Quantifier Scope in Formal Linguistics

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To appear in D. Gabbay (ed.), *Handbook of Philosophical Logic – Second Edition*

1. Introduction

The remarkable efficiency of language acquisition and linguistic communication must rely on some systematic mapping relating forms and meanings. As a result of this understanding, the study of the relations between syntactic and semantic descriptions has become a central element of all formal linguistic theories. Problems of *quantifier scope* constitute a perennial challenge for uncovering the relations between form and meaning. In some notorious examples, a linguistic element behaves semantically like a logical quantifier, but in a way that is not predicted from straightforward assumptions about its semantics or its position in the syntactic description. In many of these cases, a quantificational expression semantically behaves as if it appeared in a different position than its actual position in the sentence. Such effects are often referred to as *inverse scope effects*. Standard mechanisms that account for these phenomena often complicate the relations between the syntax and the semantics of natural language. As a result, much research has been devoted to the problem of quantifier scope, in an enduring attempt to reveal the status and the theoretical significance of scope shifting principles in formal linguistics.

In this article we give a broad overview of well-known empirical data about quantifier scope and about some proposals for its treatment in the linguistic-logical literature. The article is organized as follows. Section 2 introduces a toy grammar generating a simple fragment of English. This grammar will be used for illustrating and characterizing the problem of quantifier scope, and for discussing some methodological principles for assessing whether linguistic data support an analysis using scope shifting. In section 3, we give a small inventory of other scope problems in natural language, and then concentrate on the problem of quantified NP scope that is illustrated by the fragment of Section 2. Section 4 discusses some syntactic and semantic theories that address the problem of quantifier scope. Section 5 looks beyond the scope phenomena present in the fragment, and considers some further evidence for the theories of scope shifting discussed in section 4. Throughout, our empirical data will be drawn from English.

2. Characterizing inverse scope effects

This section aims to characterize the problem of inverse scope effects with quantified NPs (QNPs). We start by introducing a small fragment of English with a semantics that illustrates the common notion of *direct scope*. In this semantics, the scope of semantic operators corresponds to simple structural relations in the syntax. However, we show that this simple conception of the syntax-semantics interface is insufficient for capturing some semantic intuitions, which are often referred to as *inverse scope* phenomena. The postulation of *scope ambiguity* is used for describing such cases. After the exposition of these basic notions, we move on to two confounding factors that are especially relevant for identifying inverse scope effects in natural language: the influence of pragmatic effects and of logical dependency between potential readings.

2.1. A “direct scope” grammar for a fragment of English

This section defines a toy grammar for an extremely simple fragment of English. The syntax and the lexicon define the set of *Structural Descriptions* (SDs) of well-formed expressions – the syntactic structures assigned to such expressions by the syntactic derivation, which in the given fragment are described using labeled bracketing notation. The semantics for the fragment is defined by means of a *translation function* (denoted by “⇒”) into the simply typed lambda calculus. For details on these standard techniques see Gamut (1991).[1]

The following rules describe the syntax of our toy grammar.

Syntax

S → NP VP
VP → V_{tr} NP
VP → V
NP → D N’
N’ → N
N’ → N_{tr} NP
N’ → N’ S'
N’ → A N’
S' → Rel VP

These rules do not deal with number and person marking on nouns and verbs; we will silently amend the incorrect forms in our sample SDs. Note also that we use here a traditional noun phrase structure where modification occurs within an internal nominal labeled N’, and the determiner appears at the NP level. For expository purposes, we will not use the more modern syntactic assumptions about *DP* structure (see Abney 1987).[2]

For our exposition we will use the following lexicon over the above toy grammar, including corresponding logical types and translations to logical expressions of the higher order typed lambda calculus.

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[1] By using the translation to lambda-terms we do not take any position here regarding the necessity of this translation procedure. As many researchers (e.g. Barker and Jacobson 2007) stress, it is possible that syntactic representations of natural language expressions are directly interpreted in a semantic model, with no translation to an intermediate logical language. A more complete discussion of this question and its relevance to the analysis of scope phenomena is beyond the limits of the present paper.

[2] The grammar also uses the traditional designation S for sentence, rather than some theoretically more up-to-date notation, and its variant S’ in the (wholly unrealistic) rule for relative clauses.

Lexicon

Cat	**Word**	**Translation**	**Type**
N	one, man, woman, city	$\Rightarrow$ PERSON, MAN, WOMAN, CITY	<e,t>
N_{tr}	inhabitant of	$\Rightarrow \lambda y\lambda x[\mathrm{PERSON}(x) \wedge \mathrm{INHABIT}(y)(x)]$	<e,<e,t>>
D	every	$\Rightarrow \lambda A\lambda B.\forall x[A(x) \rightarrow B(x)]$	<<e,t>,<<e,t>,t>>
	no	$\Rightarrow \lambda A\lambda B.\neg\exists x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	some,a	$\Rightarrow \lambda A\lambda B.\exists x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	$\varnothing$	$\Rightarrow \lambda A\lambda B.\exists 2x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	three	$\Rightarrow \lambda A\lambda B.\exists 3x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	five	$\Rightarrow \lambda A\lambda B.\exists 5x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	exactly three	$\Rightarrow \lambda A\lambda B.\exists !3x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
	exactly five	$\Rightarrow \lambda A\lambda B.\exists !5x[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,t>>
A	midwestern	$\Rightarrow \lambda A\lambda x[\mathrm{MIDWESTERN}(x) \wedge A(x)]$	<<e,t>,<e,t>>
NP	John, Mary	$\Rightarrow \lambda A.A(\mathrm{JOHN}_e), \lambda A.A(\mathrm{MARY}_e)$	<<e,t>,t>
V	participated	$\Rightarrow$ PARTICIPATED	<e,t>
V_{tr}	inhabit	$\Rightarrow$ INHABIT	<e,<e,t>>
	admire	$\Rightarrow$ ADMIRE	<e,<e,t>>
	meet	$\Rightarrow$ MEET	<e,<e,t>>
Rel	who	$\Rightarrow \lambda A\lambda B\lambda x.[A(x) \wedge B(x)]$	<<e,t>,<<e,t>,<e,t>>>

Abbreviations

We use SOME to abbreviate $\lambda A\lambda B.\exists x[A(x) \wedge B(x)]$ (the translation of *some*, *a*);
we use EVERY to abbreviate $\lambda A\lambda B.\forall x[A(x) \rightarrow B(x)]$ (the translation of *every*).

Translation

1) Lexical items translate as stated in the lexicon.
2) For all $\gamma \in$ SD s.t. $\gamma = [_X\ \beta]$:
   if $\beta \Rightarrow \beta'$ then $\gamma \Rightarrow \beta'$.
3) For all $\gamma \in$ SD s.t. $\gamma = [_X\ \alpha\ \beta]$ or $\gamma = [_X\ \beta\ \alpha]$:
   if $\alpha \Rightarrow \alpha'_a$ and $\beta \Rightarrow \beta'_{<a,c>}$, then $\gamma \Rightarrow \beta'(\alpha')$.
4) For all $\gamma \in$ SD s.t. $\gamma = [_{VP}\ \alpha\ \beta]$ (or $\gamma = [_{N'}\ \alpha\ \beta]$) where α is a V_{tr} (N_{tr} respectively):
   if $\alpha \Rightarrow \alpha'_{<e,<e,t>>}$ and $\beta \Rightarrow \beta'_{<<e,t>,t>}$, then $\gamma \Rightarrow \lambda x.\beta'(\lambda y.\alpha'(y)(x))$.

2.2. Incompleteness of the grammar's "direct scope" strategy

The reader may verify that for sentences (1) and (2), the toy grammar above derives the (simplified) SDs in (1a) and (2a), with the accompanying translations (1b) and (2b). The latter translations contain some obvious abbreviations and appear with their reductions to first order predicate calculus.

(1) some woman admires every man
  a. [$_{NP}$ some woman] [$_{VP}$ admires [$_{NP}$ every man]]
  b. $\mathrm{SOME}(\mathrm{WOMAN})(\lambda x.(\mathrm{EVERY}(\mathrm{MAN}))(\lambda y.\mathrm{ADMIRE}(y)(x))$
  c. $\equiv\ \exists x[\mathrm{WOMAN}(x) \wedge \forall y[\ \mathrm{MAN}(y) \rightarrow \mathrm{ADMIRE}(y)(x)\ ]]$

(2) some inhabitant of every midwestern city participated
  a. [$_{NP}$ some inhabitant of [$_{NP}$ every midwestern city]] participated
  b. $\mathrm{SOME}(\lambda x.(\mathrm{EVERY}(\mathrm{MIDWEST\_CITY}))(\lambda y.\mathrm{INHABITANT\_OF}(y)(x)))(\mathrm{PARTICIPATED})$
  c. $\equiv\ \exists x[[\mathrm{PERSON}(x) \wedge \forall y[[\mathrm{MIDWESTERN}(y) \wedge \mathrm{CITY}(y)] \rightarrow \mathrm{INHABIT}(y)(x)]] \wedge \mathrm{PARTICIPATED}(x)]]$

Although highly simplified, the SDs in (1a) and (2a) display the commonly supposed constituent structures for the English sentences in (1) and (2). In particular, these SDs capture the commonly assumed syntactic asymmetry in (1) between VP-external subject and VP-internal object, and the part-whole relation in (2) between the NP-modifier *in every midwestern city* and the subject NP that contains it. The meanings of lexical items in this grammar are standard in natural language semantics. The four translation rules provide for each sentence in the fragment a translation in the simply typed lambda-calculus, which for (1b) and (2b) reduce to formulas of the first-order predicate calculus (1c) and (2c).[3] In the translations (1b) and (2b), scope relations between translations of quantificational expressions match the constituent structures assumed by the syntax. Also in more comprehensive grammars, keeping to this matching and to simple lexical semantics and interpretative strategies normally leads to the propositions in (1c) and (2c) for (1a) and (2a).

Of the four translation rules of the toy grammar, rules 1 and 2 are trivial. Translation rule 3 embodies a very simple assumption about meaning composition in natural language, under which two lambda terms (or their denotations) can only compose by way of *function application*. Translation rule 4, however, is rather *ad hoc* in the way it composes binary relations of type <e,<e,t>> with QNP meanings of the type <<e,t>,t> of *generalized quantifiers* (see section 4.1). The problem of composing meanings of relational predicates with quantifier meanings is conceptually distinct from the problem of scope ambiguity. However, as we shall see in section 4.2, most theories of QNP scope establish a connection between the two problems in one way or another. Thus, translation rule 4 in the above toy grammar should be considered as a provisional assumption for expository purposes, and not as a necessary part of theories of QNP interpretation.

The simple architecture that is assumed in our toy grammar is empirically inadequate, however, and its inadequacy illustrates the problem of quantifier scope. Consider first sentence (1). Many English speakers judge (1) true in case every man is admired by a

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[3] Similar conversions of lambda terms are henceforth performed without mention.

different woman. Therefore, it is reasonable to assume that (1) has not only the reading in (1b), but also the one in (3) below.

(3) $\forall y[\ \mathrm{MAN}(y) \rightarrow \exists x[\mathrm{WOMAN}(x) \wedge \mathrm{ADMIRE}(y)(x)\ ]]$

A similar problem is even clearer in sentence (2). This sentence is unlikely to be interpreted using the statement (2b) that the grammar generates, which would entail the unlikely existence of a person who inhabits every midwestern city. Many English speakers judge (2) unambiguous, with a meaning that is expressible using the following formula.

(4) $\forall y[[\mathrm{MIDWESTERN}(y) \wedge \mathrm{CITY}(y)] \rightarrow \exists x[\mathrm{PERSON}(x) \wedge \mathrm{INHABIT}(y)(x) \wedge \mathrm{PARTICIPATED}(x)]]$

Here again, we see that the scope relations that the grammar generates in (2b) are different than what semantic intuitions require.

As mentioned above, in the analyses (1b) and (2b), the scope relations between the logical operators are in agreement with the scope relations between the constituents that they correspond to. We will henceforth refer to such analyses as *direct scope*. But the semantics of sentences like (1) and (2) demonstrate that English may also exhibit opposite scope relations as in (3) and (4). Such interpretations will be referred to as *inverse scope*. By extension, when treating examples outside the fragment, we will also speak of *inverse scope* interpretations: statements whose representations in Predicate Calculus or the typed lambda calculus show reversed scope relations with respect to the scope relations between constituents in the commonly assumed syntactic structure. Since many scope relations in the syntactic structure are often obvious or taken for granted by syntactic theories, we will at times sloppily talk about the scope of a *constituent* (e.g. a QNP), where in fact we should properly speak of the scope of the corresponding operator in a translation of the sentence.

2.3. Methodological and empirical principles in the study of quantifier scope

Whether a given English sentence is ambiguous, and if so, whether the relevant ambiguity is one of scope, is a theoretical question that often relies on intricate syntactic and semantic intuitions. Various methodological issues arise when addressing this question, which we would like to discuss at the outset.

First, we will not assume that native speakers have direct knowledge of ambiguity. That is, we do not rely on speakers' intuitions as to whether a sentence is ambiguous; nor do we rely on speakers' ability to report reliably on semantic properties of selected readings of ambiguous sentences, which would require them to consciously differentiate between and select these readings. While the possibility of such "direct access" to different readings of a given sentence is ultimately an empirical question, we will prefer to err on the side of caution.

Consequently, our primary data will be native speakers' intuitions on truth and inference as they relate to "raw" utterances. In the present section we discuss some of the difficulties that arise in drawing conclusions from such data. We will introduce some commonly accepted guidelines for evaluating the reliability of native speakers' intuitions, and deciding whether these intuitions support an analysis of the relevant sentences as scopally ambiguous. Section 2.3.1 briefly discusses how pragmatic preferences for particular readings may interfere with the reliability of judgments; Section 2.3.2 discusses the repercussions of logical dependence between readings for the analysis of scope ambiguity. We end this section on methodological issues with a brief note on cross-linguistic variation, section 2.3.3.

2.3.1. Pragmatic effects

Particular interpretations may prove more or less accessible to speakers depending on their plausibility in the given context; such effects may interfere with the semantic judgments we seek. Crucially, a reading may appear to be absent merely because it is implausible. For instance, consider the contrast between the following examples.

(5) John saw the man with the telescope.
(6) John saw the man with the dog.

Most syntactic theories assume that both (5) and (6) are structurally ambiguous. However, for obvious pragmatic reasons the ambiguity is much clearer in (5) than in (6). Thus, we should be wary of trusting the judgment that a sentence lacks a particular reading, if that reading is an implausible one. The safest course is to accept that a reading is absent only if we have found it absent despite its being plausible -- or better, despite its being the only plausible reading of the sentence. Consider for instance the following sentence.[4]

(7) $[_{NP}$ someone $[_{S'}$ who inhabits every midwestern city]] participated
a. $\exists x[[\mathrm{PERSON}(x) \wedge \forall y[[\mathrm{CITY}(y) \wedge \mathrm{MIDWESTERN}(y)] \rightarrow \mathrm{INHABIT}(y)(x)]] \wedge \mathrm{PARTICIPATED}(x)]]$
b. $\forall y[[\mathrm{CITY}(y) \wedge \mathrm{MIDWESTERN}(y)] \rightarrow \exists x[\mathrm{PERSON}(x) \wedge \mathrm{INHABIT}(y)(x) \wedge \mathrm{PARTICIPATED}(x)]]$

Sentence (7) is judged by most speakers to be pragmatically strange, as it asserts that one and the same person can inhabit every midwestern city. Thus, it is safe to assume that sentence (7), by contrast to (2), lacks reading (7b) and allows only reading (7a). As (7a) is an implausible proposition, and (7b) is a plausible one. Thus, the fact that we perceive sentence (7) as stating the implausible statement (7a) and not as stating (7b), is reliable evidence that sentence (7) does not have (7b) as one of its readings. This contrast between sentences (2) and (7) will play an important role in Section 3.2.

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[4] To save space, we here and henceforth identify sentences with their SDs unless this may lead to confusion.

2.3.2. Logical dependence between readings

The need to postulate scope ambiguities is particularly hard to demonstrate (or disprove) in case one purported reading entails another one. Consider example (8):

(8) [$_S$ [$_{NP}$ every man] [$_{VP}$ admires [$_{NP}$ some woman]]]

a. $\forall x[\ \textsc{man}(x) \rightarrow \exists y[\textsc{woman}(y) \wedge \textsc{admire}(y)(x)\ ]]$

b. $\exists y[\textsc{woman}(y) \wedge \forall x[\textsc{man}(x) \rightarrow \textsc{admire}(y)(x)\ ]]$

Cases like (8) have often been cited as allowing the inverse scope reading (8b). However, considering that whenever (8b) is true, (8a) is true as well, how could we determine whether (8) allows the inverse scope reading in addition to its direct scope reading (8a)? Some speakers may indicate that they can interpret (8) as entailing (8b). However, as implied from our assumptions above, we do not want to rely on such judgments, which would presuppose that speakers have the ability to access intuitions on the properties of particular readings of sentences to the exclusion of other readings; the safer course is to assume that speakers cannot separate different readings. It should be stressed that this does not prevent sentences like (8) from being judged scopally ambiguous, we assume that but the decision on this question can only rely on theoretical considerations or on the behavior of similar sentences, and not on direct intuitions concerning the sentence in question. For relevant discussions of this point see Reinhart (1976:190-196), Cooper (1979:142), Kempson (1977:ch.8), Kempson and Cormack (1981), Ruys (1992:6-20), Altman et al. (2005).

We might choose to ignore examples such as (8) altogether, and concentrate on examples such as (1), for which the inverse scope reading (3) does not entail the direct reading (1b). Strictly speaking, of course, the argument against an ambiguity analysis of (8) also applies to (1), but an unambiguous analysis for (1) would have to state that it has only the inverse scope reading (3). This is highly unlikely, given the constituent structure of the sentence, and would still support the main point, namely the existence of inverse scope readings. On the other hand, admittedly, the intuitions on the existence of an inverse scope reading for (1) are not solid for all speakers (Kurtzman and MacDonald 1993). In addition, indefinite NPs such as *some woman* in (8) sometimes exhibit exceptional (inverse) scope options that are theoretically interesting, as will be discussed in section 3.3. For these reasons, let us illustrate some methods that are employed in order to test the ability of QNPs to take inverse scope.

A. We can construct examples for which the direct scope and inverse scope readings are independent. For instance, in the following example (9), the direct scope analysis in (9a) is logically independent from the inverse scope analysis in (9b).

(9) exactly three men admire some woman

a. $\exists!3x[\text{MAN}(x) \wedge \exists y[\ \text{WOMAN}(y) \wedge \text{ADMIRE}(y)(x)\ ]]$
b. $\exists y[\ \text{WOMAN}(y) \wedge \exists!3x[\text{MAN}(x) \wedge \text{ADMIRE}(y)(x)\ ]]$

It can be demonstrated that in cases such as (9), the inverse scope analysis in (9b) captures situations for which many speakers judge sentence (9) to be true, but which are not captured by the direct scope analysis (9a). Hence it is rather reasonable to conclude that indefinite object NPs allow a wide scope interpretation over the subject in cases like (8) as well.

B. Another potentially relevant piece of evidence for scope ambiguity in cases like (8) is obtained once they are embedded in negative entailing contexts, as in the following example.

(10) it is not the case that every man admires some woman
a. $\neg\forall x[\ \text{MAN}(x) \rightarrow \exists y[\text{WOMAN}(y) \wedge \text{ADMIRE}(y)(x)\ ]]$
b. $\neg\exists y[\text{WOMAN}(y) \wedge \forall x[\text{MAN}(x) \rightarrow \text{ADMIRE}(y)(x)\ ]]$

The two relevant analyses of (10) in (10a) and (10b) are the negations of (8a) and (8b). Due to the negation, the inverse scope reading (10b) is not logically stronger than the direct scope reading (10a). Hence, we could demonstrate the existence of the (10b) reading by showing that (10) is true in a model in which (10b) is true but (10a) false. Despite the fact that negation as in (10) may facilitate the decision whether the inverse scope analysis reflects a reading of (10), actual judgments have proven rather insecure.[5] This “experimental” difficulty makes it harder to use sentences like (10) as even indirect evidence for deciding whether an inverse scope analysis is justified for (8) as well.

C. We can attempt to construct grammatical tests for inverse scope. For example, (11) shows that the indefinite object in (8) introduces a "discourse referent" for a pronoun to pick up:

(11) Every man admires some woman. She is really smart.

Evidence that the anaphoric relation in (11) is available only in case the antecedent takes wide scope comes from (12), where anaphora is blocked in the second sentence in case the pronoun in the first sentence is interpreted as “bound” by the subject (i.e. the value picked for *he* in (12) may vary from man to man).

(12) ?? Every man admires some woman he knows. She is really smart.

Tests like the ones surveyed in A-C above may be used to justify a scope mechanism for QNPs also in cases where direct semantic intuitions do not necessarily support a n account that is based on scope ambiguity.

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[5] This is further complicated by the possibility that in addition to (10a) and (10b), sentence (10) may also have four potential readings where one of the QNPs, or both of them, takes scope over the negation.

2.3.3. A note on cross-linguistic variation

As the reader may have observed, all our empirical data so far have been drawn from one language, English, and we will continue to confine discussion in this article to this language. We feel that this limitation is serious, but defensible, for several reasons. Firstly, scope phenomena in English have been studied much more extensively and in more detail than in any other language. Secondly, our primary interest in this article is not so much in the description of all manner of scope phenomena as it is in the presentation of the various theoretical approaches to scope phenomena that have been proposed. Since English data suffice to illustrate the workings of the various theories of quantifier scope that we will discuss, and since we are not aware of scope phenomena in other languages that cannot in principle be described by means of the theoretical devices we will be presenting, our discussion is not seriously hampered by the limitation to English. Nonetheless, cross-linguistic variation in quantifier scope phenomena is an important topic, not only from a descriptive stand-point, but also because the existence and extent of such variation has important theoretical implications. There are numerous important works describing scope phenomena in other languages than English, including Huang (1982), Liu (1990) for Chinese, Hoji (1985) for Japanese, as well as works that focus specifically on cross-linguistic variantion: e.g. Gil (1982), Aoun & Li (1989), various papers in Szabolcsi (1997); see Pafel (1994) for an overview.

3. Some problems of QNP scope

This section gives an overview of some of the major empirical generalizations concerning problems of scope ambiguity in natural language, especially scope ambiguities with QNPs. We first give a short catalogue of phenomena that have been analyzed as scope ambiguities, and then turn to some of the special effects with QNP scope: restrictions on their scope, unexpected wide scope/narrow scope of QNPs, and "mixed scope" effects.

3.1. Overview of some scope phenomena

A. QNP-QNP. The following two examples from the fragment of Section 2 have illustrated that sentences with multiple QNPs can show scope ambiguities:

(13) some woman admires every man
(14) some inhabitant of every city participated

The inverse wide scope for the embedded NP in (14) is known as "inverse linking" (see Gabbay and Moravcsik 1974 and May 1977 for early discussion). This inverse scope reading is prominent, often more prominent than the direct scope reading. Inverse wide scope for the object in simple transitive sentences like (13) is usually less prominent than the direct reading of such sentences, but nonetheless available.

B. Negation and QNPs. Sentences containing negation and a quantified NP may show scope ambiguity:

(15) John doesn't speak exactly three languages
(16) all that glitters is not gold

Sentence (15) can be understood as asserting the falsity of the claim that John speaks exactly three languages. In this case we say that negation takes scope over the QNP. But (15) can also be interpreted as stating that there are exactly three languages that John doesn’t speak. In this case the QNP takes scope over the negation. Similarly, in (16) the sentence may either mean that nothing that glitters is gold or that there are glittering things that are not gold. For work on the scope of negation, also with respect to topic-focus structure, see Jackendoff (1972:352-362), Horn (1989:226), Beghelli and Stowell (1997) and Büring (1997).

C. Intensionality. *De re*/*de dicto* ambiguities are also commonly analysed as scope ambiguities (cf. Quine 1956, Montague 1973, Ben-Avi and Winter 2007). For instance:

(17) John is looking for a book
(18) an American runner is likely to win the race

In (17), whether the sentence means that John is looking for a specific book or for any book, is often analyzed as a scope ambiguity of the indefinite *a book* with respect to the predicate *look for*. The former, *de re*, reading is often analyzed as a case where the indefinite takes scope over the predicate, whereas the latter, *de dicto*, reading is often analyzed by giving the predicate scope over the indefinite. A similar distinction is made for (18).

D. QNPs inside questions. Questions containing quantified NPs and wh-phrases may show a scope ambiguity, as in (19):

(19) which woman does every man love?

(19) permits an individual answer (“every man loves Mary”), or a “pair-list” answer (“John loves Sue, Peter loves Mary, ...”). The pair-list reading of the question can be treated as involving *every man* quantifying into the question, taking wider scope than *which woman*; for the individual answer, *every man* scopes below *which woman*. See Karttunen & Peters (1980), Engdahl (1980), Jacobson (1999), Groenendijk & Stokhof (1984, 1997), May (1985).

E. Adverbs. Scope relations between adverbs of different types and QNPs may also vary:

(20) a John has never met a friend of mine
b someone always wins
(21) a John probably saw an article in this morning's *Times*
b someone probably spiked the punch

For instance, (20a) can either mean that John has met no friend of mine, or that there is a friend of mine that John has never met. When adverbs are analyzed as quantifiers (over times, events, possible worlds etc.), this kind of ambiguity is often analyzed as similar to the QNP-QNP kind of scope ambiguity. For two studies of the scope of adverbs and relevant further references see Larson (2003) and Schäfer (2004).

F. Coordination. Sentences like (22) have been analyzed (e.g. in Bergamann 1982) as involving scope ambiguity of coordination:

(22) (Exactly) four teachers and authors smiled.

Under one interpretation, where *and* is often assumed to take scope below *four*, the sentence makes a claim about (exactly) four people, each of them a teacher and an author.[6] Under another interpretation, where (22) makes a claim about four teachers and four authors, *and* can be analyzed as taking scope over *four*.

Another kind of sentence that was analyzed in terms of scope ambiguity of coordination is the following:

(23) John is looking for a maid or a cook.

The interpretation under which it is either a maid or a cook that John is looking for, but not necessarily both, was analyzed by Rooth and Partee (1982) as involving wide scope for the disjunction over the intensional verb *look for*. The other interpretation, where John would be both satisfied by finding a maid and by finding a cook, is considered as a case where *or* takes scope below *look for*. For more analyses of scopal effects with coordination see Hendriks (1993), Larson (1985a), Schwarz (1999) and Winter (2000b), among others.

After this review of some scope ambiguity phenomena in English, the remainder of his section formulates some generalizations that govern the distribution of direct and inverse scope readings that appear with QNPs. The facts in this domain can roughly be summarised as follows. In almost all cases (as far as our fragment in section 2.1 goes: in all cases) direct

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[6] We do not discuss here a possible interpretation, where the sentence refers to four people, some of whom are teachers and the rest are authors. An analysis of this interpretation involves the complicated question of collective readings of *and* conjunctions with nominals and predicates (Heycock and Zamparelli 2005). Yet another possible interrepretation of (22), which is however irrelevant for our purposes, is the one where the constituency of the subject is *[exactly four teachers] and [authors].*

scope is an option. Whether a structure containing quantified noun phrases A and B allows inverse scope of B over A depends on two factors: the syntactic configuration relating A and B, and the choice of B. The following subsections elaborate on some circumstances that empirically affect the availability of inverse scope.

3.2. Restrictions on scope

As is well known, not every sentence containing two QNPs allows scope inversion. The availability of inverse scope depends partly on the syntactic configuration that relates the two QNPs. Consider again the minimal pair (2) (=(14)) and (7), which are restated below.

(24) some inhabitant of every midwestern city participated
(25) someone who inhabits every midwestern city participated

As we have seen, the QNP *every midwestern city* in (24) can take scope over *some inhabitant*, which yields a pragmatically acceptable inverse scope reading. By contrast, sentence (25) allows only an unacceptable direct scope reading, as predicted by the direct scope strategy of the grammar in Section 2.

At this point we would not like to prejudge the issue whether the explanation of the inverse scope reading of (24) and its absence in (25) is to be found in syntax or semantics; we discuss this issue in some detail in Section 4. For convenience, however, we describe a generalization that roughly governs these facts in syntactic terms. A hypothesis that has often been pursued since the late 1960s is that those syntactic domains that QNPs cannot scope out of are exactly the ones that are opaque to syntactic "movement" (e.g. formation of *wh* questions). To understand this hypothesis, consider first the examples in (26):

(26) a which city$_i$ did you meet inhabitants of t$_i$?
b * which city$_i$ did you meet people who inhabit t$_i$?
c did you meet inhabitants of this city ?
d did you meet people who inhabit this city ?

The phrase *which city* in (26a) performs the same function as argument of *inhabitants of* that is performed by *this city* in (26c). In this sense, *which city* in (26a) is related to the position following *of*; we indicate the relation by marking that position with a symbol *t* (for "trace") coindexed with *which city* (see section 4.2.1 below for further explanation of the syntactic mechanisms involved). (26b) shows that the relation is disturbed when *which city* sits outside a relative clause, while the position *t* it is related to sits inside the relative clause (compare (26b) to (26d)). The restriction that (26b) illustrates is referred to as the *Complex NP Constraint* (CNPC); the NP containing the relative clause is said to function syntactically as an *island* for wh-extraction.

Returning now to the examples (24) and (25), we find a similar pattern: the quantified NP *every midwestern city* in (24), in the same position as *t* in (26a), can take sentential scope, as though, like *which city* in (26a), it occupied the sentence-initial position. But *every midwestern city* in (25), which is inside a relative clause, cannot take scope over the sentence as a whole, similarly to the unacceptability of (26b). In this sense, the NP with the relative clause in (25) functions as a scope island, and (25) suggests that the CNPC is not only an extraction island as in (26b), but also an island that holds of QNP scope. In syntactic terminology, we say that scope islands and extraction islands coincide.

As we shall see in section 4.2.1, this generalization about the similarity between scope islands and islands for extraction led to the hypothesis that inverse scope results from (covert) movement of the QNP. Below we provide some more examples of islands, not illustrated by the fragment.[7]

(27) a * which man_i will you inherit a fortune if t_i dies
b you will inherit a fortune if every man dies
(28) a. * what_i did John hiss that Smith liked t_i
b John hissed that Smith liked every painting

Both the *if*-clause in (27) and the complement clause to a verb *hiss* in (28) are islands for *wh*-extraction, and disallow matrix scope.[8] See Section 4.2.1 for further discussion of the similarity of scope taking and wh-movement, and for further examples of islands.

3.3. Unexpected wide scope: simple indefinites

Given the constraints on inverse scope illustrated in (24)-(25), the absence of a similar contrast in (29)-(30) is unexpected.

(29) every inhabitant of a/some midwestern city participated
(30) everyone who inhabits a/some midwestern city participated
(31) a $\exists x[\textsc{city}(x) \wedge \textsc{midwestern}(x) \wedge \forall y[[\textsc{person}(y) \wedge \textsc{inhabit}(x)(y)] \rightarrow \textsc{participated}(y)]]$
b $\forall y[[\textsc{person}(y) \wedge \exists x[\textsc{city}(x) \wedge \textsc{midwestern}(x) \wedge \textsc{inhabit}(x)(y)]] \rightarrow \textsc{participated}(y)]$

Many English speakers agree that both (29) and (30) allow the inverse scope reading as well as the direct scope reading, as stated in (31a) and (31b) respectively. This is clearly the case with the determiner *some*, but also (marginally) with the article *a*. A classical example, outside our fragment, that more clearly demonstrates the same effect is the following.

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[7] Example (28) is from May (1977:94,120).

[8] In many syntactic frameworks, constructions like the *if* clauses as in (27) are classified as sentential *adjuncts*, and accordingly illicit sentences like (27a) are classified as violating an *adjunct constraint*. Verbs like *hiss (that)* in (28) that prevent grammaticality in cases like (28a) are often referred to as *non-bridge* verbs (unlike other verbs like *think* and *say*); hence one might classify (28) as exemplifying a non-bridge verb island for extraction and scope.

(32) If a friend of mine from Texas had died in the fire, I would have inherited a fortune. (Fodor and Sag 1982)

Sentence (32) can be interpreted as true if I have a certain friend whose death would make me rich, even if I have other friends for whom this does not hold. Again it seems, as in (30), that the indefinite can take scope over an island, in this case the adjunct island contributed by the conditional.

The generalization seems to be that simple indefinite NPs can scope out of relative clause islands, and this pattern also persists with other scope islands types. The contrast between the ill-formedness of (26b) and the availability of the inverse scope reading (31b) for (30) is illuminating: it suggests that it would be problematic to derive (31b) for (30) by the same rule that “fronts” wh-elements as in (26a). Using such a rule for both (30) and (26a) (or the inverse scope reading of (24)) would make the contrast between (26b)/(25) and (24) completely mysterious. See Section 4.3.3 for alternative theories about the behavior of indefinite NPs as in (30).

In our fragment, the exceptional wide scope behavior seen in (30) is displayed by those NPs that are headed by *a* and *some*, as well as the numeral *three*. For instance:

(33) John met everyone who admires three midwestern cities

Sentence (33) has a reading, fitting in a context in which John is researching the popularity of three particular cities. This suggests a wide scope option for *three cities*. This description of the facts is a bit simplistic, as we shall see in See Section 3.5. We also postpone to sections 3.4 and 3.5 a discussion of the class of NPs that support this exceptional wide scope behavior.

3.4. Absence of inverse scope

There are several types of QNP that show an unexpected absence of inverse scope, even in syntactic contexts where other QNPs do show inverse scope. One prominent and fairly uncontroversial example is the bare plural. Bare plural NPs do not take inverse scope, as the following example illustrates (Carlson 1977):[9]

(34) no man met women

a $\neg\exists x[\ \mathrm{MAN}(x) \wedge \exists 2y[\mathrm{WOMAN}(y) \wedge \mathrm{MEET}(y)(x)\ ]]$

b $\exists 2y[\mathrm{WOMAN}(y) \wedge \neg\exists x[\ \mathrm{MAN}(x) \wedge \mathrm{MEET}(y)(x)\ ]]$

Sentence (34) only has the reading in (34a), not the reading in (34b). The same holds for (35) and (36):

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[9] For ease of exposition, we translate the bare plural with the quantifier ∃2, while noting that this is an extreme simplification.

(35) John met every man who inhabits midwestern cities
(36) John met every inhabitant of midwestern cities

Intuitions are particularly clear for these examples, which are pragmatically infelicitous. Inverse scope readings would be a pragmatically acceptable, but the sentences are not, which means that these sentences do not allow an inverse scope analysis.

Unfortunately, for some other classes of QNPs the relevant semantic intuitions are not as clear-cut, and their scope properties have not been studied as extensively in the available literature as e.g. the scope properties of QNPs of the *every N* variety. Nonetheless, some tentative generalizations have been proposed in the literature that deserve to be mentioned.

Consider first NPs with modified numeral determiners. Given the inverse scope option for (13), repeated as (37), a similar option for (38) is expected. It is however claimed (Liu 1990, Beghelli 1993, 1995) that this option is not available.

(37) some woman admires every man
(38) some woman inhabits exactly three cities
a $\exists x[\textsc{woman}(x) \wedge \exists 3!y[\textsc{city}(y) \wedge \textsc{inhabit}(y)(x)]]$
b $\exists 3!y[\textsc{city}(y) \wedge \exists x[\textsc{woman}(x) \wedge \textsc{inhabit}(y)(x)]]$

According to these authors, a sentence such as (38) is intuitively judged to mean only (38a): it is true if (38a) is true, and false if (38a) is false. Specifically, (38) is false if exactly three cities are each inhabited by a different woman, as allowed by (38b). This means that for the case of (38), an inverse scope analysis would be incorrect (but see Reinhart 2006b for a different view on these data). Absence of inverse scope can also be observed in (39) below.

(39) every man admires less than three women
a there are less than three women that every man admires

Sentence (39) does not allow the inverse wide scope reading for *less than three women*, as expressed by (39a).

In the second syntactic configuration our fragment contains, a PP-modified NP, it has been claimed that we find a similar effect (Beghelli 1993):

(40) an inhabitant of exactly three cities participated

Although intuitions are less secure here, (40) shows a clear preference for the (pragmatically implausible) direct scope interpretation over the (more plausible) inverse scope analysis.

The exceptional wide scope found with simple indefinites in (30) and (33) is also not found with modified-numeral NPs:

(41) John met every man who admires exactly three midwestern cities

This example is judged false if there is any man admiring any choice of three midwestern cities whom John did not meet.

Sentences (38)-(41) show NPs with a compound determiner that do not take inverse scope. We find the same behaviour with other monotone decreasing QNPs, even non-modified ones, as shown in (42):

(42) some man admires few woman

A third category of NPs that, in some respects, belongs to the class discussed here are simple numeral NPs. We saw in the previous section (see (33)) that there are indications that these NPs can take exceptional wide scope. The example in (43), on the other hand, suggests that in other cases they must take direct scope:

(43) some man admires three women
a $\exists x[\ \textsc{man}(x) \wedge \exists 3y[\textsc{woman}(y) \wedge \textsc{admire}(y)(x)\ ]]$
b $\exists 3y[\textsc{woman}(y) \wedge \exists x[\ \textsc{man}(x) \wedge \textsc{admire}(y)(x)\ ]]$

This sentence is judged to entail the proposition that there is at least one man who admires three women; the inverse scope reading is judged to be much harder to obtain than in (13). The seemingly contradictory behaviour of the *three N* class is the subject of the next section.

3.5. Mixed scope

Below we repeat examples (33) and (43), and add examples (46) and (47):

(44) John met everyone who admires three midwestern cities
a $\forall x[[\textsc{person}(x) \wedge \exists 3y[\textsc{midwestern}(y) \wedge \textsc{city}(y) \wedge \textsc{admire}(y)(x)]] \rightarrow \textsc{meet}(\textsc{john},x)\ ]$
b $\exists 3y[\textsc{midwestern}(y) \wedge \textsc{city}(y) \wedge \forall x[[\textsc{person}(x) \wedge \textsc{admire}(y)(x)] \rightarrow \textsc{meet}(\textsc{john},x)\ ]]$
(45) some man admires three women
a $\exists x[\ \textsc{man}(x) \wedge \exists 3y[\textsc{woman}(y) \wedge \textsc{admire}(y)(x)\ ]]$
b $\exists 3y[\textsc{woman}(y) \wedge \exists x[\ \textsc{man}(x) \wedge \textsc{admire}(y)(x)\ ]]$
(46) no man admires three midwestern cities
(47) a John met someone who inhabits three midwestern cities
b John met some inhabitant of three midwestern cities
c $\exists x[[\textsc{person}(x) \wedge \exists 3y[\textsc{midwestern}(y) \wedge \textsc{city}(y) \wedge \textsc{inhabit}(y)(x)]] \wedge \textsc{meet}(\textsc{john},x)\ ]$
d $\exists 3y[\textsc{midwestern}(y) \wedge \textsc{city}(y) \wedge \exists x[[\textsc{person}(x) \wedge \textsc{inhabit}(y)(x)]] \wedge \textsc{meet}(\textsc{john},x)\ ]$

Unmodified numeral plurals display a seemingly contradictory scope behaviour. On the one hand, their scope is not limited to their surface position: from object position, they can "escape" the scope of the subject in (46), and even from relative-clause embedded position, they seem to escape the scope of the containing quantifier in (44). Thus, (44) is not felt to entail that John met everyone who admired any choice of three midwestern cities; rather, this sentence can apparently be about three particular midwestern cities. Likewise, sentence (46) allows more than just the direct scope reading; this is clear from the fact that (46) is true even if some men do admire some choice of three midwestern cities. In view of these facts, these bare numeral QNPs appear to behave much like simple indefinites (*a N*), which allow both "normal" inverse scope and exceptional wide scope (see section 3.3, as well as section 4.3.3 below).

On the other hand, a description of these non-narrow scope readings for the plural indefinites in (44) and (46) as "wide scope readings" would be too simplistic, as already mentioned in Section 3.4. Bare numeral QNPs do not simply take inverse wide scope out of islands: (44) does not allow the reading (44b), and (47a) does not allow the wide scope reading (47d). Furthermore, the inability of such QNPs to take inverse wide scope extends to non-island contexts: (45) and (47b) show that these QNPs behave much like the exceptional narrow scope modified numeral QNPs of section 3.4: the inverse scope readings given in (45b) and (47d) are highly marked (Ioup 1975, Liu 1990, Beghelli 1993).

3.6. Summary of QNP scope problems

In Section 2 we showed readings of sentences which suggest that the simple “direct scope” interpretative strategy of our toy grammar does not cover the interpretations of sentences in the fragment. We saw that in many cases this incompleteness can be a result of an “inverse scope” strategy for interpreting syntactic structures. In this section we saw some central challenges for the inverse scope strategy. First, inverse scope readings are often constrained by syntactic restrictions that seem parallel (at least partially) to the restrictions on overt extraction. However, simple indefinite NPs seem exceptionally free, and can often display an inverse scope behavior that does not seem to obey these syntactic restrictions. Conversely, some other NPs seem exceptionally restricted, and hardly show any inverse scope phenomena. Further, some plural indefinite NPs seem both exceptionally free and exceptionally restricted in their inverse scope potential, in a way that may lead to “mixed” scope behavior. The next section is an overview of some theories that attempt to account for (parts) of this complex array of linguistic scope phenomena.

4. Logical and linguistic theories of quantifier scope

4.1. Preliminaries on quantifier scope

A common approach to quantification in natural language, which was clearly manifested in Montague (1973, henceforth PTQ) and substantiated and popularized in Barwise and Cooper (1981) and Keenan and Stavi (1986), is to consider all QNPs as denoting *generalized quantifiers.* This assumption means that all QNPs denote sets of sets of entities, or, isomorphically, predicates over predicates over entities. For instance, in this approach a QNP like *every man* denotes the predicate that holds of the predicates that hold of all individual men in the model. In grammars with an extensional semantics such as the one of Section 2, using typed lambda terms, such a generalized quantifier receives the type <<e,t>,t> and is represented as follows:

(48) $\lambda B.\forall x[\textsc{man}(x) \rightarrow B(x)]$

Compositionally, this treatment entails that the determiner *every* receives the denotation of a function from predicates over entities to generalized quantifiers. This means that the type of such determiners, as in the grammar of Section 2, is <<e,t>,<<e,t>,t>>. The standard lambda term assumed for representing the extensional meaning of the determiner *every* is also as in the grammar of Section 2:

(49) $\lambda A\lambda B.\forall x[A(x) \rightarrow B(x)]$

Most semantic frameworks assume that transitive predicates like *admire* denote two-place relations, of type <e,<e,t>>. This is also the typing strategy assumed in the grammar of Section 2. In order to derive a meaning for sentences like *some/every woman admires every man*, the semantic mechanism should be able to compose the binary relation for *admire* with the two generalized quantifiers for the subject and the object. Many works assume, as we did in translation rule 4 of the grammar in Section 2, that the way to reach an interpretation for such transitive sentences involves lambda abstraction over variables that take the argument positions in the predicate. The two linear orders of composition with the binary predicate (object first or subject first) lead to the following two propositions, with Q1 and Q2 as the lambda terms for the subject and object quantifiers, respectively, and R the binary predicate.

(50) a $Q1(\lambda x.Q2(\lambda y.R(x,y)))$
b $Q2(\lambda y.Q1(\lambda x.R(x,y)))$

For our expository purposes here it is important to note that representations like (50) involve what we call a "standard" approach to quantifier scope. Two basic principles underlie this approach: (i) QNPs denote generalized quantifiers; (ii) the denotations of QNPs and relational predicates are amalgamated using "linear" composition as in (50a) and (50b), equivalent to a formula where one of the quantifiers takes scope over the other. As we will see in the sequel, these assumptions are not necessarily sufficient for describing all scope phenomena. However, as a baseline approach these “standard scope” principles allow one to capture many basic facts about inverse scope phenomena. We now move on to some theories that adopt and substantiate these principles.

4.2. "Standard scope" mechanisms

Familiar mechanisms that adopt the standard approach to scope can roughly be divided into two categories: syntactic and semantic ones. We call an approach *syntactic* if it requires a modification of the rules of syntax in order to derive inverse scope. In case of scope ambiguity, syntactic approaches normally postulate multiple distinct syntactic representations (structures, derivations) underlying the same string, with a different meaning assigned to each of them. We call an approach *semantic* if it keeps to the most straightforward syntactic account of the constituent structure of the language and only postulates a modification of the semantics so as to derive inverse scope readings. In case of ambiguity, a semantic approach postulates a single syntactic representation, to which rules of semantic interpretation can apply in different ways.

It should be remarked, however, that the distinction between *syntactic* and *semantic* approaches is a rather crude one. In many cases a syntactic scope mechanism has semantic repercussions and vice versa. In the following sections, we shall outline a selection of syntactic and semantic scope mechanisms from the literature. We will first introduce two well-known scope mechanisms: the methods of *Quantifier Raising* and *Quantifying-in*. The first approach is mostly followed in works in generative linguistics following May (1977), whereas Quantifying-in was introduced in PTQ and followed by much work in the tradition of Montague Grammar. Then we move on to a brief overview of the semantic scope mechanism of Cooper (1975,1983), known as *Cooper Storage*, and the flexible type mechanism of Hendriks (1993). Lastly, we will outline two categorial approaches to quantifier scope, which show a tight interaction between syntax and semantics.

4.2.1. Quantifier Raising

The “Quantifier Raising” (QR) theory of quantifier scope ambiguity was first proposed by Chomsky (1976) and May (1977) as a revision of the dominant generative theory of the time, known as the Extended Standard Theory (Chomsky 1972). The QR theory persisted into the subsequent Principles & Parameters framework (the basis of the well-known Government Binding theory following Chomsky 1981; see Chomsky and Lasnik 1993), and it still plays a role in the currently dominant Minimalist Program of Chomsky (1993,1995).

In these syntactic models, an expression is associated with multiple phrase structure representations, which are related by rules of movement (and other transformations). This is illustrated in (51):

(51) I wonder who John thinks Peter likes

a I wonder [$_{CP}$ John thinks Peter [$_{VP}$ likes who]]

b I wonder [$_{CP}$ who$_i$ John thinks Peter [$_{VP}$ likes t$_i$]]

(51a) is the (simplified) Deep Structure (or: *D-Structure*) representation of (51). This representation is generated by a set of Base Rules (for instance, rewrite rules as used for our fragment in section 2.1 above). The constituent structure at this level of representation captures the fact that *who* in (51) functions as the object of *likes*. (51b), the Surface Structure (or: *S-Structure*) representation, is derived from (51a) via a *movement rule*, which displaces the wh-element *who* to the front of the embedded question. The movement operation leaves a "trace" denoted *t*, which functions like a phonetically empty constituent coindexed with the moved constituent. The presence of indexed traces makes it possible to recover the D-Structure role of moved elements from the S-Structure representation. In the S-Structure (51b), the coindexing between the wh-element *who* and the trace keeps track of the fact that *who* is related to the object position of the verb *likes.* The S-Structure in turn is further input to rules of the phonological component of the grammar, which yields the phonetic form of the sentence.

Chomsky (1976) proposed that the S-Structure representation is input to a further set of rules, QR among them, which derive the *Logical Form* of the sentence. Representations at the level of Logical Form are interpreted by a semantic mechanism.[10] A simple configuration of this setting is one in which each LF is mapped to one, and only one, semantic analysis of the sentence.[11] Since the rules deriving LF do not feed into the phonological component (hence do not affect phonetic form), they are known as "covert" operations, as opposed to "overt" movement operations such as the *wh*-movement illustrated in (51).

On this approach, scope ambiguities arise through optionality in the application of a movement rule called *Quantifier Raising* (QR). This rule derives from one given S-Structure several different LFs with different scope relations between elements in the sentence. On its earliest formulation (May 1977), this movement rule operates as shown in (52):

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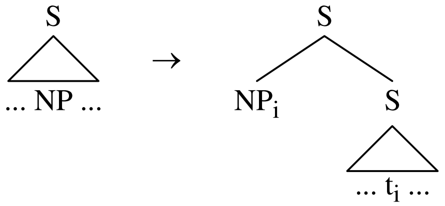
[10] The term *Logical Form* has of course been chosen to suggest similarity with the logician's notion of the logical form of a proposition which underlies its inference properties, as distinguished from the grammatical form. However, it has repeatedly been stressed, in particular by Chomsky (see e.g. Chomsky 1980), that the representation of a sentence at the grammatical level of LF is not to be equated with its "logical form." The contribution of LF is in structural aspects of meaning determined by syntax, potentially leaving other aspects unspecified. Representations at the level of LF are (almost always) taken as phrase structure representations, derived by syntactic rules and subject to syntactic well-formedness conditions, for which independent evidence is sought in other grammatical phenomena (such as conditions on *wh*-phrases left in situ at S-Structure, and on the coreference behavior of pronouns and anaphors), not necessarily semantic ones.

[11] It has been proposed (esp. by May 1985, Aoun and Li 1989) that the level of LF is not disambiguated: these authors combine a syntactic account of scope ambiguities (QR deriving LF) with a non-syntactic approach to deriving various interpretations from a given LF-representation.

(52)



This version of the QR rule takes the S-structure representation of a sentence S containing a quantified noun phrase NP, moves NP, and attaches it to the node S by "splitting" S into two nodes and attaching the NP under the highest of these.[12] Since the rule is a standard movement rule, by convention it leaves a trace *t* coindexed with the moved NP, as shown in (52).[13]

Adding such a rule to the grammar of section 2.1 will yield at least the following LFs for examples (13) and (24), respectively:

(53) a $[_S [_{NP}$ some woman$]_1 [_S [_{NP}$ every man$]_2 [_S t_1 [_{VP}$ admires t_2]]]]

b $[_S [_{NP}$ every man$]_2 [_S [_{NP}$ some woman$]_1 [_S t_1 [_{VP}$ admires t_2]]]]

(54) $[_S [_{NP}$ every city$]_2 [_S [_{NP}$ some inhabitant of $t_2]_1 [_S t_1 [_{VP}$ participated]]]]

The interpretive rules in the grammar should now apply to these LF representations. In order to modify our toy grammar so that structures derived by QR are properly interpreted, we add the following translation rule:

5) For all $\gamma \in$ SD s.t. $\gamma = [_S\ \beta_i\ \ \alpha\ ]$, β is an NP and α is an S, for all i $\in$ N:
if $\alpha \Rightarrow \alpha'$ and $\beta \Rightarrow \beta'$, then $\gamma \Rightarrow \beta'(\lambda x_i.\alpha')$.

This rule relies on the afore-mentioned assumption that when a movement rule adjoins a QNP to a sentence node S, that sentence contains a trace that is coindexed with the QNP. Furthermore, Translation Rule 5 also relies on the assumption that a trace with an index *i* is translated using a free variable x_i.[14] This assumption about the translation of traces is satisfied by the following scheme for traces in the lexicon, which is added on top of the lexicon of section 2.1.

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[12] The manner in which the moved NP in (52) is attached is known as "(Chomsky-)Adjunction"; hence May's formulation of the rule: "Chomsky-adjoin a QNP to S" (May 1977: 18). For a formal definition of Chomsky-adjunction, see Lasnik and Kupin (1977).

[13] The extensive literature on the topic contains a variety of other definitions, differing e.g. in what NP types are subject to QR (May 1985, Reinhart 1991, Ruys 1992), what nodes besides S it may target (Williams 1977, May 1985), whether it may also move material downward (May 1977, 1985, Fox 1995), under what conditions it may or must apply (May 1977, Fox 1995, 2000, Reinhart 2006a), whether it should be equated with other supposed covert operations (Hornstein 1995), whether or not it involves adjunction (Hornstein 1995, Beghelli & Stowell 1997, Bruening 2001) and even in whether or not it feeds into phonetic form (Kiss 1991, Fox and Nissenbaum 1999, and references cited there). See Kiss (2006) for a recent overview.

[14] It is assumed further that every QNP receives a "fresh" index, to prevent accidental coindexing of variables.

Cat	**Word**	**Translation**	**Type**
NP	t_i	$\Rightarrow \lambda P.P(x_i)$	$\langle\langle e,t\rangle,t\rangle$

This scheme follows Montague (1973) in that traces, like proper names, are translated into generalized quantifier terms, with the variable filling the role of the constant JOHN_e in terms like $\lambda A.A(\text{JOHN}_e)$, which appear in the lexicon of section 2.

The LFs in (53) and (54) are now interpreted similarly to the general representations we gave in (50) to simple transitive sentences. For instance, the verb phrase [*admires* t_2] in (53b) now receives the following translation using translation rule 4 in the grammar of section 2.1.

$$\lambda x.(\lambda P.P(x_2))(\lambda y.\text{ADMIRE}(y)(x)),$$

which is equivalent to:

$$\lambda x.\text{ADMIRE}(x_2)(x).$$

Using translation rule 5 above we get the following translation for the LF in (53b):

$$(\lambda A.\forall y[\text{MAN}(y) \rightarrow A(y)])\ \ (\lambda x_2.(\lambda B.\exists z[\text{WOMAN}(z) \wedge B(z)])(\lambda x.\text{ADMIRE}(x_2)(x))),$$

which is equivalent to the inverse scope reading of sentence (13):

$$\forall y[\text{MAN}(y) \rightarrow \exists x[\text{WOMAN}(x) \wedge \text{ADMIRE}(y)(x)\ ]]$$

In most treatments, such rules as translation rule 5 above are left implicit (but see e.g. May 1989). Keenan and Faltz (1985) and Heim and Kratzer (1998) manage without the extra translation rules by effectively adding the lambda operator for variable binding as an extra node to the syntactic representation.

Evaluating the LF / QR approach

The QR theory, which holds that quantifier scope is mediated through a syntactic movement rule deriving a syntactic level of representation, has several types of empirical consequences. First and foremost, it leads one to expect that conditions on quantifier scope can be stated as conditions on rules of movement; this implication is our primary topic in this section.

We want to stress, however, that the QR/LF theory has further implications, some of which are only indirectly related to quantifier scope phenomena. It has been argued, for instance, that additional (movement) operations besides QR apply in deriving LF from S-Structure (e.g. a rule fronting *wh*-phrases left in situ at S-Structure). These operations are held responsible for other semantic effects besides relative scope, and even for the well-formedness of certain constructions and aspects of cross-linguistic variation. Since the QR theory presupposes the existence of LF as a grammatical level of representation, any independent evidence for such LF operations affects the status of the QR theory. In addition, since QR derives a syntactic level of representation, one expects that there might be further rules of syntax that take the output of QR as their input: either further derivation rules, or syntactic constraints that apply to LF representations derived by QR; the treatment of "Antecedent Contained Deletion" (ACD) phenomena discussed in Section 5.2 may be a case in point. A full evaluation of the QR approach to scope phenomena must take these various types of indirect evidence into account.

Primarily, however, evidence for QR exists to the extent that generalizations on quantifier scope can be stated in terms of syntactic properties of the relevant constructions, and to the extent that these generalizations apply to other purported movement operations as well. Ultimately, on the QR approach, a unified theory explaining properties of both overt and covert movement should be possible.

As far as our fragment goes, there are two factors affecting quantifier scope, and the occurrence of inverse scope: choice of QNP, and syntactic context. Some of the effects of the choice of the QNP on scope are mentioned in section 3.4. However, by far the most widely discussed prediction associated with QR theory is that limitations on scope and limitations on (overt) movement which arise from the syntactic context should coincide. As mentioned in section 3.2 above, many of the islands for extraction that were discovered in Ross (1967) have also been identified as scope islands. We repeat some earlier examples and add some further types:

(55) a * which city$_i$ did you meet [$_{NP}$ people who inhabit t$_i$]
b [$_{NP}$ someone who inhabits every midwestern city] participated
(56) a * which man$_i$ will you inherit a fortune [$_{CP}$ if t$_i$ dies]
b you will inherit a fortune [$_{CP}$ if every man dies]
(57) a * which student does Prof Jones [$_{VP}$ despise t$_i$] and [$_{VP}$ admire the dean]
b some professor [$_{VP}$ despises every student] and [$_{VP}$ admires the dean]
(58) a * who$_i$ did you see [John's picture of t$_i$]
b I saw [John's picture of everyone]

(55) illustrates the effect of the Complex NP Constraint (CNPC), introduced in section 3.2: an NP with a relative clause does not allow overt *wh*-extraction of *which city* in (55a); it also does not allow wide scope for *every Midwestern city* in (55b). (56) shows the effect of an *Adjunct Island*: the *if*-clause serves as an island for both extraction (cf. the ungrammaticality of (56b)) and scope, witness the fact that sentence (56) does not have a reading where the noun phrase *every man* takes scope over the conditional (see more on this observation in section 4.3.3). (57) shows the effect of the *Coordinate Structure Constraint* (CSC): an element may not be extracted out of one conjunct in a coordination structure in (57a), and a quantifier does not scope out of such a construction in (57b) (*every student* does not scope over *some professor*). (58) illustrates the *Specificity Constraint*: a definite NP, especially one

with an overt subject (*John's*) is an island for both extraction (58a) and scope: (58b) has only a narrow scope reading for *everyone* (it's a single group photograph).[15]

The parallelism between the a.-examples and the b.-examples in (55)–(58) provides strong prima facie evidence that the rule responsible for quantifier scope ambiguities is indeed a movement rule, of the same type, hence largely subject to the same conditions, as the rule responsible for overt (wh-)movement. This provides the primary motivation for the QR theory.[16]

Prima facie evidence, of course, need not be conclusive. An alternative for describing scope islands in terms of restrictions on overt movement might be that quantifier scope is *clause-bounded*; this would trivially prevent scoping out of clauses that happen to be syntactic islands. For instance, CNPC islands consist of an NP containing a relative clause; if scoping out of the clause is blocked, scoping out of the island as a whole is blocked as well. This was the argument raised by Chomsky (1975) against Rodman's (1976) syntactic approach to quantifier scope based on Montague's Quantifying-in operation (see section 4.2.2 below). Rodman demonstrated that quantifier scope is sensitive to CNPC islands; Chomsky countered that quantifier scope simply cannot escape finite clauses, as shown by the non-ambiguity of (59):

(59) John said that everyone had left (Chomsky: 1975: (13))

One might thus argue that the similarity of syntactic islands to scope islands is an illusion, and that the former happen to be a subset of the latter -- although it remains to be seen, of course, whether this would support any other approach to quantifier scope. That would depend on whether clause-boundedness could be implemented insightfully in, say, a semantic theory of quantifier scope.

One empirical answer to Chomsky's challenge can be based on the observation that clause-boundedness may both be too restrictive and too permissive as an account of quantifier scope. Sometimes, quantifier scope is more restricted than the minimal clause, namely when a QNP is embedded in an island smaller than the minimal clause: this is illustrated in (57b) and (58b) above. At the same time, a quantifier may sometimes scope out of the minimal clause, especially when the minimal clause in non-finite (see e.g. (60), from Hornstein 1995), and for some speakers also when the clause is finite, as in (59) (see May 1977:217); see also Reinhart (1997).

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[15] For more recent discussion of the CSC effect on quantifier scope, see Ruys 1992, Fox 1995 (who discusses certain classes of exceptions). For the Specificity Constraint, see Chomsky 1973, Fiengo & Higginbotham 1981, Davies & Dubinsky 2003.

[16] In fact, the observation that islands for overt movement coincide with scope islands, and the account of quantifier scope in terms of a quantifier movement rule, precedes the QR theory. Lakoff (1970), working in the framework of Generative Semantics, presents many of the basic observations and proposes a similar account (see also Postal 1974): in the deep structure underlying a sentence with a quantified NP, the quantificational determiner (e.g., *many*) occupies the scope position, from which it is lowered to its surface position by a lowering rule which is sensitive to the same island conditions that block overt wh-movement.

(60) someone expected [$_S$ every Republican to win]

While Chomsky’s alternative description may thus be rejected as oversimplified, the contrast between (59), where a QNP cannot scope out of a finite clause for most speakers, and (51) above, where a wh-phrase does move out of such a clause, is indicative of a more fundamental challenge to the QR theory: there is no perfect parallelism between scope and overt movement. In itself, this observation does not falsify the movement approach to scope phenomena: given that QR and *wh*-movement differ in the type of object being moved, the landing site for the movement, and the (c)overtness of the movement, it is possible that conditions on syntactic movement, properly formulated, predict some observational divergence of wh-movement and scope. In the case of Chomsky's example (59), May (1977) showed that his own account correctly predicts the distinction between (51) and (59) (see below). In general, whether the syntactic approach to quantifier scope is correct is not decided on the basis of superficial (dis-)similarities of *wh*-movement and quantifier scope. What matters for a critical evaluation of QR theory is whether we can construct a successful theory of movement which provides an insightful account of both *wh*-movement and QR.

In order to provide a concrete illustration of these points, we conclude this section by briefly returning to the fragment of section 2, and illustrating some of the problems that have arisen in providing a syntactic, QR account of the scope ambiguities it contains. Our purpose here is emphatically not to provide an overview, either historic or systematic, of constraints on movement developed in the generative framework and their applicability to QR; it is merely to provide some sense of the type of problems and solutions that arise.

May (1977) proposed that both (overt) *wh*-movement and QR obey Chomsky’s (1973) *Subjacency* condition. This syntactic condition states that no movement may cross two bounding nodes, where S and NP are considered bounding nodes. This correctly predicts that quantifier scope obeys the CNPC. Given the subjacency restriction on QR, sentence (25) above does not allow the LF below:

(61) [$_S$ every city$_i$ [$_S$ [$_{NP}$ someone [$_S$ who inhabits t$_i$]] participated]]

In (61) there are three bounding nodes (two Ss and one NP) that separate the trace t$_2$ and the landing site for *every city*. Likewise, the CNPC effect with overt wh-movement in (55a), repeated below, is explained by Subjacency: three bounding nodes separate *which city* from its trace.

(62) * which city$_i$ [$_S$ did you meet [$_{NP}$ people who [$_S$ inhabit t$_i$]]]

Crucially, May (1977) argues that the Subjacency condition also explains the observation that QNPs cannot, but wh-phrases can, escape finite clauses. The LF for (59) that would give wide scope to *everyone*, given in (63), violates Subjacency:

(63) [$_S$ everyone$_i$ [$_S$ John said that [$_S$ t$_i$ had left]]]

(51), however, does not violate Subjacency, since a *wh*-phrase moving out of a finite clause, unlike a quantifier NP, can make an intermediate landing at the left edge of the finite clause, as indicated in (64) by the trace t*$_i$ in this position:

(64) I wonder [$_{S'}$ who$_i$ [$_S$ John thinks [$_{S'}$ t*$_i$ [$_S$ Peter [$_{VP}$ likes t$_i$]]]]]

While the empirical implications of this analysis are satisfactory, two problems arise. First, the supposed LF for (13) which yields the available inverse scope reading, given below, also appears to violate Subjacency.

(65) [$_{S2}$ [$_{NP}$ every man]$_i$ [$_{S1}$ [$_{NP}$ some woman]$_j$ [$_{S0}$ t$_j$ [$_{VP}$ admires t$_i$]]]]

Assuming that the noun phrase *some woman* also undergoes QR, the noun phrase *every man* has to cross two S-nodes in order to take scope above it. This led May to a revision of the Subjacency condition for which no independent evidence from overt movement was available at the time (although the problem was resolved in the framework of Chomsky 1986a): multiple S-nodes in a relation of immediate domination (S0 and S1 in (65)) count as one bounding node.

The problem illustrated in (65) was perhaps purely technical. However, example (66) below drives a more substantive wedge between QR and overt movement, and the problem it illustrates remains to this day:

(66) * who [$_S$ did [$_{NP}$ pictures of t] please you]

This ill-formed example shows that *wh*-movement out of a subject-NP is disallowed, an effect that has also been attributed to Subjacency (Chomsky 1977:112): the element *who* in (66) crosses both the NP and S nodes. On this count, we would expect that our third syntactic context disallows extraction as well: the LF that yields the inverse scope reading for (24) should also violate Subjacency according to its definition above. This LF is given below.

(67) [$_S$ [$_{NP}$ every city]$_i$ [$_S$ [$_{NP}$ some inhabitant of t$_i$]$_j$ [$_S$ t$_j$ [$_{VP}$ participated]]]]

May's (1977:214) solution to this puzzle added a clause to the Subjacency condition: NP does not count as a bounding node in case the relevant movement is QR. Clearly, this does not resolve the conflict, but rather codifies the divergence of wh-movement and QR seen in (66) – (67); a proliferation of such divergences would render the "unification" of QR with an overt movement rule vacuous.

One solution to this puzzle was offered by May (1985), who suggested that QR does not extract a QNP from another QNP in inverse linking constructions, but rather adjoins the embedded QNP to the containing one:

(68) $[_S\ [_{NP}\ [_{NP}$ every city$]_i\ [_{NP}$ some inhabitant of $t_i]]_j\ [_S\ t_j\ [_{VP}$ participated$]]]$

In (68), Subjacency is not violated. For discussion of the semantic interpretation of structures like (68), see May (1989) and Larson (1985b). We will not trace the history of the treatment of these problems any further; the reader is referred to May and Bale (2006) for a recent overview.

A considerable amount of further work has been done on the QR theory of quantifier scope ambiguity in various stages of the generative framework; space does not allow us to discuss, or even outline, this body of literature. We refer to Reinhart (1997) for an overview of many of the issues involved in determining the conditions on covert movement, and arguments that, on balance, the Subjacency condition remains the preferred account of QR-determined quantifier scope phenomena. We conclude by observing that, at the time of writing, although progress has been made in several areas, a complete theory of movement restrictions as they apply to scope does not appear within reach.

4.2.2. Quantifying-in

Montague's (1973) PTQ introduced a grammar for a fragment of English that, among other phenomena, treats quantifier scope ambiguities. The syntactic formalism that is assumed in PTQ is somewhat non-standard, and it is therefore hard to illustrate its treatment of scope ambiguities using the phrase structure grammar of section 2. We will here illustrate only the general idea behind Montague's operation of *Quantifying-in* – a syntactic treatment of NPs that generates quantifier scope ambiguities in the PTQ fragment. For full details see PTQ itself, or the more friendly introductions in Dowty et al. (1981:ch.7) and Gamut (1991:ch.6).

A syntactic rule in PTQ takes a sequence of expressions $\alpha_1, \alpha_2, ..., \alpha_n$ and their syntactic categories $C_1, C_2, ..., C_n$, and generates an expression α and a category *C*. Crucially, syntactic rules in PTQ can generate α using non-concatenative operations on the expressions $\alpha_1, \alpha_2, ..., \alpha_n$. This is unlike ordinary phrase structure rules, which only concatenate the input expressions. To see how this allows PTQ to capture quantifier scope ambiguities, consider our example (13) from section 2.1, restated below:

(69) some woman admires every man

To generate the object wide scope reading of this sentence, PTQ generates the following two expressions, with the respective categories:

α_1, category *t*:	*some woman admires* him_n
α_2, category T:	*every man*

The expression α_1 is of category *t* – PTQ's category for sentences – and it contains a pronoun *him*, derived with an arbitrary index *n*. The expression α_2 is of category *T* – PTQ's category for noun phrases. Both α_1 and α_2 are generated using rules that are mostly similar to standard phrase structure rules in using concatenation of lexical expressions. However, PTQ's quantification rule (S14) uses a syntactic operation of *substitution* to replace the pronoun in α_1 by the noun phrase α_2. This derives the output expression α = *some woman admires every man* in (69). The rule determines that this expression, like the input expression α_1, is of category *t* (=sentence).

On the semantic side, PTQ assigns each derived expression in the grammar a translation in Montague's *intensional logic* (IL – an intensional variant of the typed lambda calculus, see Dowty et al. 1981, Gamut 1991). Each syntactic rule has a corresponding translation rule responsible for deriving the translation of the output expression. In the case of the syntactic quantification rule, the corresponding translation rule (rule T14 in PTQ) is responsible for the wide scope interpretation of the object in (69). The sentential expression α_1, with the pronoun him_n, is derived with the following translation β_1, containing a free variable x_n. The translation β_1 is given here after some simplifications, and ignoring the intensional aspects of PTQ translations:

$$\beta_1 = \exists x[\text{WOMAN}(x) \wedge \text{admire}\ (x_n)(x)]$$

The noun phrase expression α_2 is derived with the following generalized quantifier translation β_2 (again, with some simplifications):

$$\beta_2 = \lambda B.\forall y[\text{man}(y) \rightarrow B(y)]$$

The translation rule T14 for quantification lets the quantifier bind the free variable x_n in β_1 using lambda abstraction over this variable:

$$\beta = \beta_2(\lambda x_n.\beta_1)$$

The resulting translation β of the sentential output expression α (= *some woman admires every man*) is equivalent to the object wide scope reading of the sentence:

$$\forall y[\ \text{MAN}(y) \rightarrow \exists x[\text{woman}(x) \wedge \text{ADMIRE}(y)(x)]]$$

Montague's method of Quantifying-in does not on its own account for island constraints on quantifier scope. Considering the complex NP constraint (CNPC), Rodman (1976) addresses this problem for an extension of PTQ that also treats ordinary relative clauses with *who* and *that* relative pronouns, in addition to the rather artificial *such that* construction of PTQ. To see the problem for the PTQ grammar, reconsider sentence (25) from section 2.3.1, restated below as (70), or its equivalent in the PTQ grammar that is given in (71).

(70) someone who inhabits every midwestern city participated

(71) someone such that he inhabits every midwestern city participated

Without further assumptions, PTQ and its straightforward extension in Rodman (1976) allow such sentences to be interpreted with a sentential scope for the noun phrase *every midwestern city*. This is because rules S14 and T14 of quantification allow such NPs to compose with the sentential expression in (72), which contains the free pronoun it_n.

(72) someone who inhabits it_n participated

Further, the translation rule T14 allows the quantifier translation of the noun phrase *every midwestern city* to bind the free variable corresponding to the pronoun it_n. This leads to the counterintuitive analysis of (70) (=(25)) in (7b). Rodman proposes to block such illicit interpretations by marking the indices on pronouns within relative clauses with a special sign that blocks application of the Quantifying-in rule from outside the relative construction. Rodman uses the superscript 'R' to mark such pronouns, disallowing sentential expressions like (72) that do not contain 'R' on pronouns within their relative clauses. As a result, the expression in (72) is not derived by Rodman's grammar, and instead the following expression is derived, with the index n^R on the pronoun.

(73) someone who inhabits it_{n^R} participated

The syntactic rule S14 in Rodman's extension of the PTQ fragment can only substitute a noun phrase for occurrences of pronouns with indices *unmarked* by 'R'. Consequently, sentence (70) cannot be derived using (73) and the noun phrase *every midwestern city.* The net outcome of this treatment is that sentences like (70) and (71) are derived by Rodman's fragment, but without an analysis that gives sentential scope to the NP within the relative clause.

Rodman further notes that because of the way in which his relative clause rules are construed, pronouns with an 'R-ed' index cannot be used for forming more complex relative clauses. For instance, from (73) Rodman's fragment cannot generate the following ungrammatical sentence:

(74) * I admire the city which someone who inhabits participated

As Rodman argues, this proposal captures the parallelism between island restrictions on overt wh-"movement" (to wit, the movement of the relative clause operator *which* in (74)) and scope islands (witness the absence of a wide scope reading for (70)).

4.2.3. Cooper Storage

One of the first alternatives to Quantifying-in, and the first semantic approach to QNP scope, was the proposal of Cooper (1975,1979,1983) known as *Cooper Storage.* For Cooper, a central motivation for this technique (Cooper 1975:ch.4) was to show that syntactic representations for natural language sentences need not be "disambiguated" in the sense of PTQ. Each syntactic representation in Cooper's system may have more than one semantic analysis. The reason that examples showing quantifier scope ambiguity, such as (69), are seen to justify such an approach, is that straightforward syntactic considerations (relating e.g. to well-formedness, or to syntactic constituency tests) do not appear to support assumptions about syntactic ambiguity in the relevant examples, or about the existence of multiple syntactic derivations. For instance, sentences like (69) receive only one syntactic analysis in the grammar of Section 2. If one considers that inverse scope readings of such sentences are not by themselves sufficient reason for postulating a syntactic ambiguity, the conclusion that their syntactic representation must receive more than one semantic analysis may seem inevitable.

Cooper's account of "purely semantic" ambiguity is obtained by generalizing meaning representations.[17] First, meanings in Cooper's account are represented using ordered *pairs*, where the core lambda term representing the expression's meaning is coupled with a *store*. A store is a sequence of pairs of quantifiers and variables they bind. Such representations need to be processed in order to interpret the expression. For instance, one of the representations for sentence (69) above is the following one:

$\Phi_1 = \langle\ \mathrm{ADMIRE}(x)(y),\ \langle\ x/Q1,\ y/Q2\ \rangle\ \rangle$,

where: $Q1 = \lambda A.\forall z[\mathrm{MAN}(z) \rightarrow A(z)]$

$Q2 = \lambda B.\exists u[\mathrm{WOMAN}(u)\ ) \wedge B(u)]$

The first element in such a representation as Φ_1 is a lambda-term (in this case $\mathrm{ADMIRE}(x)(y)$), possibly with free variables, which can be bound by one of the quantifiers in the store. Cooper essentially assumes that each quantifier in the store can bind the respective variable at any point in the process of meaning derivation. NPs are the syntactic elements that contribute quantifiers to meaning representation. As a result, each NP occurring in an expression may either combine with the core meaning directly, or be stored and, at a later stage of the semantic interpretation process, taken out of storage and combined with the core meaning at that point. Hence, each expression containing one or more NPs may in principle have more than one representation using Cooper storage. For instance, in addition to Φ_1, sentence (69) also have the following representations:

$\Phi_2 = \langle\ Q1(\lambda x.\mathrm{ADMIRE}(x)(y)),\ \langle\ y/Q2\ \rangle\ \rangle$

$\Phi_3 = \langle\ Q2(\lambda y.\mathrm{ADMIRE}(x)(y)),\ \langle\ x/Q1\ \rangle\ \rangle$

$\Phi_4 = \langle\ Q2(\lambda y.Q1(\lambda x.\mathrm{ADMIRE}(x)(y))),\ \langle\ -\ \rangle\ \rangle$

$\Phi_5 = \langle\ Q1(\lambda x.Q2(\lambda y.\mathrm{ADMIRE}(x)(y))),\ \langle\ -\ \rangle\ \rangle$

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[17] Our account of Cooper Storage here essentially follows Carpenter (1997:ch.7). For another overview of Cooper Storage see Hendriks (1993:ch.1).

In representation Φ_2, the quantifier Q1 binds the variable x associated with it, whereas Q2 remains on the store. In representation Φ_3 it is the opposite situation, whereas in representation Φ_4 and Φ_5, both quantifiers bind their variables and the store is empty, with the different scope construals of the quantifiers with respect to one another. Φ_5 is equivalent to the object wide scope reading of the sentence; it is obtained when the translation of the object is stored, and taken out of storage after the translation of the subject has been combined with the core meaning. Only the last two representations are fully interpretable, and lead to the actual two meanings of the sentence.

In Cooper (1979:157-158) and Cooper (1983:61) a preliminary account of CNPC restrictions on scope is proposed using Cooper's method of quantifier storage.

4.2.4. Type Flexibility

An approach to QNP scope that is also purely semantic, yet quite different from Cooper Storage, was proposed by Hendriks (1993). The three approaches to standard QNP scope that were reviewed above all capture scope ambiguity using operations on noun phrases or the quantifiers they denote. Unlike these approaches, Hendriks' proposed method takes predicates to be the locus of scope ambiguity. Following Partee and Rooth (1983), Hendriks assumes that predicates in natural language have multiple semantic types. On the one hand, as in our toy grammar of section 2 and in many traditional accounts, it is assumed that natural language predicates can take *entities* as their arguments. On the other hand, Hendriks follows Montague and Partee/Rooth, and allows predicates in natural language to have generalized quantifiers as their direct arguments.

One of Montague's motivations for allowing quantifiers to be direct arguments of predicates comes from the semantics of *intensional predication* in natural language. Consider the following classical example.

(75) John is looking for a unicorn.

Sentences like (75) cannot be fully treated by analyzing the verb *look for* as a relation between *e*-type entities. Sentence (75) can of course be true if no unicorns exist. No plausible interpretation for the object *a unicorn* would capture this fact if the object argument of verb *look for* were to be treated as a simple entity. Montague's conclusion from this difficulty was to allow intensional predicates like *look for* to take an *intensional quantifier* as their direct object argument. In extensional terms, this analysis can be presented as treating the transitive verb *look for* with type <<<e,t>,t>,<e,t>>. For a discussion of this analysis and intensional verbs see Gamut (1991, pp. 168-9) and Zimmermann (1993), among others.

Following his general assumptions about uniform type assignment to syntactic categories, Montague also assigned intensional types to non-intensional predicates like *participate* above, or *admire* or *inhabit* in (69) and (70). In extensional terms, this means that also transitive verbs like *admire* or *inhabit* receive the analysis above of the predicate *look for* as allowing a quantificational direct argument. Partee and Rooth diverged from Montague's type uniformity, and proposed that extensional verbs like *participate*, *admire* or *inhabit* may have *multiple types*. In Partee and Rooth's account, extensional transitive predicates lexically denote relations between entities, but their arguments can be adjusted to fit the quantifier type <<e,t>,t> when the meaning derivation process requires it.

Hendriks exploits the type ambiguity in Partee and Rooth's proposal in order to derive QNP scope ambiguity in his semantic system. Simplifying Hendriks' mechanism, we introduce the following *type shifting operators*, both of which map a relation of type <e,<e,t>> between entities to a relation between quantifiers.

$$\sum_{ONS} = \lambda R_{<e,<e,t>>} \lambda Q_{<<e,t>,t>}\, \lambda P_{<<e,t>,t>}.\ P(\lambda y.Q(\lambda x.R(x)(y)))$$

$$\sum_{OWS} = \lambda R_{<e,<e,t>>} \lambda Q_{<<e,t>,t>}\, \lambda P_{<<e,t>,t>}.\ Q(\lambda x.P(\lambda y.R(x)(y)))$$

Under the assumption that these operators can apply to the transitive predicate *admire* in (69), we derive the object-narrow-scope (direct scope) reading using the first operator and the object-wide-scope (inverse scope) reading using the second one. This is illustrated below.

$$\sum_{ONS} \text{(ADMIRE)(EVERY(MAN))(SOME(WOMAN))}$$
$$\Leftrightarrow \exists x[\text{WOMAN}(x) \wedge \forall y[\ \text{MAN}(y) \rightarrow \text{ADMIRE}(y)(x)]]$$

$$\sum_{OWS} \text{(ADMIRE)(EVERY(MAN))(SOME(WOMAN))}$$
$$\Leftrightarrow \forall y[\text{MAN}(y) \rightarrow \exists x[\text{WOMAN}(x) \wedge \text{ADMIRE}(y)(x)]]$$

In addition to these direct/inverse scope readings of simple transitive sentence, Hendriks shows that his system also allows deriving wide scope readings of QNPs beyond embedded structures, like the ones that were illustrated by example (60) in section 4.2.1. See Hendriks (1993:p.85-88) for further details.

Hendriks suggests that (island) constraints on quantifier scope may be captured in his system by only allowing type shifting operations for a subclass of lexical items (e.g., for transitive verbs, but not for relative clause operators).

4.2.5. Categorial approaches

A purely semantic proposal to quantifier scope was tentatively suggested by Van Benthem (1986:130-131; 1991:61,113-114), based on a *non-directional* version of Categorial Grammar, known as the *Lambek Calculus* with permutation (LP). Van Benthem's LP system can be conceived of as an extension of the core semantic calculus for meaning composition. Early categorical approaches (e.g. Ajdukiewicz 1935) only allow *function application*, which is used as the core principle for composing types (or categories). In a general format, function application allows one to "eliminate" the functional relation between types A and B in a complex type <A,B> by providing an <A,B>-type function *f* with its A-type argument *x*. Officially, this simple type/meaning change is written as follows in natural deduction format:

$$<A,B>:f \qquad A:x$$

$$B{:}f(x)$$

This rule of function application corresponds to translation rule 3 of the grammar in section 2. For instance, when composing a quantifier EVERY(MAN) of type <<e,t>,t> with a one place predicate PARTICIPATE of type <e,t>, Ajdukiewicz Calculus allows function application with the appropriate outcome of type *t*. In natural deduction format, this simple inference of types and meanings is written as follows:[18]

$$\frac{\langle\langle e,t\rangle,t\rangle{:}\ \text{EVERY(MAN)} \qquad \langle e,t\rangle{:}\ \text{PARTICIPATE}}{t{:}\ (\text{EVERY(MAN)})(\text{PARTICIPATE})}$$

In addition to function application, Van Benthem's LP Calculus, like other calculi following Lambek (1958), also contains a rule of *hypothetical reasoning*. In natural deduction format, this rule allows one to introduce an element into the meaning derivation as a variable, which is later eliminated using *abstraction*, and which derives a function type. In natural deduction format, hypothetical reasoning looks as follows:

$$\frac{\dfrac{\begin{array}{c}[A{:}x]_1\\ \cdot\\ \cdot\\ \cdot\end{array}}{B{:}y}}{\langle A,B\rangle{:}\lambda x.y}\ \mathbf{E}_1$$

- introduction of assumption 1

- using assumption 1 for derivation

- eliminating assumption 1 using hypothetical reasoning

In this scheme, LP's hypothetical reasoning rule "pretends as if" a type A with meaning *x* is present in the derivation (assumption 1), uses it for deriving a type B with meaning *y*, and then "discharges" assumption 1 by creating a type <A,B> with meaning λ*x*.*y*.

Hypothetical reasoning allows LP to do away with the fairly artificial translation rule 4 of section 2, while at the same time deriving QNP scope ambiguity. Consider the following meaning derivation for sentence (69).

(76) some woman admires every man

$$\frac{\dfrac{\dfrac{\dfrac{\langle e,\langle e,t\rangle\rangle{:}\ \text{ADMIRE} \qquad [e{:}y]_1}{\langle e,t\rangle{:}\ \text{ADMIRE}(y)} \qquad [e{:}x]_2}{t{:}\ \text{ADMIRE}(y)(x)}}{\langle e,t\rangle{:}\lambda y.\text{ADMIRE}(y)(x)}\ \mathbf{E}_1 \qquad \langle\langle e,t\rangle,t\rangle{:}\ \text{EVERY(MAN)}}{t{:}\ (\text{EVERY(MAN)})(\lambda y.\text{ADMIRE}(y)(x))}$$

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[18] Also the meaning and type of the quantifier EVERY(MAN) are derived using a similar application from the standard types of the determiner and the noun as assumed in the grammar.

-- E_2

<<e,t>,t>:SOME(WOMAN)   <e,t>: λ*x*.(EVERY(MAN))(λ*y*.ADMIRE(*y*)(*x*))

----

t: (SOME(WOMAN))(λ*x*.(EVERY(MAN))(λ*y*.ADMIRE(*y*)(*x*)))

This direct scope reading is derived because hypothetical reasoning allows LP to "feed" the transitive predicate with its entity arguments by postulating them in the derivation, and then to "discharge" these assumptions at the steps preceding the application of the object/subject quantifier. A similar use of hypothetical reasoning also derives the inverse scope reading, as in the derivation below.

(77) some woman admires every man

<e,<e,t>>: ADMIRE $[e{:}y]_1$

<e,t>: ADMIRE(*y*) $[e{:}x]_2$

----

t: ADMIRE(*y*)(*x*)

------------------------------ E_2

<e,t>:λ*x*.ADMIRE(*y*)(*x*) $[\langle\langle e,t\rangle,t\rangle{:}Q]_3$

----

t: Q(λ*x*.ADMIRE(*y*)(*x*))

----------------------------------- E_1

<e,t>: λ*y*.Q(λ*x*.ADMIRE(*y*)(*x*))   <<e,t>,t>: EVERY(MAN)

----

t: (EVERY(MAN))(λ*y*.Q(λ*x*.ADMIRE(*y*)(*x*)))

-- E_3

<<e,t>,t>:SOME(WOMAN)   <<<e,t>,t>,t>: λQ.(EVERY(MAN))(λ*y*.Q(λ*x*.ADMIRE(*y*)(*x*)))

----

t: (EVERY(MAN))(λ*y*.(SOME(WOMAN))(λ*x*.ADMIRE(*y*)(*x*)))

This inverse scope reading of (69) is here derived because of the possibility to introduce a subject quantifier *Q* by assumption 3, which takes narrow scope below the object *every man*, and which is later discharged before the quantifier denoted by the subject *some woman* is composed in the derivation.[19]

Unfortunately, as pointed out by Hendriks (1993:69), this derivation of QNP scope ambiguity is accompanied by massive overgeneration. The principle of hypothetical reasoning allows the introduction of "traces" of arguments before they actually appear in the derivation. A too simplistic usage of this principle may also allow binding of such traces by the "wrong" quantifier in the sentence. For instance, if assumption 2 in derivation (76) were to be discharged immediately prior to the composition with the object quantifier, and

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[19] Note that there is an apparently simpler way of deriving the inverse scope reading of (69) than the one in (77), using a derivation similar to (76) where assumption 1 is discharged after assumption 2, and the subject quantifier composes with the transitive verb before the object quantifier. This analysis would be completely symmetrical to the one in (76), and it is therefore often assumed in the categorical literature. We show here the more complicated derivation (77) of the inverse scope reading, in order to show that the problem demonstrated in (78) below persists even with the standard [Subject [Verb Object]] constituency, which we adopt throughout this paper.

similarly for assumption 1 and the subject quantifier, the result would have been the following one.

(78) some woman admires every man

$$\dfrac{\langle\langle e,t\rangle,t\rangle{:}\text{SOME}(\text{WOMAN}) \qquad \dfrac{\dfrac{\dfrac{\dfrac{\dfrac{\langle e,\langle e,t\rangle\rangle{:}\ \text{ADMIRE} \qquad [e{:}y]_{\mathbf{1}}}{\langle e,t\rangle{:}\ \text{ADMIRE}(y)} \qquad [e{:}x]_{\mathbf{2}}}{t{:}\ \text{ADMIRE}(y)(x)}\ \mathbf{E_2}}{\langle e,t\rangle{:}\lambda x.\text{ADMIRE}(y)(x)} \qquad \langle\langle e,t\rangle,t\rangle{:}\ \text{EVERY}(\text{MAN})}{t{:}\ (\text{EVERY}(\text{MAN}))(\lambda x.\text{ADMIRE}(y)(x))}\ \mathbf{E_1}}{\langle e,t\rangle{:}\ \lambda y.(\text{EVERY}(\text{MAN}))(\lambda x.\text{ADMIRE}(y)(x))}}{t{:}\ (\text{SOME}(\text{WOMAN}))(\lambda y.(\text{EVERY}(\text{MAN}))(\lambda x.\text{ADMIRE}(y)(x)))}$$

In the resulting proposition, this analysis states that there is a woman who is admired by every man, which is not consistent with any interpretation of sentence (69).

In the categorial grammar literature on scope ambiguity there have been two major attempts to overcome this kind of overgeneration. Moortgat (1997) proposes a *multimodal* version of categorical grammar, which uses a special scoping type constructor different from the functional constructor in standard functional type <A,B>. In this way hypothetical reasoning in the semantics is properly coupled with the syntax of the sentence without generating illicit derivations like (78). A more recent strategy, first proposed in De Groote (2001) and Muskens (2003), who attribute the original approach to Oehrle (1994), is that of *Abstract Categorial Grammar* (sometimes also referred to as *Lambda Grammar*), where the relations between syntax and semantics allow a more sophisticated separation between word order and semantic composition than in LP and traditional categorical grammars. We will not try to discuss the technical details of these works here, and refer the reader to the overviews in Carpenter (1997:ch.7) and Muskens (2003). Importantly, these categorical approaches keep the treatment of QNP scope phenomena rather close to the treatment of "overt movement" phenomena. Thus, it is conceivable that parallelisms between scope and movement can be captured in categorical approaches similarly to QR theory. For some remarks on this point in relation to the Coordinate Structure Constraint see Carpenter (1997:241).

Yet another approach to quantifier scope, not entirely "categorial", but quite in the spirit of the categorial approaches surveyed above, was proposed by Barker (2002). Barker uses the notion of *continuation* from computer science, as an account of the apparent mismatch between quantifier types and their function in syntax. This move allows an elegant account of quantifier scope as well.

A general survey and evaluation of various approaches to quantifier scope appears in Jacobson (2002). Jacobson distinguishes among four types of theories: direct compositional approaches (e.g. Cooper Storage, Hendriks' type shifting); weaker compositional approaches that include some enrichments of the syntax (e.g. Quantifying-in); generative semantic approaches (modeling scope relations at Deep Structure); and "modern" syntactic approaches to scope (modeling scope relations at LF). We believe that it is worthwhile to consider Jacobson's classification as a basis for discussion on the merits and disadvantages of various techniques, also in light of categorial approaches (e.g. Moortgat) and more recent proposals like the ones by Barker, de Groote and Muskens. However, we will not attempt this analysis here.

4.2.6. Discussion – different emphases by different approaches to QNP scope

The approaches to QNP scope that were surveyed above are rather heterogeneous in terms of their empirical coverage and methodological standpoints. The QR theory, being a syntactic theory, is most concerned about characterizing different syntactic configurations for quantifier scope, and motivating the derivation of LF using the QR movement rule. Cooper Storage and Hendriks' type shifting mechanism are purely semantic theories which aim at avoiding syntactic representations of QNP scope. In the Quantifying-in technique and the categorial approaches surveyed, syntactic or derivational processes are still used for describing QNP scope, but the main focus is on securing a tight connection between these operations and the semantic component.

These different methodological and technical emphases complicate the comparison between the different approaches to QNP scope. In terms of empirical content the QR theory is by far the most comprehensive among these proposals. Problems like the nature of the restrictions on QNP scope have been much better studied and described in the QR literature. By contrast, the other approaches have studied more extensively the methodological and technical questions surrounding the notion of *compositionality*, and in general – the matching between syntax and semantics, as revealed by QNP scope phenomena. We cannot address here the question of compositionality in detail, and refer the reader to some of the many works on this topic: Montague (1970), Janssen (1983,1996), Hendriks (1993:ch.2), Jacobson (2002), and Barker and Jacobson (2007).

To compare specific theories in this situation is a rather difficult task. Explicit comparisons among the "Montagovian" theories have been at times carried out in the literature: see for instance Carpenter's (1997:ch.7) comparison of Moortgat's scoping type constructor and the methods of Quantifying-in and Cooper Storage. However, while these comparisons are beneficial for choosing between the non-QR theories, they only lightly touch on the empirical concerns of most QR-theorists. Conversely: in the QR literature there is considerably less emphasis on foundational questions regarding the mathematical properties of the relations between syntax and semantics.

We believe that further developments in the theory of QNP scope may ultimately depend on the general understanding of "movement phenomena" (cf. discussion at the end of section

4.2.1). Perhaps only such a comprehensive theory could settle the current discrepancies between rival approaches to standard QNP scope. Once the more general problem is resolved, current technical differences between some alternative theories of scope may appear less central they currently do.

4.3. Non-Standard Scope Mechanisms

The direct scope and inverse scope readings that we have discussed so far can all be treated using standard scope mechanisms. Despite the many technical differences between these mechanisms, they all produce *linear* relations between QNPs as exemplified in (50). In most contemporary theories, such linear quantification – or "Fregean" quantification (cf. Keenan 1992) – technically means that the QNPs in the sentence are interpreted as a sequence of standard <<e,t>,t> generalized quantifiers, which are composed using standard translation rules or compositional principles. However, as mentioned above, there are semantic phenomena that involve more complicated mismatches between syntactic structure and the scopal semantics of QNPs. This section gives a brief overview of some of these challenges and attempts that have been made to address them.

4.3.1. Branching quantification

The assumption that scopal relations between quantifiers in natural language are essentially linear draws to a large extent on the tradition of first order Predicate Calculus. In the Predicate Calculus, quantifiers can only take scope (i.e. be prefixed to formulas) in a linear order, as in the following formula.

(79) $\forall x \exists z \forall y \exists u \; \Phi(x,y,z,u)$

Following Henkin (1961), logicians have also explored other possible ordering relations between quantifiers, especially the following *branching* scheme.

(80)
$$\begin{array}{l} \forall x \exists z \\ \forall y \exists u \end{array} \!\! > \; \Phi(x,y,z,u)$$

Henkin proposed a semantics for branching schemes as in (80) using the notion of *Skolem functions*, which is defined below.

(81) A *n*-ary *Skolem function* over a domain E is a function that sends any non-empty subset A of E and a tuple of *n* elements in E to an element of A.

For instance, a 2-ary Skolem function f over E sends every non-empty set $A \subseteq E$ and any two elements x and y in E to an element $f(x,y,A)$ in A. A 0-ary Skolem function f is a function that sends any non-empty subset A of E to one of its elements $f(A)$. Such 0-ary Skolem functions, which are discussed in more detail in section 4.3.3 below, are also known as *choice functions*. In Henkin's proposal, linear quantification using Skolem functions is used for interpreting formulas with branching first-order quantifiers. For instance, the formula in (80) is interpreted as the non-first-order formula below, using linear existential quantification over Skolem functions f and g of arity 1, where the set E is the whole domain of individuals in the model.[20]

(82) $\exists f \exists g \forall x \forall y\ \Phi(x,y,f(x,E),g(y,E))$

By the semantics in (82), the branching formula in (80) is not equivalent to any formula with a linear ordering of the quantifiers.

Let us now concentrate on possible linguistic manifestations of differences between branching interpretations and standard linear schemes of first order quantifiers. The claim that natural language sentences can exhibit branching quantification that should be interpreted similarly to Henkin's scheme was first made in Hintikka (1973) and Gabbay and Moravcsik (1974). One of Hintikka's well-known examples is the following.

(83) Some book by every author is referred to in some essay by every critic.

Hintikka suggests that sentence (83) should have an analysis equivalent to the scheme of branching quantification given in (84) below. Following Schlenker (2006), we adopt in (84) a format of *restricted quantification* that is more convenient than Henkin's scheme for displaying the parallelism between the branching formula and the sentence.[21]

(84)
$$\begin{array}{l} [\forall x{:}\mathrm{AUTHOR}(x)]\ [\exists z{:}\mathrm{BOOK\text{-}BY}(z,x)] \\ [\forall y{:}\mathrm{CRITIC}(y)]\ [\exists u{:}\mathrm{ESSAY\text{-}BY}(u,y)] \end{array} > \mathrm{REFERRED\text{-}TO\text{-}IN}(z,u)$$

Using a proper adjustment of Henkin's strategy in (80)-(82), formula (84) can be interpreted as follows using Skolem functions of arity 1, similar to (82).

(85)
$$\exists f \exists g [\forall x{:}\mathrm{AUTHOR}(x)]\ [\forall y{:}\mathrm{CRITIC}(y)]$$
$$\mathrm{REFERRED\text{-}TO\text{-}IN}(f(x,\lambda z.\mathrm{BOOK\text{-}BY}(z,x)),\ g(y,\lambda u.\mathrm{ESSAY\text{-}BY}(u,y)))$$

Assuming that every author wrote at least one book and every critic wrote at least one essay, the proposition expressed by (85) can roughly be paraphrased as follows:

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[20] In the literature on Skolem functions, the set argument in definition (81) of Skolem functions is sometimes suppressed when this set argument is the whole domain of individuals E. For linguistic purposes, however, quantification is often *restricted* and the set argument in (82) is replaced by a proper subset of E, as in formula (85) below representing the meaning of the restricted branching quantification in (84).

[21] In a restricted quantifier notation, the formula $[\forall x{:}P(x)]\Phi$ is equivalent to the standard predicate calculus formula $\forall x[P(x)\rightarrow\Phi]$, whereas the formula $[\exists x{:}P(x)]\Phi$ is equivalent to $\exists x[P(x)\wedge\Phi]$.

"There is a way to map each author *x* and his books *B*(*x*) to a particular book *b*(*x*), and there is a way to map each critic *y* and his essays *E*(*y*) to a particular essay *e*(*y*) s.t. for each author *x* and critic *y*: *b*(*x*) is referred to in *e*(*y*)."

What this paraphrase entails, in the terms of Sher (1991), is that there is a "massive nucleus" N of books and essays, such that each book in N is referred to by each essay in N, and the writers of the books and essays in N cover the set of all authors and critics.

Whether such a reading that involves a "massive nucleus" exists for sentences like (83) has been debated in the literature (Fauconnier 1975, Beghelli et al. 1997, Landman 2000:ch.9.5, Schlenker 2006). One of the problems for deciding on this question is similar to the problem discussed in relation to sentence (8) in section 2.3.2 with respect to inverse scope readings. As Fauconnier pointed out, the branching scope analysis in (85) is logically stronger than some of the linear readings for (83). For instance, if a "massive nucleus" of books and essays exists as required by (85), then the following, linear scope reading of (83) is automatically satisfied as well.

(86) $$[\forall x{:}\text{AUTHOR}(x)]\ [\forall y{:}\text{CRITIC}(y)]\ [\exists z{:}\text{BOOK-BY}(z,x)]\ [\exists u{:}\text{ESSAY-BY}(u,y)]\ \text{REFERRED-TO-IN}(z,u)$$

Thus, using truth-conditional evidence alone, it is hard to determine if sentence (83) should have an interpretation as formalized in (84) and (85).

Independently of this empirical debate, other works (Barwise 1979, Westerstähl 1987, Van Benthem 1989, Sher 1991) suggested an extension of Henkin's definition of branching quantification to generalized quantifiers beyond the existential and universal quantifiers of first order logic. This makes it possible to construct branching schemes without a linear equivalent, using only two (generalized) quantifiers. For instance, Sher suggested the definition in (88) below for interpreting the branching formula (87) with the generalized quantifiers Q_1 and Q_2.

(87) $$\begin{array}{l} Q1\ x \\ Q2\ y \end{array} > \Phi(x,y)$$

(88) Formula (87) is true iff there are sets *X* and *Y* such that the following conditions hold:

1. Q_1 holds of *X* and Q_2 holds of *Y*;
2. each element of *X* is in the relation Φ to each element of *Y*;
3. *X* and *Y* are maximal sets satisfying condition 2.[22]

Under this definition, the branching analysis of sentence (89) below, with non-monotone numeral quantifiers, should be interpreted as paraphrased in (90).

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[22] That is, no element can be added to X or Y such that condition 2 remains satisfied.

(89) Exactly four critics read exactly ten books.

(90) There is a “massive nucleus” N of four critics and ten books, such that each critic in N read each book in N, and this nucleus is a *maximal* one: no critic *c* outside N read all the books in N, and no book *b* outside N was read by all the critics in N.

As in the case of Hintikka’s original example, whether sentences like (89) require an analysis along the lines of (90) was debated in the literature (Beghelli et al. 1997).

Here we will not try to settle the empirical debates that surround the linguistic status of branching analyses. Rather, we will now move on to other problems of non-linear scope, where there are fewer empirical doubts surrounding the validity of the core factual judgments challenging standard theories of linear QNP scope. However, as we will see, accounts of other non-linear scope phenomena have been proposed that bear a strong resemblance to the mechanisms that were used to characterize “branching” quantification.

4.3.2. Cumulative quantification

A non-linear scopal interaction between quantifiers, which is somewhat similar to “branching” but more solidly supported by empirical evidence, is *cumulative quantification*. The phenomenon was illustrated in Scha (1981) using the following example, which Scha paraphrased as in (92).

(91) (exactly) 600 Dutch firms use (exactly) 5000 American computers.

(92) The total number of Dutch firms that use an American computer is 600, and the total number of computers that are used by a Dutch firm is 5000.

Similarly to the “branching” analysis (90) of (89), the analysis of (91) in (92) does not give priority to the scope of any of the two QNPs over the other. Like branching analyses, also cumulative interpretations cannot be expressed using any linear combination of unary generalized quantifiers like the ones generated in section 4.1 above.[23] Empirically, the situation is clearer with such “cumulative” effects than with the “branching” effects discussed above. Even if Scha’s strategy of paraphrasing sentence (91) in (92) is not completely accurate, it is rather clear that (92) comes close to capturing a scope effect in (91) that does not involve simple linear composition of <<e,t>,t> generalized quantifiers. Intuitively, speakers agree that sentences like (91) can be true in situations that render the linear scope analysis (or analyses) of the sentence false, but where the proposition expressed by (92) is

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[23] For a proof of this fact, as well as more examples of such cases of *inherently polyadic* quantification, which is not reducible to linear composition of unary quantifiers, see Van Benthem (1989), Keenan (1992).

true.[24] Unlike the branching paraphrase of (89) in (90), however, Scha's paraphrase of (91) in (92) makes no requirement of a "massive nucleus", which is the part of the branching semantics that is most debated by researchers who deny the relevance of this semantics for natural language (Beghelli et al. 1997).

There are quite a few mechanisms that have been proposed in the literature in order to deal with cumulative effects. Scha proposed to compose the standard meanings of determiners like *exactly three* and *exactly five* into complex determiners, which can combine with the two nouns (e.g. *men* and *women* in (91)) and derive a cumulative reading. Another proposal, by Schein (1993:ch.9), is to use a mechanism that combines *event semantics* with the *linear* scope mechanism of QR and anaphoric analysis for deriving a cumulative reading of sentences like (91) or (93). Landman (2000:222-280) addresses the problem of cumulative readings for such sentences using another mechanism in event semantics, involving *maximality principles* of the sort used for implicatures of numeral expressions (Krifka 1989).

We will not embark here upon a critical evaluation of these proposals. One of the complicating factors in such an evaluation is the status of possible interactions between cumulativity and collective readings. For instance, Scha considers examples with two definites like *the soldiers hit the targets*, and contends that the prominent reading of such sentences is to be paraphrased using vague predication over collective entities, roughly: *there is a hitting relation between the group of soldiers and the group of targets*. This kind of interpretation is sometimes also referred to as *cumulative*. Whether such effects with "referential" plural NPs are to be distinguished from cases like (91) or (93) is an open question (see Sternefeld 1997, Winter 2000a, Beck and Sauerland 2001, among others). However, it should be noted that cumulative quantification in the sense of Scha is also observable with singular NPs, and not only with plurals. For instance, consider the following cases, classified as "resumptive" by May (1989):

(93) Exactly one man admires exactly one woman.
(94) No man admires no woman.

Cases like (93) and (94) also admit readings that are paraphrased using Scha's cumulative strategy in (92), which takes into account the total numbers of men admiring women and women admired by men. Thus, to say the least, the relations between cumulative quantification and plurality are not obvious.

4.3.3. Wide-scope indefinites and quantification over Skolem functions

As mentioned in sections 3.3 and 3.5, one of the long-standing challenges for theories of QNP semantics is the scopal behavior of indefinite NPs. So far, we have assumed that like

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[24] This conclusion also holds when considering the object-wide-scope analysis of sentences like (91), since the cumulative analysis is also independent of this analysis. However, as mentioned in section 3.4, this inverse scope construal is unlikely to reflect a true reading of sentences like (91) with numeral indefinites.

other noun phrases, indefinites should denote generalized quantifiers, possibly augmented with branching/cumulative schemes of interpretation as discussed above. However, it is a well-established fact in the extensive literature about the restrictions on QNP scope (see section 3.3) that some indefinites do not seem to obey the same restrictions as other QNPs. We repeat example (32), from the *locus classicus*, Fodor and Sag (1982):

(95) If a friend of mine from Texas had died in the fire, I would have inherited a fortune.

Fodor and Sag's intuition, widely agreed on in the literature, is that sentence (95) can be interpreted as true if I have a certain friend whose death would make me rich, even if I have other friends for whom this does not hold. Under the standard treatment of indefinites as quantifiers, this behavior looks quite exceptional. This is because, as was pointed out in section 3.2, the scope of most other QNPs is restricted (at least) by island constraints. In (95) the indefinite is within an adjunct island (the *if* clause, see section 3.2). As a result, standard scope mechanisms are expected to be restricted so that if the indefinite denotes an existential quantifier, this quantifier would not take scope over the conditional. The only reading expected for (95) using island restricted standard scope mechanisms is the following one (where the conditional is treated as material implication).

(96) $[\exists x\ [\text{FRIEND}(x) \wedge \text{DIE}(x)]] \rightarrow \text{INHERIT\_FORTUNE}(I)$

The proposition in (96) entails that in *any* event in which a friend of mine dies I inherit a fortune. The interpretation of (95) that Fodor and Sag point out is however more similar to the following analysis, where the existential quantifier takes sentential scope, over the material implication.

(97) $\exists x\ [\text{FRIEND}(x) \wedge [\text{DIE}(x) \rightarrow \text{INHERIT\_FORTUNE}(\mathbf{I})]]$

The contrast between (95) and its variation (98) with a universal quantifier is instructive. For (98), the analysis in (99) is the *only* plausible reading available for the sentence.

(98) If every friend of mine from Texas had died in the fire, I would have inherited a fortune.
(99) $[\forall x\ [\text{FRIEND}(x) \rightarrow \text{DIE}(x)]] \rightarrow \text{INHERIT\_FORTUNE}(I)$

Indeed, sentence (98) unequivocally claims that I inherit a fortune if *all* my friends die, which is the statement that (99) models.

The following example includes more of the indefinite NPs that have been reported to show the same effect illustrated by (95) above.

(100) If *a certain friend/some friend/some friends/three friends* of mine from Texas had died in the fire, I would have inherited a fortune.

Work on the scope of indefinites has shown a wide range of syntactic contexts where indefinites show a freer scopal behavior than other QNPs. Specifically, the singular and plural indefinite NPs in (95) and (100) seem able to violate all island constraints, not only adjunct islands, and including the CNPC island present in our fragment: see section 3.3, example (30). Since the standard scope mechanisms (such as QR, Storage, Quantifying in, Type Shifting) must be made subject to these island constraints (or we no longer account for the usual island effects with other QNPs illustrated in (98)), the exceptional scope of indefinites must be due to some non-standard scope mechanism, or due to some other peculiarity of their interpretation.

There have been various attempts to address the challenge that the behavior of indefinites raises for the theory of QNP scope. We can roughly identify two extremes in the approaches that have proposed. One approach has been to derive the "wide scope" behavior of indefinites from their traditional treatment as existential quantifiers. Another approach analyses the "wide scope" impression with indefinites as an effect resulting from their exceptional descriptive (or "referential") properties. According to the first approach, sentence (95) should have an analysis equivalent (or logically similar) to the one given in (97). According to the second, sentence (95) has no such reading, and the "wide scope" effect is a result of analyzing the indefinite *a friend of mine* in (95) as close in meaning to a definite description or a demonstrative (i.e. *the/this friend of mine*).

We will not review or analyze in detail these two approaches and the various ways in which they are combined in actual proposals. Instead, we refer the reader to some of the many works on this problem (Egli & Von Heusinger 1995, Schwarzschild 2002, Farkas 1997, Ruys 1992, Abusch 1994 etc.). In the context of the current discussion of non-standard scope mechanisms, however, it is worthwhile to mention one logical semantic mechanism that has been proposed for treating "wide-scope" indefinites: the mechanism of *choice functions*, or more generally, Skolem functions. Skolem functions as defined in (81) above were used in Henkin's treatment of branching schemes with first order quantifiers. Assuming that f is a variable over choice functions (0-ary skolem functions), the following formula can be used to model the "wide-scope" effect in (95).

(101) $\exists f\,[\mathrm{die}(f(\mathrm{friend})) \rightarrow \mathrm{inherit\_fortune}(\mathrm{I})]$

The proposition in (101) claims that there is a value for a choice function f that satisfies the following formula:

$$\textsc{die}(f(\textsc{friend})) \rightarrow \textsc{inherit\_fortune}(\mathrm{I})$$

Assuming that the set of my friends is non-empty, let us denote the element that *f* assigns this set by *r*. By definition of *f* as a choice function, *r* is a friend of mine. Hence, the following proposition now holds:

$$\text{DIE}(r) \rightarrow \text{INHERIT\_FORTUNE}(\text{I})$$

This means that using the choice function representation in (101) is logically close to the predicate calculus representation in (97).[25]

Semantic mechanisms using choice functions for treating “scopal” phenomena were used in Reinhart (1992,1997), Kratzer (1998), Winter (1997) and many more recent works, with notable variations in the details of their usage. Importantly, Kratzer proposed to use choice functions as a “referential” (or *deictic*) semantic mechanism, without existential quantifiers like the one in (101). The reason that many works have found representations as in (101) attractive for treating the “wide-scope” of indefinites is that, unlike standard existential quantification (e.g. (97)), the representation using choice functions does not require that the restrictive predicate of the indefinite is “pulled out” of its surface position. In (101), the predicate FRIEND that is denoted by the indefinite’s restriction *friend of mine* remains within the scope of the conditional, in accordance with the surface constituent structure of the sentence, and is not “pulled out” of the adjunct island. The felicitous consequence is that no scope mechanism is required that violates island conditions.

One advantage of not having to pull out the restriction of the indefinite out of the island was pointed out in Winter (1997), based on observations in Ruys (1992) discussed in section 3.5. These works show that despite the fact that some plural indefinites show wide scope effects beyond islands, the scope of their *distributivity* is restricted to remain within the island. Relevant examples were given in sections 3.3 and 3.5, and two more examples are the following ones.

(102) If three friends of mine from Texas had died in the fire, I would have inherited a fortune.

(103) If three workers in our staff have a baby soon we will have to face some hard organizational problems.

In both (102) and (103), the sentence can be interpreted as a statement on three people (relatives or works), and possible scenarios that would occur under certain events happening to these people (death, having a baby). However, in both cases the events would have to happen to *all* three people in order for the conditional to take effect. Thus, for instance, sentence (102) can be interpreted as in (104) below, but not as in (105).

(104) $\exists A\ [\ |A|=3 \wedge [\forall x \in A\ \text{FRIEND}(x)] \wedge [[\forall y \in A\ \text{DIE}(y)] \rightarrow \text{INHERIT\_FORTUNE}(\text{I})]]$

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[25] The difference between (101) and (97) is in the case where the argument of the choice function *f*, i.e. the predicate FRIEND, is empty (which may occur if I happen to have no friends). The implications of this point for the usages of choice functions in formal semantics were extensively discussed in Winter (1997,2001). See Ruys (2006) for a somewhat different view.

(105) $\exists A\ [\ |A|=3 \wedge \forall x \in A\ [\text{FRIEND}(x) \wedge [\text{DIE}(x) \rightarrow \text{INHERIT\_FORTUNE}(I)]]$

In (104) distribution over elements in the set *A* is independent for each of the predicates FRIEND and DIE. By contrast, in (105) distribution takes scope over the conditional. Winter further discusses cases like (103) of mixed scope, where distribution over different workers (and different babies!) is pragmatically prominent due to world knowledge. Such cases strengthen the conclusion that distribution cannot violate syntactic islands, and must, if existent, remain constrained within the island. This fact cannot be easily captured if restrictions on indefinites are free to violate islands, but it directly follows from the choice function mechanism.

Other works on the scope of indefinites (Kratzer 1998, Chierchia 2001, Winter 2004, Schlenker 2006) have shown various reasons to adopt the more general Skolem function mechanism for treating not only branching quantifiers as in (83) above, but also for some cases of more ordinary scope taking indefinites. Schlenker (2006) points out that this decision has interesting implications for the debate surrounding branching quantification. Reconsider sentence (83), repeated below.

(106) Some book by every author is referred to in some essay by every critic.

With previous works, Schlenker assumes a Skolem function mechanism for interpreting the *scopal* behavior of indefinites in sentences like (96) and (100). Schlenker then argues that using the same mechanism, we expect the indefinites *some book* or *some essay* in (106) to lead to a branching reading of this sentences as formalized in (82) following Henkin's use of unary Skolem functions. If this is the case, the origins of branching quantification in such cases may be explained on independent considerations about the scope of indefinites. Further, the same Skolem mechanism would be unlikely to derive any "branching" reading for sentence (89) and similar ones, with indefinites like *exactly four critics* or *exactly ten books*. The reason is that this kind of modified numeral indefinites was argued (Liu 1990) not to show any exceptional "wide scope" behavior. Therefore, it was concluded (e.g. in Winter 2001:ch.3-4) that modified numeral indefinites like these ones should not be treated using Skolem functions. Non-linear quantificational effects in cases like (89) exist, but independently of whether we classify them as "cumulative" or "branching", they are not likely to be captured by a linguistic mechanism that employs Skolem functions for interpreting indefinites.

5. Two empirical extensions

Our discussion so far of scope inversion phenomena and their theoretical implications has focused exclusively on one type of empirical data: examples in which a scope bearing element takes wider scope than would be expected given its standard semantics and its position in the syntactic structure. The present section discusses two additional types of data that provide evidence that some scope shifting rule, of which we discussed various implementations in section 4.2, is operative in natural languages. Section 5.1 deals with examples in which a scope bearing element takes narrower scope than expected given its syntactic position ("scope reconstruction"). Section 5.2 presents data in which ellipsis resolution data, rather than intuitions arising from relative scope, provide evidence for the operation of a scope shifting rule. Because most literature on these topics is in the QR/LF tradition surveyed in section 4.2.1, our discussion will also mostly take this perspective. It is not our intention, however, to suggest that these phenomena necessarily constitute an argument in favor of the QR approach: other plausible analyses have been proposed, and we will briefly mention a few of them.

5.1. Quantifier scope reconstruction – syntactic and semantic accounts

Let us repeat some examples of quantifier scope ambiguity from section 3.1.

(107) all that glitters is not gold
(108) an American runner is likely to win the race
(109) someone always wins
(110) someone probably spiked the punch

The scope problems in our fragment that have been treated so far all involve a QNP which is optionally assigned a wider scope than would be expected given its position in the overt syntactic structure. The examples repeated above, on the other hand, allow the QNP to take *narrower* scope than its surface position would lead one to expect. Thus, (108) allows a reading which can be paraphrased by 'it is likely that there exists some American runner who wins the race'. Under this reading, presumably, the noun phrase *an American runner* is interpreted with narrow scope relative to *likely*: a *de dicto* reading. Similarly, in the other examples the subject can scope below negation, the adverb of quantification, and the modal adverb, respectively.

May (1977) discussed examples like (108) and proposed that his QR rule (see section 4.2.1 above) can sometimes move a QNP downward. This instance of applying QR is referred to as 'Quantifier Lowering' (QL)[26]. For (108) QL results in the following derivation.

(111) a DS: is $[_{AP}$ likely $[_S$ [an American runner]$_i$ to win the race]]
b SS: [an American runner]$_i$ is $[_{AP}$ likely $[_S$ t_i to win the race]]
c LF: t is $[_{AP}$ likely $[_S$ [an American runner]$_i$ $[_S$ t_i to win the race]]]
d $\text{LIKELY}(^\wedge\exists x[\text{AMERICAN}(x) \wedge \text{RUNNER}(x) \wedge \text{WIN\_THE\_RACE}(x)])$

(111a) is the D-Structure, where *an American runner* occupies its base position as logical subject of *win the race*. (111b) is the S-Structure, derived via NP-movement of *an American*

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[26] The term Quantifier *Raising* is therefore somewhat of a misnomer in theories that assume QL.

runner to the grammatical subject position of *be likely*. QL then results in the LF given in (111c), where the lowered NP still binds its original trace, with scope relations giving rise to the *de dicto* reading formalized in (111d).[27] In each of the examples given above, a similar derivation can be proposed: the QNP moves across the negation or adverb at S-Structure, a movement that can optionally be 'undone' at LF via QL.

Motivation for a syntactic movement analysis is weaker in these examples than in examples that motivated QR, for which sensitivity to syntactic island effects can be demonstrated. Indeed, the QL operation is syntactically suspect, as it is believed that movement operations in general do not move material downward. For instance, the derivation in (112) is ill-formed:

(112) a DS you asked who$_i$ [$_{CP}$ [John loved Mary]]
b SS * you asked t$_i$ [$_{CP}$ who$_i$ [John loved Mary]]

There is assumed to be no operation that derives the illicit SS in (112b) by "lowering" *who* from its position in the main clause, in the DS representation (112a), to a position in the embedded clause, as in the SS representation (112b). This is not decisive evidence against the QL hypothesis, however. The reason (112) is ruled out might be that the wh-operator at S-Structure does not bind a trace (violating a ban on vacuous quantification) and its trace is unbound (violating e.g. Chomsky's (1986b:85) Strong Binding condition). The putative examples of QL in (1512)-(1517) are different. The QL operation in these examples is assumed to be preceded by an overt Raising operation. For instance, in (111), the SS (111b) is already assumed to be derived from the DS in (111a) by a movement operation. As a result, the lowered QNP in the LF representation (111c) still binds its original trace after QL; hence, (111c) does not violate a ban on vacuous quantification. Indeed, QL is not allowed if not preceded by a Raising operation, even if the ban on vacuous quantification is respected:

(113) [an American runner]$_i$ is eager [PRO$_i$ to win the race]
a t$_i$ is eager [[an American runner]$_i$ [PRO$_i$ to win the race]]

In (113), the S-Structure of which is not derived by movement of *an american runner* out of the embedded clause, a *de dicto* reading for the noun phrase *an American runner* is not available, presumably because QL would result in the LF (113a) in which the trace of *an American runner* in argument position is unbound (see May 1977, 1985).

Because QL is assumed to (partly) undo a preceding movement, the data are often considered to reveal a "reconstruction" effect: the effect found when an element moved out of its DS position functions at LF as though it occupies its pre-movement position (these effects are also found, e.g., with Binding Theoretic phenomena; see Sportiche 2006 for a recent

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[27] The '^' operator from Montague (1973) is meant to guarantee that the argument of the operator LIKELY is the *intension,* rather than the extension, of the complement proposition (equivalent to the clause "an American runner will win the race"). For details see Gamut (1991), or, in a more perspicacious format, Gallin (1975).

overview). This has led to the hypothesis that, instead of a QL operation, the trace of the raised QNP might be playing a role in determining its scope.[28] One possible implementation makes use of the supposition in Chomsky's (1995) Minimalist Program that a movement trace is in fact a copy of the moved element. If so, the surface syntactic form (111b) is actually (114):

(114) [an american runner] is likely [$_{IP}$ [an american runner] to win the race]

The phonological component is assumed to delete the downstairs copy of *an American runner*. By contrast, the semantic component is assumed to have an interpretative strategy that ignores the upstairs copy. This results in the *de dicto* reading.

A semantic alternative to the syntactic approaches to scope reconstruction phenomena outlined above appears to be readily available. Consider, for instance, the ambiguous example (115), which allows the readings paraphrased in (115a) and (115b):

(115) [How many people]$_i$ should John talk to t_i
a for how many people x, John should talk to x
b for which number n, John should talk to n-many people

Roughly speaking, reading (115b) involves "reconstruction" of *n-many people* into the scope of *should*. The solution proposed by e.g. Cresti (1995) (see also references cited there) involves the assumption that the trace of *how many people* can be translated as a variable of different types. *How many people* (or rather, *n-many people*, after *how* is separated out) is composed with its sister after abstraction over this variable. If it is type *e*, the result is (115a). If it is type <s,<<s,<e,t>>,t>> (the type of the intension of a Montagovian generalized quantifier) then the translation of *n-many people* is converted into the scope of *should*, resulting in (115b).

A similar strategy can be employed to deal with the examples (107)-(110). This is illustrated in (116) below for (108).

(116) [$_S$ [an american runner]$_i$ [is likely [$_S$ t_i to win the race]]
a $\lambda P_{<s,<e,t>>}.\exists y[\ \mathrm{AMERICAN}(y) \wedge \mathrm{RUNNER}(y) \wedge {}^{\vee}P(y)]$
b $\lambda x_e.\mathrm{LIKELY}({}^{\wedge}\mathrm{WIN\_THE\_RACE}(x))$
c $\lambda X_{<s,<<s,<e,t>>,t>>}.\mathrm{LIKELY}({}^{\wedge}([{}^{\vee}X]({}^{\wedge}\mathrm{WIN\_THE\_RACE})))$

Assume, with Cresti, that the composition rule can freely apply to the intension or extension of an expression (depending on type requirements); that the trace of NP movement can be translated as a variable of type *e* or <s,<<s,<e,t>>,t>>; and that in the translation of a

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[28] As e.g. in Aoun & Li 1989. In some languages, quantifier scope ambiguities between subject and object appear to arise *only* in situations that are analyzed as reconstruction.

structure [$_{S}$ NP$_{i}$ VP] the relevant x_i variable in the translation of VP is abstracted over. Then in (116), the translation of the subject (116a) can be combined either with (116b) or (116c), giving the two readings discussed above.

We will not discuss the relative merits of a syntactic or semantic approach to scope reconstruction here. See Cresti (1995) for arguments that her semantic approach can deal with the island effects observed with scope reconstruction after wh-movement. See Fox (1995, 1999), on the other hand, for arguments that scope reconstruction is subject to Binding Theory and economy constraints on movement.

5.2. Antecedent Contained Deletion (ACD)

The phenomenon of Antecedent Contained Deletion (ACD) has been used to argue for the existence of a scope shifting rule.[29] Consider (117) and (118) (from May 1985):

(117) Dulles [$_{VP1}$ suspected Philby], and Angleton did [$_{VP2}$ e] too
(118) Dulles [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]]

The VP in the second conjunct of (117) has been *elided*, where such *ellipsis* is an operation that is allowed under identity with the VP of the first conjunct (the *antecedent* of the ellipsis). Although the exact nature of the relevant identity constraint and the nature of the ellipsis operation are subject to debate, cases as in (118) create a problem for almost every approach.[30] As noted by May (1985) (see also Bouton 1970, Sag 1976), the elided VP2 is contained in its antecedent VP1.[31] If ellipsis resolution involves copying the antecedent into the empty VP, the copying procedure never terminates, as illustrated in (119) (the infinite regress problem). If ellipsis involves deletion of an underlying full form, (118) would require an infinite underlying structure.

(119) 1 Dulles [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]]
2 Dulles [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]]]]
3 Dulles [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP1}$ suspected

---

[29] We would like to stress that this section only scratches the surface of the large and expanding body of literature on ellipsis and ACD; our purpose here is merely to point out the connection between scope and ellipsis resolution phenomena. We repeat that, for convenience, our discussion is phrased mostly from the perspective of a QR theory of quantifier scope, and an LF VP-copying theory of VP-ellipsis, but the problems raised by ACD exist independently of this approach and reoccur in various forms in other approaches.

[30] See e.g. Williams (1977), Sag (1976), Vanden Wyngaerd & Zwart (1991), Lasnik (1993), Hornstein (1994), Rooth (1992), Fiengo & May (1994), Heim (1997), Merchant (2001), Wilder (2003). See Jacobson (1992,1996,1998), Jäger (2001,2005) for views of ACD and VP ellipsis in a categorial approach.

[31] For the simple case (118), the problem might be circumvented by assuming it is only V, not VP, that has been elided; then the antecedent does not contain the ellipsis site. But this simple expedient does not resolve the ACD in more complicated cases such as (122) or (123a); a scope shifting rule does. For a sophisticated version of a V-ellipsis approach, see Cormack (1985), Jacobson (1992).

[$_{NP}$ everyone who Angleton did [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]]]]]]

May (1985) proposed that QR moves the NP containing VP2 out of VP1 (step 2); the resulting LF allows copying without regress (step 3):

(120) 1 Dulles [$_{VP1}$ suspected [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]]
2 [$_{NP}$ everyone who Angleton did [$_{VP2}$ e]]$_i$ [$_S$ Dulles [$_{VP1}$ suspected t$_i$]]
3 [$_{NP}$ everyone who Angleton did [$_{VP1}$ suspected t$_i$]]$_i$ [$_S$ Dulles [$_{VP1}$ suspected t$_i$]]

This approach predicts, correctly, that the QNP containing the elided VP must scope out of the antecedent VP (Sag 1976; examples from Bruening 2001):

(121) a Ozzy wanted every book that Kate wrote
b Ozzy wanted every book that Kate did [$_{VP}$ e]

While (121a) allows a *de dicto* reading (see section 3.1) for the object, (121b) does not.

The hypothesis that the operation that resolves ACD is also the one responsible for inverse scope predicts that ACD will be allowed just where scope inversion is allowed. Thus, for instance, ACD is allowed in inverse linking structures (Kennedy 1997):

(122) John [$_{VP1}$ wrote [$_{NP}$ a report on [$_{NP}$ every student Peter did [$_{VP2}$ e]]]]

ACD resolution is blocked by a CNPC island (section 3.2), but this may be due to a corresponding CNPC island violation inside the ellipsis site. Better evidence that scope islands affect ACD comes from the following paradigms (from Larson & May 1990; see also Wilder 2003):

(123) a John [$_{VP1}$ believed [$_S$ [$_{NP}$ everyone you did [$_{VP2}$ e]] to be a genius]]
b John [$_{VP1}$ believed [$_S$ [$_{NP}$ everyone you *believed to be a genius*] to be a genius]]
c * John [$_{VP1}$ believed [$_{CP}$ (that) [$_{NP}$ everyone you did [$_{VP2}$ e]] was a genius]]

When the elided VP is contained in the subject of a non-tensed subclause, as in (123a), the matrix VP can antecede the ellipsis: (123a) allows the paraphrase (123b). But ACD cannot be resolved in this manner when the ellipsis site is contained in the subject of a tensed subclause; hence the ill-formedness of (123c). This corresponds to the scope options for quantified NPs in these positions: the subject of a non-tensed clause easily scopes into the matrix clause, even higher than the matrix subject; but the subject of a tensed subclause does not, as illustrated in (124) (although intuitions differ).

(124) a someone believes [$_S$ everyone to be a genius]
b someone believes [$_{CP}$ (that) everyone is a genius]

Observe, incidentally, that (122) and (123a) are examples where the antecedent for the ellipsis contains more material than a single V, in a way that renders more secure the diagnosis that, barring a scope shifting operation, the ellipsis is antecedent-contained (cf. footnote 31).

It is further predicted that NPs that are not subject to QR (or other covert movement operations) do not allow ACD; this is confirmed by (125), from Lasnik (1993) (the indicated NP is not quantificational, and receives Case in situ):

(125) * Mary stood near [$_{NP}$ Susan, who Emily did [$_{VP}$ e] as well]

Finally, we expect that the correlation between scope and ACD resolution breaks down with NPs that are subject to a non-standard scope mechanism which does not “displace” the NP. This is confirmed by (126) (from Kennedy 1997):

(126) John [$_{VP1}$ believed that Bill [$_{VP2}$ had seen a certain film that I did [$_{VP3}$ e]]]

(126) has a *de re* reading with *a certain film that I did* taking wide scope relative to *believed*, but even on this matrix scope reading, only VP2 may antecede the empty VP. The example does not have a reading ‘there is a certain film I believed that Bill had seen, that John believed that Bill had seen’; the absence of this reading follows if ACD resolution indeed requires LF movement of the NP, but exceptional wide scope for indefinite NPs is due to a different mechanism (see section 4.3.3).

6. Conclusions

In this paper we have tried to give a broad overview of QNP scope phenomena and some prominent approaches to their treatment. By way of conclusion, we would like to highlight three topics that have reoccurred in our review at various places and seem to us especially central.

Syntax vs. Semantics

We believe that there is little reason to prejudge scope phenomena as belonging to either syntax or semantics. Even though the primary data of inverse and non-linear scope readings are always semantic, the mechanisms that account for them may reasonably involve syntactic considerations and principles. The real challenge, we think, is to provide a theory of scope effects that makes the optimal division of labor between syntax and semantics, in terms of empirical coverage, conceptual clarity and technical soundness and elegance. As our overview above has clarified, this is by no means an easy challenge: more comprehensive solutions to this challenge are still to be found.

Scope effects as "movement"?

One of the major theoretical decisions that any theory of scope has to make is whether to treat inverse scope effects as a "movement" phenomenon. Are the mechanisms that are responsible for inverse scope relations also responsible for phenomena that involve "overt" extraction? A positive answer to this question, as most clearly given in QR theory, does not yet determine completely the description of a phenomenon like QNP scope in the grammar. However, any answer to this question has direct implications for the overall organization of the grammar. Specifically, a positive answer to this question leads to far-reaching challenges that emerge from the many discrepancies between scope effects and "movement" effects, as surveyed in section 4.2.1. Conversely, a decision to clearly dissociate scope effects from "movement" phenomena may require substantial justification for any proposed account of the former.

"QNP Scope" as an epiphenomenon

Pre-theoretically, and in the face of such a simple set of examples as we initially employed in section 2.2 in order to illustrate the incompleteness of the direct scope strategy in our toy grammar, one might have expected that the available scope options for quantified NPs might be described as a simple permutation of quantifiers, as illustrated in (50), and might be explained by postulating one syntactic or semantic rule (such as QR, or Storage), or one set of rules of a given type, which would be enough to derive the available options. Instead, as has become clear from several decades of research on this topic, and as we have attempted to illustrate in this article, the scope of quantified NPs is not a unified phenomenon, and it is unlikely that it is mediated by one component of the grammar, a dedicated "scope module". Various NP types "take scope" in different ways: sometimes their scope is mediated through a "movement-like" rule, sometimes through one of the non-standard mechanisms described in section 4.3.3. Unforeseen factors have often been found to influence the available scope options. This makes the study of scope phenomena all the more challenging, as it requires a non-trivial balance between descriptive accuracy and theoretical frugality and elegance.

The many questions surrounding the notion of QNP scope, and scope effects in general, leave much room for further research. We do believe, however, that more than forty years of extensive linguistic-logical research of scope phenomena also leave room for hope. The important theoretical and empirical advances that have been made and the unique collaboration that they have prompted between logicians and formal linguists promise to keep the study of scope phenomena an active area of research for years to come.

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