handle sentences without embedded sentential structures.

7.4.6.1 Type Distinctions

In section 7.3.1, I introduced a distinction between *scope-typ* and *func-typ* in the HPSG signature. Both have an IN and an OUT type. The rationale for the distinction between *scope-typ* and *func-typ* is this:

1. In $\mathscr{L}_{\text{GOA}}$, scopal order equals order of function application, as was shown in chapter 3.

2. Functors which are not scopal can thus apply immediately. The application of scopal functors, however, must be delayed until all scopal elements are collected. Only then they should apply in free order.

To show what this means in practice, I first provide some lexical entries in (27).

(27) a.
$$\begin{bmatrix} \text{PHON} & \textit{some} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \textit{pobj} \\ \text{OUT} & \begin{bmatrix} \textit{scope-typ} & \\ \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \textit{some} \end{bmatrix} \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{PHON} & \textit{the} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \textit{pobj} \\ \text{OUT} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \textit{the} \end{bmatrix} \end{bmatrix}$$

c.
$$\begin{bmatrix} \text{PHON} & \textit{quickly} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \textit{quickly} \end{bmatrix}$$

d.
$$\begin{bmatrix} \text{PHON} & \textit{probably} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{scope-typ} & \\ \text{IN} & \textit{ppev} \\ \text{OUT} & \textit{ppev} \end{bmatrix} \end{bmatrix} \\ \text{VAL} & \textit{probably} \end{bmatrix}$$

The entry for *some* contains a *scope-typ* type. Since *some* can interact in scope ambiguities, the result of applying *some* to a noun should be a generalized operator of the type $(\wp\wp\mathbf{Ev} \rightarrow \wp\wp\mathbf{Ev})$, which does not immediately apply. The first saturation step (when *some* takes the noun) should, however, be an immediate application. Since *the* usually does not combine to form scopal NPs, the result of the first saturation of *the* is a *func-typ*, and not a *scope-typ*.

The situation is even simpler with adverbs, which are of the generalized operator type $(\wp\wp\mathbf{Ev} \rightarrow \wp\wp\mathbf{Ev})$ to begin with. It can be a *scope-typ*, as in the case of *probably*, or a *func-typ*, as in the case of *quickly*.

7.4.6.2 The SCOPES Store

Finally, we need a mechanism which collects scopal operators instead of applying them. This will be implemented in a new version of the Semantics Principle (cf. (17)). However, I first need to modify the partition of *synsem* and add a constraint on *word*. The modification will have the effect of adding a list-valued SCOPES feature to SYNSEM. SCOPES is to be filled with scopal functors up to the point where they can scope (apply) in random order. The constraint requires the SCOPES of *word* to be empty.

(28) a. Partition of *synsem*: *scopes*, . . .

b. *scopes* : *list*

c. *word* $\rightarrow$ [SCOPES $\langle\rangle$]

The modified semantics principle now needs to take into account four different cases:

1. The non-head is a non-scopal functor.
2. The head is a non-scopal functor.
3. The non-head is a scopal functor.
4. The head is a scopal functor.

In case the functor is scopal, its CONT is added to the SCOPES list of the resulting phrase. Otherwise, application takes place just as before. In both cases, SCOPES which have already been accumulated in the daughters are appended to the SCOPES list of the result. The final version is given in (29), with the now customary abbreviations.

(29) **Semantics Principle (version with scope)**

binary-phrase $\rightarrow$

$$
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{1} \\ \text{VAL} & \begin{bmatrix} \text{FUNC} & \boxed{2} \\ \text{ARG} & \boxed{3} \end{bmatrix} \end{bmatrix} \\
\text{SCOPES} & \boxed{5} \oplus \boxed{6} \\
\text{HD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\ \text{SCOPES} & \boxed{5} \end{bmatrix} \\
\text{NHD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \boxed{4} \\ \text{OUT} & \boxed{1} \end{bmatrix} \\ \text{VAL} & \boxed{2} \end{bmatrix} \\ \text{SCOPES} & \boxed{6} \end{bmatrix}
\end{bmatrix}
\vee
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{1} \\ \text{VAL} & \begin{bmatrix} \text{FUNC} & \boxed{2} \\ \text{ARG} & \boxed{3} \end{bmatrix} \end{bmatrix} \\
\text{SCOPES} & \boxed{5} \oplus \boxed{6} \\
\text{HD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{func-typ} & \\ \text{IN} & \boxed{4} \\ \text{OUT} & \boxed{1} \end{bmatrix} \\ \text{VAL} & \boxed{2} \end{bmatrix} \\ \text{SCOPES} & \boxed{6} \end{bmatrix} \\
\text{NHD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\ \text{SCOPES} & \boxed{5} \end{bmatrix}
\end{bmatrix}
\vee
$$

$$
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\
\text{SCOPES} & \langle \boxed{7} \rangle \oplus \boxed{5} \oplus \boxed{6} \\
\text{HD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\ \text{SCOPES} & \boxed{5} \end{bmatrix} \\
\text{NHD-DTR} & \begin{bmatrix} \text{CONT} & \boxed{7} \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{scope-typ} & \\ \text{IN} & \boxed{4} \\ \text{OUT} & \textit{typ} \end{bmatrix} \\ \text{VAL} & \textit{val} \end{bmatrix} \\ \text{SCOPES} & \boxed{6} \end{bmatrix}
\end{bmatrix}
\vee
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\
\text{SCOPES} & \langle \boxed{7} \rangle \oplus \boxed{5} \oplus \boxed{6} \\
\text{HD-DTR} & \begin{bmatrix} \text{CONT} & \boxed{7} \begin{bmatrix} \text{TYP} & \begin{bmatrix} \textit{scope-typ} & \\ \text{IN} & \boxed{4} \\ \text{OUT} & \textit{typ} \end{bmatrix} \\ \text{VAL} & \textit{val} \end{bmatrix} \\ \text{SCOPES} & \boxed{6} \end{bmatrix} \\
\text{NHD-DTR} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{3} \end{bmatrix} \\ \text{SCOPES} & \boxed{5} \end{bmatrix}
\end{bmatrix}
$$

An example of how this revised SP builds up a SCOPES store is exemplified in (30), where all syntax features are omitted.

(30)

```
[ head-argument-phrase
  PHON    some frog loves all pigs
  CONT    [1]
  SCOPES  ⟨[2],[3]⟩
  HD-DTR  [ head-argument-phrase
            PHON    loves all pigs
            CONT    [1]
            SCOPES  ⟨[2]⟩
            HD-DTR  [ PHON    loves
                      CONT    [1] [ TYP [4] ppev
                                    VAL love ]
                      SCOPES  ⟨⟩ ]
            NHD-DTR [ PHON    all pigs
                      CONT    [2] [ TYP [ scope-typ
                                          IN   [4] ppev
                                          OUT  ppev ]
                                    VAL [ FUNC int1-all
                                          ARG  pig ] ]
                      SCOPES  ⟨⟩ ] ]
  NHD-DTR [ head-argument-phrase
            PHON    some frog
            CONT    [3] [ TYP [ scope-typ
                                IN   [4] ppev
                                OUT  ppev ]
                          VAL [ FUNC ext-some
                                ARG  frog ] ]
            SCOPES  ⟨⟩ ] ]
```

Finally, a unary phrase is needed to unload the SCOPES store step by step. It requires a relation `select()` which takes a random element from a list and returns the resulting reduced list (and the removed element). It is defined in (31).

(31) `select`(⟨[1]|[2]⟩,[2],[1]).
`select`(⟨[1]|[2]⟩, ⟨[1]|[3]⟩,[4]) ↔ `select`([2],[3],[4]).

Given `select()`, the principle controlling the unary scope phrase is the Scope Principle (33). For more or less technical reasons, we introduce a new sort for *head* (usually *verb*, *noun*, etc.), viz. *scoping*. The Scope Principle produces a phrase with *scoping* as the value for CAT|HEAD to block adjuncts (which are specified so as to only attach to projections of a verb) from attaching after scope unloading has started. Otherwise, sentential adverbials could create spurious ambiguities by applying in the middle of the scoping process, possibly adding their CONT to SCOPES, only to have it unloaded from SCOPES in one of the next unloading steps.

(32) Partition of *head* : *scoping*, *verb*, *noun*, . . .

(33) **Scope Principle**

$$\textit{scope-phrase} \rightarrow \left(\begin{array}{l} \begin{bmatrix} \text{PHON} & \boxed{8} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{scoping} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{5} \\ \text{VAL} & \begin{bmatrix} \text{FUNC} & \boxed{6} \\ \text{ARG} & \boxed{7} \end{bmatrix} \end{bmatrix} \\ \text{SCOPES} & \boxed{2} \\ \text{DTR} & \begin{bmatrix} \text{PHON} & \boxed{8} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{TYP} & \boxed{4} \\ \text{VAL} & \boxed{7} \end{bmatrix} \\ \text{SCOPES} & \boxed{3}\ \textit{ne-list} \end{bmatrix} \end{bmatrix} \\ \wedge\ \texttt{select}\left(\boxed{3},\boxed{2}, \begin{bmatrix} \text{TYP} & \begin{bmatrix} \text{IN} & \boxed{4} \\ \text{OUT} & \boxed{5} \end{bmatrix} \\ \text{VAL} & \boxed{6} \end{bmatrix}\right) \end{array} \right)$$

The Scope Principle takes a CONT value from the SCOPES list, and it creates an applicative structure for the resulting *scope-phrase*. In that structure, the VAL of the selected scopal element is the value of CONT|VAL|FUNC, and the DTR|CONT|VAL is structure-shared with CONT|VAL|ARG. This only happens when the TYP|IN value of the selected element from the SCOPES list matches the TYP value of the single DTR. Finally, the TYP of the *scope-phrase* is structure-shared with the TYP|OUT of the scoping element from the list, as expected in applicative structures.

Continuing with the example from (30), the following two readings are assigned to the string *some frog loves all pigs* by the grammar, (34).

(34) a.

```
[ scope-phrase
  PHON       [1] some frog loves all pigs
  CAT|HEAD   scoping
  CONT       [ TYP  [11] ppev
               VAL  [ FUNC [5]
                      ARG  [8] ] ]
  SCOPES     ⟨⟩
  DTR        [ scope-phrase
               PHON      [1]
               CAT|HEAD  [2]
               CONT      [ TYP  [10] ppev
                           VAL  [8] [ FUNC [6]
                                      ARG  [7] ] ]
               SCOPES    ⟨ [4] [ TYP  [ IN  [10] ppev
                                        OUT [11] ppev ]
                                 VAL  [5] [ FUNC int1-all
                                            ARG  pig ] ] ⟩
               DTR       [ head-argument-phrase
                           PHON      [1]
                           CAT|HEAD  verb
                           CONT      [ TYP [9] ppev
                                       VAL [7] love ]
                           SCOPES    ⟨ [ TYP  [ IN  [9] ppev
                                                OUT [10] ppev ]
                                         VAL  [6] [ FUNC ext-some
                                                    ARG  frog ] ] , [4] ⟩ ] ] ]
```

b.

```
[scope-phrase
 PHON      [1] some frog loves all pigs
 CAT|HEAD  scoping
 CONT      [TYP [11] ppev
            VAL [FUNC [6]
                 ARG  [8]]]
 SCOPES    ⟨⟩
 DTR       [scope-phrase
            PHON      [1]
            CAT|HEAD  [2]
            CONT      [TYP [10] ppev
                       VAL [8] [FUNC [5]
                                ARG  [7]]]
            SCOPES    ⟨ [3] [TYP [IN  [10] ppev
                                  OUT [11] ppev]
                             VAL [6] [FUNC ext-some
                                      ARG  frog]] ⟩
            DTR       [head-argument-phrase
                       PHON      [1]
                       CAT|HEAD  verb
                       CONT      [TYP [9] ppev
                                  VAL [7] love]
                       SCOPES    ⟨ [3], [TYP [IN  [9] ppev
                                              OUT [10] ppev]
                                         VAL [5] [FUNC int1-all
                                                  ARG  pig]] ⟩]]]
```

This concludes the minimal implementation of $\mathscr{L}_{\mathsf{GOA}}$ for HPSG. Many aspects were left open, such as alternative meaning, which would effectively require the CONT value to be split into CONT|PRIMARY and CONT|ALTERNATIVES. Also, ordinary PPs cannot enter into the scoping mechanism with the given grammar, and reclustering operators (as discussed in chapter 4) are not available. Reclustering is only required to produce differences in readings with certain scopal elements. A good solution would thus be to allow the *scope-rule* (i) to either unload the scope by first inserting a reclustering operator, then unload the next scopal element from SCOPES, or (ii) to just unload the aforementioned element. This can be implemented by introducing a disjunction into the Scope Principle. Since the purpose of this chapter was only to show that the primary compositional mechanisms of $\mathscr{L}_{\mathsf{GOA}}$ can be implemented in an exact theory of syntax, the current grammar is satisfactory, however.

Chapter 8

Last Remarks

8.1 Achievements

In summary, I have achieved the following independent goals in this thesis.

1. A semantic framework based on Event Semantics was established, which offers a significantly simplified compositional mechanism by interpreting all arguments and adjuncts as operators on set-denoting expressions. The theory only requires one simple type (that of individuals) and also reduces adverbials and arguments to the same functional type. The problems surrounding so-called operator approaches were discussed and solved in chapter 2 and chapter 3, defining subset operators and quantificational operators.

2. An ontology-based theory of information as conveyed in a discourse was provided in chapter 2–chapter 5. It relies on classical model-theory for a language of set theory but allows discourse-level evaluation of meaning. A detailed procedure for the integration of the meaning of a sentence into a larger discourse was given (prominently in chapter 5).

3. The theory was enriched by an integrated view of alternative semantics (for focus constructions), and negation in chapter 4. Thanks to the discourse-level interpretation procedure, a definition of negation was possible, which relied on positive information about events with negative polarity. Finally, I showed that through the introduction of larger event objects (called frame events), scope effects between negation, quantifiers, and scopal adverbial operators can be modeled.

4. A cursory treatment of coordination and plurality, relying on sum formation in the domain of objects was added in chapter 6.

5. I have shown in chapter 7 that some major concepts of the proposed syntax-semantics can be implemented in an exact theory of syntax (HPSG).

Despite the many areas not covered by this study, I have shown that the theory proposed here allows a radically simple semantic compositional mechanism.

8.2 Some Major Desiderata

The primary desideratum seems to be a further examination of the notions of frames and sentence denotata in the semantic component of the theory presented here. Intuitively, there seems to be a close relation between my concept of frames and the concept of situations in Situation Semantics, and between classical Fregian propositions (as sets of possible worlds) and the sets of sets of events proposed here. To develop a theory of intensionality, further formal investigation into these similarities is in order.

In general, I strongly believe that a lot insight into problems of intensionality can be gained by a closer examination of the similarities of the events of linguistic theory and of the events of probability theory (Kolmogorov 1955). Probabilistic explanations are rare in standard semantics (cf. Cohen 1999, Schäfer 2007), but besides the clearly probabilistic core meaning of modifiers like *probably*, *occasionally*, etc., it is also clear that natural language conditionals can be captured in terms of conditional probabilities. This is even more plausible since when we hear sentences like (1a), we usually allow for exceptions (continuation (1b)) without doubting the validity of the conditional.

(1) a. If a mug is dropped on a hard surface, it breaks.
 b. But when I dropped my Kermit mug a minute ago, it didn't break.

The *usually* feeling of conditionals like (1a) is completely lost if one adopts the notion of a conditional from standard logics. It could be easily accounted for by analyzing conditionals as expressing conditional probabilities with values which ever actually reach 1.0 (or 0.0, for that matter).

Finally, the interaction of probabilities of frame events, sums of events and micro-events and macro-events promises to be a non-trivial field. Probabilistic extensions of the theory are thus another main area of possible future research.

Bibliography

Abbott, B.: 2006, Definiteness and Indefiniteness, *in* L. R. Horn and G. Ward (eds), *Handbook of Pragmatics*, Blackwell, pp. 122–49.

Ajdukiewicz, K.: 1935, Die syntaktische Konnexität, *Studia Philosophica* **1**(1-27).

Alchourròn, C. E., Gärdenfors, P. and Makinson, D.: 1985, On the logic of theory change: Partial meet contraction and revision functions, *Journal of Symbolic Logic* **50**(510-30).

Barwise, J.: 1989, *The Situation in Logic*, CSLI, Stanford.

Barwise, J. and Cooper, R.: 1981, Generalized quantifiers and natural language, *Linguistics and Philosophy* **4**, 159–219.

Barwise, J. and Perry, J.: 1983, *Situations and Attitudes*, MIT Press, Cambridge, MA.

Blackburn, S. and Simmons, K. (eds): 1999, *Truth*, OUP, Oxford.

Bradley, F.: 1907, On Truth and Copying, *Mind* **16**.

Carlson, G.: 1984, On the role of thematic roles in linguistic theory, *Linguistics* **22**, 259–79.

Carlson, G. N.: 1977, *Reference to Kinds in English*, PhD thesis, University of Massachusetts.

Carpenter, B.: 1997, *Type-Logical Semantics*, MIT Press, Cambridge, MA.

Christophersen, P.: 1939, *The Articles: A Study of their Theory and Use in English*, Munksgaard, Copenhagen.

Cohen, A.: 1999, Generics, frequency adverbs and probability, *Linguistics and Philosophy* pp. 221–53.

Davidson, D.: 1967, The logical form of action sentences, *in* N. Rescher (ed.), *The Logic of Decision and Action*, University of Pittsburgh Press, Pittsburgh, pp. 81–95.

Devlin, K.: 1991, *Logic and Information*, CUP, Cambridge.

Dowty, D.: 1991, Thematic proto-roles and argument selection, *Language* **67**, 547–619.

Dowty, D. R., Wall, R. E. and Peters, S.: 1981, *Introduction to Montague Semantics*, Kluwer, Dordrecht.

Dretske, F.: 1972, Constrastive statements, *Philosophical Review* pp. 411–37.

Eckardt, R.: 1998, *Adverbs, Events, and Other Things: Issues in the Semantics of Manner Adverbs*, Niemeyer, Tübingen.

Eckardt, R.: 2002, Event semantics, *Linguistische Berichte* **Sonderheft 10**, 91–127.

Ernst, T. B.: 2001, *The Syntax of Adjuncts*, CUP, Cambridge.

Gallin, D.: 1975, *Intensional and Higher-Order Modal Logic: With Applications to Montague Semantics*, North-Holland Publishing, Amsterdam.

Groenendijk, J. and Stokhof, M.: 1990, Dynamic Montague grammar, *Technical Report LP–90–02*, Faculty of Mathematics and Computer Science, Roeterssraat 15, 1018WB Amsterdam, Holland.

Groenendijk, J. and Stokhof, M.: 1991, Dynamic predicate logic, *Linguistics and Philosophy* **14**(1), 39–100.

Haji-Abdolhosseini, M. and Penn, G.: 2003, *TRALE Reference Manual*, Dept. of Computer Science, University of Toronto, Toronto.
URL: http://www.ale.cs.toronto.edu/docs/

Heim, I.: 1982, File change semantics and the familiarity theory of definiteness, *in* R. Bäuerle, C. Schwarze and A. von Stechow (eds), *Meaning, Use and the Interpretation of Language*, de Gruyter, Berlin, pp. 164–89.

Heim, I. and Kratzer, A.: 1998, *Semantics in Generative Grammar*, Blackwell, Malden.

Horn, L.: 2001, *A Natural History of Negation*, CSLI, Stanford.

James, W.: 1907, *Pragmatism: A New Name for Some Old Ways of Thinking*, Longman, New York, chapter Pragmatism's Conception of Truth, pp. 197–236.

Kadmon, N.: 2001, *Formal Pragmatics*, Blackwell, Malden.

Kamp, H.: 1975, Two theories about adjectives, *in* E. Keenan (ed.), *Formal Semantics of Natural Language*, CUP, Cambridge, pp. 123–55.

Kamp, H.: 1984, A theory of truth and semantic representation, *in* J. Groenendijk, T. Janssen and M. Stokhof (eds), *Truth, Interpretation, Information*, Foris, pp. 277–322.

Kamp, H. and Reyle, U.: 1993, *From Discourse to Logic*, Kluwer, Dordrecht.

Katz, G.: 2000, Anti neo-Davidsonianism, *in* C. Tenny and J. Pustejovsky (eds), *Events as Grammatical Objects*, CSLI, pp. 393–414.

Katz, G.: 2003, Event arguments, adverb selection, and the Stative Adverb Gap, *in* E. Lang, C. Maienborn and C. Fabricius-Hansen (eds), *Modifying Adjuncts*, de Gryuter, Berlin, pp. 455–74.

Kempson, R., Meyer-Viol, W. and Gabbay, D.: 2001, *Dynamic Syntax: The Flow of Language Understanding*, Backwell, Oxford.

Kim, J.: 1976, Events as property exemplifications, *in* M. Brand and D. Walton (eds), *Action Theory*, Reidel, Dordrecht, pp. 159–77.

Kleene, S. C.: 1967, *Mathematical Logic*, Wiley, New York.

Klima, E.: 1964, Negation in English, *in* J. D. Fodor and J. Katz (eds), *The Structure of Language*, Prentice-Hall, Englewood Cliffs, pp. 246–323.

Kolmogorov, A. N.: 1955, *Foundations of the Theory of Probability*, Chelsea, New York.

Kratzer, A.: 1995, Stage-level and individual-level predicates, *in* G. Carlson and J. Pelletier (eds), *The Generic Book*, University of Chicago Press, Chicago, pp. 125–75.

Krifka, M.: 1989, Nominal reference, temporal constitution and quantification in an event semantics, *in* R. Bartsch (ed.), *Semantics and Contextual Expression*, Foris, Dordrecht, pp. 75–115.

Krifka, M.: 1991, A compositional semantics for multiple-focus constructions, *in* J. Jacobs (ed.), *Informationsstruktur und Grammatik*, Buske, Hamburg, pp. 17–53.

Krifka, M.: 1992, Thematic relations as links between nominal reference and temporal constitution, *in* I. Sag and A. Szabolcsi (eds), *Lexical Matters*, CSLI, pp. 29–53.

Krifka, M.: 2006, Basic notions of information structure, *in* C. Féry, G. Fanselow and M. Krifka (eds), *Notions of Information Structure*, Vol. 06 of *Interdisciplinary Studies on Information Structure*, Potsdam, pp. 13–56.

Landman, F.: 2000, *Events and Plurality*, Kluwer, Dordrecht.

Lewis, D.: 1975, Adverbs of quantification, *in* E. L. Keenan (ed.), *Formal Semantics of Natural Language*, CUP, Cambridge, pp. 3–15.

Link, G.: 1983, The logical analysis of plurals and mass terms: a lattice-theoretical approach, *in* R. Bäuerle, C. Schwarze and A. von Stechow (eds), *Meaning, Use, and the Interpretation of Language*, de Gruyter, Berlin, pp. 303–23.

McConnell-Ginet, S.: 1982, Adverbs and logical form, *Langugage* **58**, 144–84.

Milsark, G.: 1977, Toward an explanation of certain peculiarities of the existential construction in English, *Linguistic Analysis* **3**, 1–29.

Minker, J.: 1989, Toward a foundation of disjunctive logic programming, *in* E. L. Lusk and R. A. Overbeek (eds), *Proceedings of the North American Logic Programming Conference*, MIT Press, Massachusetts.

Montague, R.: 1970, Universal Grammar, *Theoria* **36**, 373–98.

Montague, R.: 1973a, The proper treatment of quantification in ordinary English, *in* K. J. J. Hintikka, J. M. E. Moravcsik and P. Suppes (eds), *Approaches to Natural Language*, Kluwer, Dordrecht, pp. 221–42.

Montague, R.: 1973b, The proper treatment of quantification in ordinary English, *in* K. J. J. Hintikka, J. M. E. Moravcsik and P. Suppes (eds), *Approaches to Natural Language*, Kluwer, Dordrecht, pp. 221–42.

Müller, S.: 2008, *Head-Driven Phrase Sturcture Grammar: Eine Einführung*, 2 edn, Stauffenburg, Tübingen.

Parsons, T.: 1990, *Events in the Semantics of English*, MIT Press, Cambridge, MA.

Partee, B. H.: 2007, Type theory and natural language: Do we need two basic types?, Script for a talk held at 100th meeting of the Seminar, Moscow State University. http://people.umass.edu/partee [retrieved 2007/08/15].

Partee, B., ter Meulen, A. and Wall, R. E.: 1990, *Mathematical Methods in Linguistics*, Kluwer, Dordrecht.

Pollard, C. and Sag, I. A.: 1994, *Head-driven Phrase Structure Grammar*, CSLI, Chicago.

Quine, W. V. O.: 1956, Quantifiers and propositional attitudes, *Journal of Philosophy* **53**, 177–87.

Roberts, C.: 1990, *Modal Subordination, Anaphora, and Distributivity*, Garland, New York.

Rooth, M.: 1985, *Association with Focus*, Phd, University of Massachusetts, Amherst.

Rooth, M.: 1992, A theory of focus interpretation, *Natural Language Semantics* **1**(1), 75–116.

Russell, B.: 1905, On denoting, *Mind* **14**, 479–93.

Sailer, M.: 2003, Combinatorial semantics and idiomatic expressions in head-driven phrase structure grammar, *Arbeitspapiere des SFB 340 161*, University of Tübingen, Tübingen.

Scha, R.: 1981, Distributive, collective and cumulative quantification, *in* J. Groenendijk, T. Jannsen and M. Stokhof (eds), *Formal Methods in the Study of Language*, Mathematical Center Tracts, Amsterdam, pp. 131–58.

Schäfer, R.: 2007, On frequency adjectives, *Proceedings of Sinn und Bedeutung 11 (2006)*.

Schwarzschild, R.: 1994, The contrastiveness of associated foci. ms., Hebrew University of Jerusalem.

Stokhof, M.: 2006, The future of semantics?, *Theoretical Linguistics* **32**(1), 91–100.

Stoll, R. R.: 1961, *Set Theory and Logic*, Dover, New York.

Tarski, A. M.: 1957, *Logic, Semantics, Mathematics*, OUP, Oxford.

Thomason, R. H. and Stalnaker, R. C.: 1973, A semantic theory of adverbs, *Linguistic Inquiry* (2), 195–220.

Vendler, Z.: 1962, Each and every, any and all, *Mind* **71**(282), 145–60.

Wyner, A.: 1994, *Boolean Event Lattices and Thematic Roles in the Syntax and Semantics of Adverbial Modification*, PhD thesis, Corness University.

Eidesstattliche Versicherung

Hiermit versichere ich an Eides statt, dass ich die eingereichte Dissertation *“Arguments and Adjuncts at the Syntax-Semantics-Interface”* selbständig und ohne unerlaubte Hilfe verfasst habe. Anderer als der von mir angegebenen Hilfsmittel und Schriften habe ich mich nicht bedient. Alle wörtlich oder sinngemäß den Schriften anderer Autorinnen oder Autoren entnommenen Stellen habe ich kenntlich gemacht. Die Abhandlung ist noch nicht veröffentlicht worden und noch nicht Gegenstand eines Promotionsverfahrens gewesen.

Berlin, den 01.06.2008

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