Cardinality Noun Phrases, *Wh*-Questions, and Scope Ambiguity*

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This paper deals with the scope properties of cardinality *wh*-phrases and proposes a decomposition analysis that treats these phrases as involving both a cardinality *wh*-operator and an existential group quantifier. This approach is motivated by examples involving cardinality noun phrases in which the cardinality quantifier and the existential group quantifier take separate scope. The decomposition analysis provides a precise and natural account of scope ambiguity in *How many* questions, which has not been explained in literature. We also examine constituent questions with quantificational noun phrases, and show that they may take scope over each other. Considering a wide range of examples, we argue against the view that the relative scope order between an interrogative operator and a universal quantifier exhibits subject-object asymmetry and is subject to a syntactic constraint.

1. Introduction

In constituent questions, *wh*-question interpretations are obtained by scoping of interrogative operators associated with *wh*-phrases. When a *wh*-interrogative involves a quantificational noun phrase (QP, hereafter), it has been widely assumed that the scope of the involved *wh*-phrase may interact with that of the QP, yielding more than one possible relative scope orders, just like the sentences with multiple QPs. In this paper, we will show another case of a *wh*-question that involves a quantifier. We will show that it is possible that a single phrase contains both a quantifier and a *wh*-operator, and argue that cardinality *wh*-phrases like *how many cars* should be analyzed

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as involving both an interrogative operator and an existential quantifier. We will also show that this is attributed to a more general case of cardinality NPs like *five books* which can be represented as containing an existential group quantifier.

In order to see what kind of problem we are dealing with in this paper, consider the following:

(1) How many books does Mary think Bill read?

Cardinality *wh*-phrases such as *how many books* exhibit an interesting scope ambiguity that does not occur with other *wh*-phrases. As in (2), when an ordinary *wh*-phrase such as *which car* is fronted from a semantically opaque context, the resulting *wh*-question does not exhibit a scope ambiguity as long as there are no other quantificational elements or operators. This contrasts with the example with an ordinary QP in (3).

(2) a. Which car does Mary think Bill likes?
b. 'For what car x does Mary think Bill likes x?'

(3) a. Mary thinks Bill likes a sports car.
b. There exists a sports car x that Mary thinks Bill likes. (*de re*)
c. Mary thinks there exists a sports car x that Bill likes. (*de dicto*)

On the other hand, the same type of example with a cardinality *wh*-phrase exhibits *de re/de dicto* ambiguity as in (4):

(4) a. How many books does Mary think Bill read?
b. 'For what number n do there exist n books that Mary thinks Bill read?'
c. 'For what number n does Mary think there exist n books that Bill read?'

In the *de re* reading in (4b), there is a specific group of books whose cardinality is n such that Mary thinks that Bill read the books in that group, and the speaker wonders what the number n is. On the other hand, in the *de dicto* reading in (4c), Mary thinks that Bill read n books although she doesn't necessarily know what particular (group of) books Bill read, and the speaker asks about the number n.

The existence of the *de dicto* reading in examples like (4) poses a serious problem for existing theories of operator scope wherein scope of a

wh-phrase or QP is determined by syntactic movement of such phrase in some level of representation. Since *how many* phrase is a syntactic constituent that moves as a unit, it is surprising that operators involved in a single phrase exhibit separate scope.

In this paper, we argue that cardinality *wh*-phrases and ordinary cardinality NPs contains two operators, including an existential group quantifier. After discussing how to represent the ambiguity in (4a) in logical forms, we will show that this kind of ambiguity can be neatly explained by the theory of scope in Yoo (1997) and Pollard & Yoo (1998), within the framework of Head-Driven Phrase Structure Grammar (HPSG).

Furthermore, scope interaction between a *wh*-phrase and a QP is re-investigated in this paper. Considering a wide range of examples, we will show that the commonly assumed subject-object asymmetry in *wh*-/quantifier scope ambiguity is not a real asymmetry that should be accounted for on syntactic grounds.

2. Scope Ambiguity of Amount Phrases

In section 1, we introduced the example (4), wherein a *how many* phrase exhibits *de re/de dicto* ambiguity. The same ambiguity occurs in the corresponding Korean example.

(5) a. Mary-nun [Bill-i myech kwen-uy chayk-ul
Mary-TOP Bill-NOM how many volume-GEN book-ACC
ilk-ess-ta-ko sayngkakha-ni?
read-PST-DC-COMP think-Q
'How many books does Mary think Bill read?'

b. 'For what number n do there exist n books that Mary thinks Bill read?'

c. 'For what number n does Mary think there exist n books that Bill read?'

In Fiengo *et al.* (1988: 66~67), the same kind of scope property of *how many* phrases is pointed out in the following examples:

(6) How many students has every professor taught?

(7) How many students does every professor believe he has taught?

Fiengo *et al.* note that in these examples, "the NP *how many students* actually contains two operators: a [+wh] operator ranging over numbers (e.g. 1, ..., n), and a [-wh] existential quantifier ranging over individual students." They argue that the two operators must be distinguished, since *every professor* may have scope between the [+wh] operator and the [-wh] existential quantifier, i.e. scope narrower than the [+wh] operator and wider than the existential quantifier. Both (6) and (7) can be answered with a number, say 76. With this answer, the natural reading in (6) is that every professor has each taught 76 students, but not the same 76 students for each professor, and the one in (7) is the *de dicto* reading that every professor believes that there are 76 students that he has taught.[1] Based on this observation, they suggest the following (8) for the LF representation of the relevant reading in (7):

(8) (For which x: x a number) (For every y: y a professor) (y believes that (for x-many z: z a student)(y has taught z))

They observe that in this case, the quantifier ranging over individual students takes narrower scope than the syntactic position that it occurs, and argue that in a theory wherein scope is defined in terms of a c-commanding domain, this provides evidence for a quantifier lowering operation such as May's (1977).

Actually, examples (6) and (7) have other readings wherein *every professor* takes scope over the *wh*-phrase *how many students*. This kind of reading will be discussed in section 4. The reading that we are interested in here is perhaps more natural in (9) and the corresponding Korean example (10).

(9) How many correct answers must everyone get in order to pass?

(10) Hapkyekha-lyemyen (nwukwutunci) (ceketo) myech
pass -in-order-to everyone at-least how-many
kay-uy tap-ul macchwu-eya ha-ni?
item-GEN answer-ACC get should-do-Q
'How many correct answers should everyone get (at least) in order to pass?'

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[1] A less natural reading will be, of course, that there is a specific group of 76 students that every professor (believes that he) has taught.

In (9) and (10), the most natural reading is that there is a certain (minimum) number, say 19, such that every examinee must get that number of correct answers. Under normal circumstances, each examinee will have correct answers for a different subgroup of questions in the exam. Thus the universal quantifier takes scope between the *wh*-operator and the existential quantifier associated with *correct answers*.[2]

Although Fiengo *et al.*'s observation that *how many* phrases involve two operators gives us a correct characterization of the scope properties in these examples, it is questionable whether a detailed analysis can be worked out based on their suggestion described above. Presumably, one may consider the lowering movement of *students* at LF, as in (11); however, it is not clear how the LF in (8) can be acquired by quantifier lowering.[3]

(11) [[How many $e_1]_2$ [every professor$_3$ [e_3 believes [that [students$_1$ [he$_3$ has taught e_2]]]]]]

Crucially, in a structure like (11), the empty category e_1 is problematic, since it violates the ECP (and the PCC in May 1985).[4 5]

Before discussing scope assignment mechanisms, let us first consider the appropriate logical representations of these examples. Under the more or less standard assumption that *how many* phrases are operators of roughly the form '[how many x book(x)]', the *de re* readings in (4b) and (5b) can be roughly represented as '[how many x book'(x)](think'(m, read'(b,x)))'. However, the *de dicto* readings in (c) examples are impossible to be represented under the assumption. In order to fix this problem, a different

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[2] It should be noted that this reading of (10) constitute a counterexample for the claim that a *wh*-phrase cannot take scope over a c-commanding QP (Hoji 1985, Kim 1991, Lasnik & Saito 1992, and Aoun & Li 1993), since only the *wh*-operator part of the *wh*-phrase outscopes the QP. This shows that operator scope interaction cannot be constrained by simply stating a condition between two (or more) phrases in the surface structure.

[3] Actually, the LF form in (8) itself is questionable, since it introduces a quantifier whose determiner contains a variable.

[4] In May (1985), *students* may first adjoin to the *how many* phrase in the COMP and then lowered, but this also violates the PCC.

[5] In that the empty category left behind by the lowering is in an $\bar{A}$-position, this case is different from lowering in raising verb constructions discussed in May (1977, 1985). May (1985) argues that the empty category created by lowering in a raising construction is an expletive.

assumption needs to be made about representing cardinality quantifiers in general.

We also observe that decomposition of quantifiers associated with *how many* phrases (viz. into a *wh*-operator and an existential quantifier) is necessary in order to explain the ambiguity in (4). In particular, Pollard (1989) shows that such a decomposition analysis is also motivated by scope properties of comparative cardinality NPs (e.g. *more than five students*), and discusses how decomposed quantifiers can be logically represented.

Pollard (1989) begins with the assumption that collective and mass entities and quantifiers are contained in the model as individuals representing quantities.[6] He observes that under this assumption, the usual generalized cardinality quantifiers can be realized as existential quantifiers, as in (12) and (13):[7]

(12) a. Five men sneezed.
b. $[(\exists x\ (men(x)\ \&\ meas(x) \geq 5))\ sneeze(x)]$

(13) a. Five men met.
b. $[(\exists x\ (men(x)\ \&\ meas(x) \geq 5))\ meet(x)]$

In (12b) and (13b), 'meas' is a unary function symbol that is used to represent the measures of quantities. Thus for example, if x is a group of five men, then *meas(x)* denotes the integer 5. Unlike in (13a), *five men* in (12a) receives a distributive interpretation, and we can assume that this is a consequence of the meaning of a distributive predicate itself. (See Roberts (1990: 94) for discussions in favor of this view.)

Pollard further proposes that a more complex example like (14a), which can be rendered as (14b) using an existential group quantifier, be represented as in (14c) using two existential quantifiers that range over an integer scalar and a group, respectively:

(14) a. More than five consultants work.
b. $[(\exists x\ (consultants(x)\ \&\ meas(x) > 5))\ work(x)]$
c. $[(\exists n\ (n > 5))\ [(\exists y\ (consultants(y)\ \&\ meas(y) \geq n))\ work(y)]]$

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[6] In that collective and mass entities are treated as individuals, not sets of individuals, this assumption resembles Link (1983). In addition to these entities, Pollard assumes that "degrees" (e.g. three feet, two liters) are also contained in the model.

[7] See also Kadmon (1985) for the proposal that noun phrases with numeral quantifiers (e.g. *four chairs, three fish*) can be treated as a singular indefinites.

One motivation for such a double quantifier analysis can be found in the following 'comparative subdeletion' example:

(15) John believes that more consultants work than (consultants) actually do work.

Example (15) has, among others, a reading, 'there is a specific number n which exceeds the number of actual working consultants, and John believes that n consultants work', which is represented as follows:

(16) $[(\exists n\ [(\forall m\ [(\exists x\ (\text{consultants}(x)\ \&\ \text{meas}(x) \geq m))\ \text{work}(x)])\ n > m])\ \text{believe}(j,\ [(\exists y\ (\text{consultants}(y)\ \&\ \text{meas}(y) \geq n))\ \text{work}(y)])]$

This kind of decomposition is also motivated by examples like the following (Carl Pollard (p.c.)):

(17) a. Mary wants to read a prime number of books.
b. 'There is a group of books x of prime cardinality such that Mary wants to read x.'
c. 'Mary would like it to be the case that there is a group of books x of prime cardinality such that she reads x.'
d. 'There is a prime number n such that Mary would like it to be the case that there is a group of books x of cardinality n such that she reads x.'

The reading that we are interested in is the one in (17d), and in order to get this reading, the cardinality quantifier part must be separated from the existential (group) quantifier. This can be represented as (18), by positing two existential quantifiers.[8]

(18) $[(\exists n\ (\text{prime}'(n)))\ \text{want}'(m)([(\exists x\ (\text{books}'(x)\ \&\ |x| = n))\ \text{read}'(m,x)])]$

The reading (18) can be obtained, for example, when there is a specific number (say 7) such that Mary set a goal to read that many books (even without realizing that the number is a prime number), but she does not have any specific group of books in mind. Thus the cardinality quantifier

[8] As our discussion is limited to cardinality quantifiers, instead of the more inclusive functional symbol 'meas', we hereafter use the notation '|x|' to represent the cardinality of x.

gets a *de re* interpretation while the group quantifier gets a *de dicto* interpretation.

The same kind of representation can be also obtained when there is another quantifier that can intervene between the cardinality quantifier and the group quantifier, as in the following (19):

(19) Every student must read a prime number of books.

Example (19) has a reading where there is a specific number assigned (which accidentally is a prime number) such that each student must read one or another group of books of that cardinality.

Now the two readings of (4) can be represented as follows, employing two operators, i.e. a *wh*-operator ranging over a number and an existential quantifier ranging over a group:

(20) a. How many books does Mary think Bill read?
b. [(which n (number'(n)))[(∃x (books'(x) & |x| = n)) think'(m, ([read'(b,x)]))]]
c. [(which n (number'(n))) think'(m, ([(∃x (books'(x) & |x| = n)) read'(b,x)]))]

It should be noted that the ambiguity in (20) is similar to the *de re/de dicto* ambiguity observed for the following (21):

(21) a. Mary thinks Bill read 5 books.
b. [(∃x (books'(x) & |x| = 5)) think'(m, ([read'(b,x)]))]
c. [think'(m, ([(∃x (books'(x) & |x| = 5)) read'(b,x)]))]

Likewise, the ambiguity of (7) can be represented as in (22):

(22) a. How many students does every professor believe that he has taught?
b. [(which n (number'(n))) [(∃x (students(x) & |x| = n)) [(∀y (professor'(y)) believe'(y, ([has-taught'(y,x)])))]]]
c. [(which n (number'(n))) [(∀y (professor'(y)) believe'(y, ([(∃x (students(x) & |x| = n)) has-taught'(y,x)]))]]

One thing that should be noted about the representations involving double quantifier analysis of cardinality phrases is that the cardinality quantifier must take wide scope over the existential group quantifier. Thus, in

examples (17-20) and (22), the reading wherein the existential group quantifier have wide scope over the cardinality quantifier or the *wh*-operator is not logically possible. This is because such readings will contain an unbound variable. We assume that such unbound variable is prohibited by a constraint such as the Quantifier Binding Condition in Pollard & Sag 1994.[9]

3. Analysis

In Yoo (1997) and Pollard & Yoo (1998) a unified account of quantifier and interrogative scope is proposed. Within the framework of Head-Driven Phrase Structure Grammar, this theory of scope provides accounts for various scope phenomena including those in raising verb constructions and unbounded dependency constructions, which were problematic in Pollard & Sag 1994 (P&S hereafter). We will show that how this theory of scope can explain the ambiguities that we discussed in section 2.

Our representation of quantifier scope is based on that of P&S. In P&S, given a sign, viz., a word or phrase, its semantic contribution is represented as the value of the CONTENT (CONT) attribute in the feature structure. Given a CONTENT value of type *psoa* (*parameterized-state-of-affairs*), the quantifier in the value of QUANTS (QUANTIFIERS) is taken to have scope over the value NUCLEUS. For example, the CONTENT value of the sentence *Mary knows every student* is described as in (23a) and roughly rendered in an informal quantificational logic notation in (23b). In (23a), the tag [1] indicates the quantifier in (24):[10]

(23)

a.
$$\begin{bmatrix} \textit{psoa} & \\ \text{QUANTS} & \langle \boxed{1}_{\boxed{4}} \rangle \\ \text{NUCLEUS} & \begin{bmatrix} \textit{know} & \\ \text{KNOWER} & \boxed{2}\ [\textit{3rd, fem, sing}] \\ \text{KNOWN} & \boxed{4} \end{bmatrix} \end{bmatrix}$$

b. $[\forall x \mid \text{stduent}'(x)]\ (\text{konw}'(\text{mary}', x))$

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[9] Quantifier Binding Condition (Pollard & Sag 1994)
Given a quantifier contained within a CONTENT value, every occurrence within that CONTENT value of the quantifier's index must be captured by that quantifier.

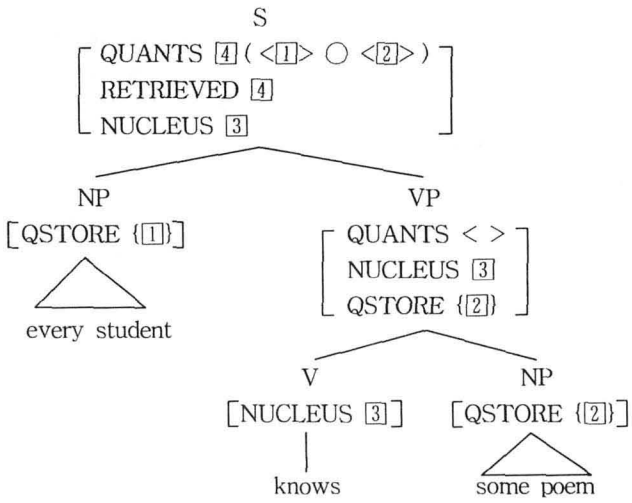
[10] The subscript tag [4] is used for the INDEX value. Thus $\boxed{1}_{\boxed{4}}$ in (23) indicates the quantifier whose RESTIND|INDEX value is [4].

(24)

$$\boxed{1}\begin{bmatrix} \textit{quant} \\ \text{DET } \textit{forall} \\ \text{RESTIND } \boxed{5} \begin{bmatrix} \text{INDEX } \boxed{4} \\ \text{RESTR } \left\{ \begin{bmatrix} \text{QUANTS } < > \\ \text{NUCLEUS} \begin{bmatrix} \textit{student} \\ \text{INST } \boxed{4} \end{bmatrix} \end{bmatrix} \right\} \end{bmatrix} \end{bmatrix}$$

When multiple quantifiers are involved as in *Every students like some poem*, they are listed in the QUANTS, wherein thier relative scope is determined by the order of quantifiers in the list. This is illustrated in (25): [11]

(25)



By employing a variant of Cooper's (1975, 1983) quantifier storage technique, we assume that all quantifiers and *wh*-operators 'start out in storage' as the QSTORE (QUANTIFIER-STORE) value and are 'inherited' by successively larger constituents, and then 'retrieved' at an appropriate site in the structure. The use of such terms as 'start out in storage', 'inherited', and 'retrieved' should not be taken to imply that we assume that such processes actually take place in the hierarchical structure. These terms are adopted for the exposition of the structure in a more familiar, bottom-up fashion. In HPSG, all the constituents of a sentence are represented as parts of the

[11] In (25), "○" indicates Reape's (1994) *sequence-union* or *shuffle* operation, and is employed here in order to abbreviate two fully scoped structures in P&S, viz. one with the QUANTS value <1,2> and the other with the QUANTS value <2,1>.

feature structure representation of the sentence, which is defined by recursive feature constraints. As we will see shortly, inheritance and retrieval of operators are formulated in terms of several declarative constraints.

On the basis of P&S's assumptions outlined above, we introduce a set of new assumptions, for the sake of a more precise, unified account of operator scope. They are stated in (26):

(26) i. The QSTORE feature is relocated as a LOCAL attribute.
ii. A new feature POOL is introduced as an additional LOCAL attribute.
iii. "Ordinary" lexical heads "collect" all the QSTORE values of their "selected arguments".
iv. QSTORE values are inherited only from the semantic daughter of a phrase.
v. Quantifier retrieval is possible either at a lexical head or at a phrase.

First, in (26i), the main motivation of relocating the QSTORE feature as a LOCAL attribute in the feature geometry is to make structure-sharing of QSTORE values possible between a raising controller and the unexpressed subject of the complement and between a filler and a trace. (Cf. Yoo 1997, Pollard & Yoo 1998) Second, in (26ii), the POOL feature is introduced in order to keep track of a set of quantifiers from which a subset of quantifiers is retrieved. In (26iii), "ordinary" lexical heads refer to a word which is neither a *quantifier-word* nor a *semantically vacuous* word. The following (27) shows the partitions of *word* that we are assuming:

(27) *word* → *ord-head* ∨ *quant-word* ∨ *sem-vac*

The *quant-word* refers to words that introduce a nonempty QSTORE value, e.g. *every, some, who,* or *which.* Another kind of words that is referred to as *sem-vac* (*semantically vacuous* word) are the ones whose CONTENT value is structure-shared with that of one of its complements, e.g. *to, be,* or nonpredicative *on.*[12] As an illustration of a *quant-word,* the lexical entry of *every* is represented in (28):

[12] Thus these words satisfy the following description:

(28)
$$\begin{bmatrix} \text{PHON} & \langle \text{every} \rangle \\ \text{SYNSEM} \mid \text{LOC} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{det} \begin{bmatrix} \text{SPEC N}' : \boxed{2} \end{bmatrix} \\ \text{SUBCAT} & \langle\ \rangle \end{bmatrix} \\ \text{CONT} & \boxed{3} \begin{bmatrix} \text{DETERMINER} & \textit{forall} \\ \text{RESTIND} & \boxed{2} \end{bmatrix} \\ \text{QSTORE} & \{ \boxed{3} \} \end{bmatrix} \end{bmatrix}$$

Third, the assumption in (26iii) plays an important role in determiming QSTORE and POOL values of lexical heads, and can be stated as a constraint as in (29):

(29) Constraint on Quantifier Storage of Heads
For an ordinary lexical head, the POOL is the union of the QSTORE of all *selected arguments*, defined as either
(i) thematic elements selected via the SUBJ or COMPS feature
(ii) elements selected via the SPR feature, or
(iii) elements selected via the MOD feature.

Accordingly, given a lexical head with its selected arguments, the operator(s) in those arguments' QSTORE value also appear in the POOL of the lexical head. This is exemplified in the following lexical entry of *student* contained in the phrase *every student*, in which *every* has a nonempty QSTORE value as in (28):

(30) *studenet* (in *every student*)
$$\begin{bmatrix} \text{CAT} \mid \text{VAL} \mid \text{SPR} & \langle [\, \text{LOC} \mid \text{QSTORE} \{ \boxed{1} \} \,] \rangle \\ \text{POOL} & \{ \boxed{1} \} \end{bmatrix}$$

The fourth assumption in (26iv) is about inheritance of QSTORE and POOL values, and can be stated as a constraint (31):

(31) Constraint on Quantifier Inheritance
For a phrase, the POOL value is token-identical with the QSTORE value of the semantic head daughter.[13]

(i) sem-vac =
$$\begin{bmatrix} \text{SYNSEM} \mid \text{LOC} & \begin{bmatrix} \text{CAT} \mid \text{VAL} \mid \text{COMPS} & \left\langle \ldots \begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{QSTORE} & \boxed{3} \end{bmatrix} \ldots \right\rangle \\ \text{CONT} & \boxed{1} \\ \text{QSTORE} & \boxed{3} \end{bmatrix} \\ \text{RETRIEVED} & \langle\ \rangle \end{bmatrix}$$

For the retrieval of operators, we assume the following constraints:

(32) Constraint on Quantifier Retrieval
a. The RETRIEVED value is nonempty only when the CONTENT value is of sort *psoa*.
b. For a sign, the RETRIEVED value is a list whose set of elements forms a subset of the POOL value; and the QSTORE value is the relative complement of that set.
c. For a semantically nonvacuous lexical head, the QUANTS value is token-identical with its RETRIEVED value.

The constraint (32a) is based on the assumption (26v). Since it does not refer to either a lexical head or a phrase as a possible retrieval site, it follows from this that retrieval takes place at either site.

Meanwhile, we need some constraint that governs the CONTENT of a phrase, and this is adopted from the Semantics Principle of P&S.

(33) Constraint on CONTENT
a. For a headed phrase whose CONTENT is not of sort *psoa*, the CONTENT value is token-identical to that of the semantic head.
b. For a headed phrase whose CONTENT is of sort *psoa*, the NUCLEUS value is identical with that of the semantic head, and the QUANTS value is the concatenation of the RETRIEVED value and the semantic head's QUANTS value.

The constraints (29) and (31-33) are all applied to both ordinary quantifiers and interrogative operators. In the case of interrogative operators, however, an additional syntactic licensing constraint may be needed for their retrieval, especially in languages whose *wh*-questions involve syntactic movement of *wh*-phrases. Following Yoo (1997), and Pollard & Yoo (1998), we assume the following constraint for English *wh*-interrogatives:

(34) Syntactic Licensing Constraint on *wh*-Retrieval (for "English-like"

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[13] The notion of *semantic head* is defined in P&S as in (i):
(i) The *semantic head* of a headed phrase is
a. the adjunct daughter in a head-adjunct phrase,
b. the head daughter otherwise.

syntactic *wh*-movement languages)

a. At any node, retrieval, if any, of *wh*-operators must include the member of the left peripheral daughter's QUE value (which must, therefore, be nonempty).

b. At any filler-head node, if the filler has nonempty QUE value, then its member must beong to the node's RETRIEVED value.

In our theory, *wh*-words are treated parallel to quantifier words, in that an operator originates in their QSTORE/POOL, which is inherited and retrieved in order to take scope. On the other hand, unlike a quantifier word, a *wh*-word bears a nonempty QUE value, which is token-identical with its QSTORE/POOL value. Within the feature structure, *wh*-operators are distinguished from ordinary quantifiers by its DETERMINER value *which*.

Let us now consider how the readings of the examples discussed in section 2 are accounted for in our theory. The proposed logical representation (20) of the two readings in (4) is repeated in the following (35):

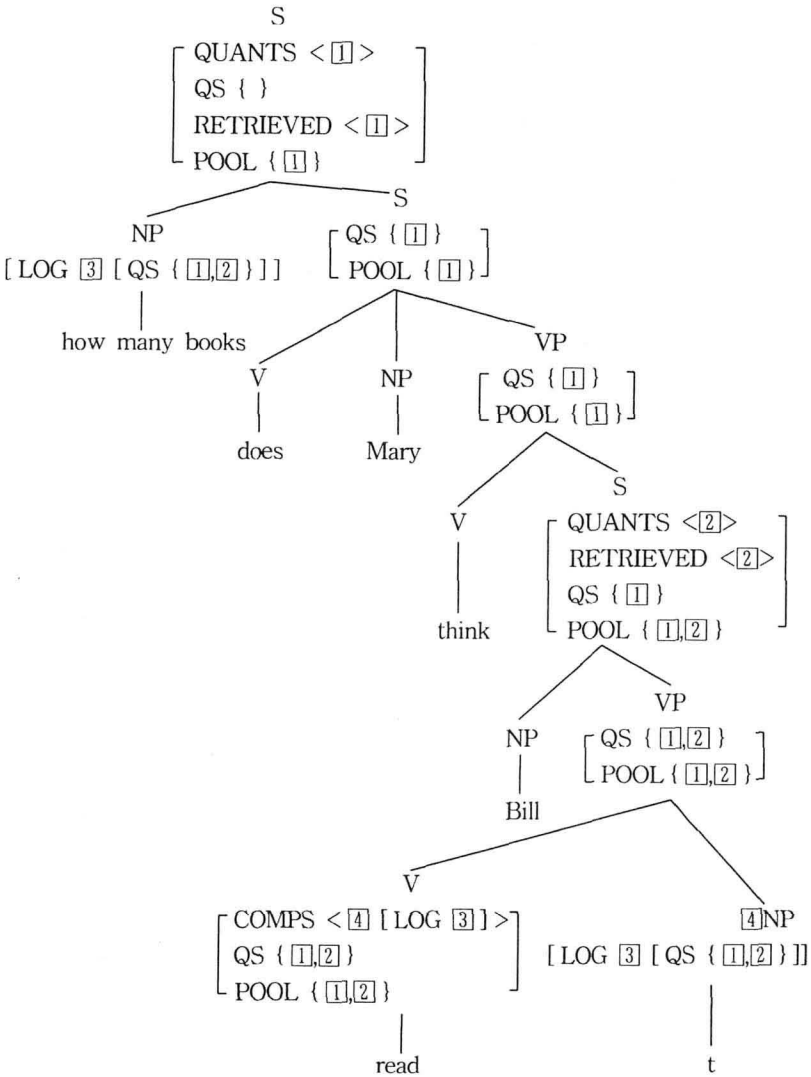
(35) a. How many books does Mary think Bill read?

b. [(which n (number'(n)))[(∃x (books'(x) & |x| = n)) think'(m, ([read'(b,x)]))]]

c. [(which n (number'(n))) think'(m, ([(∃x (books'(x) & |x| = n)) read'(b,x)]))]

We have seen that this kind of examples may involve a syntax-semantics mismatch, in that the existential (group) quantifier may take a narrower scope than its syntactic position. We have also pointed out that this poses a problem for a movement-based analysis. By contrast, in our theory, no additional mechanism is needed in order to achieve the desired quantifier lowering effect. This is because we assume that quantifiers associated with an argument also appear in the POOL of the lexical head that "selects" the argument. Therefore, the two operators originating from the *how many* phrase appear in the POOL and QSTORE of the lower verb in (35a). Then the narrow scope readings in (35c) is achieved by retrieving the existential quantifier at the lower clause and the *wh*-operator at the higher clause. The following (36) is a diagram representing the narrow scope reading of (35c):

(36) Narrow scope reading

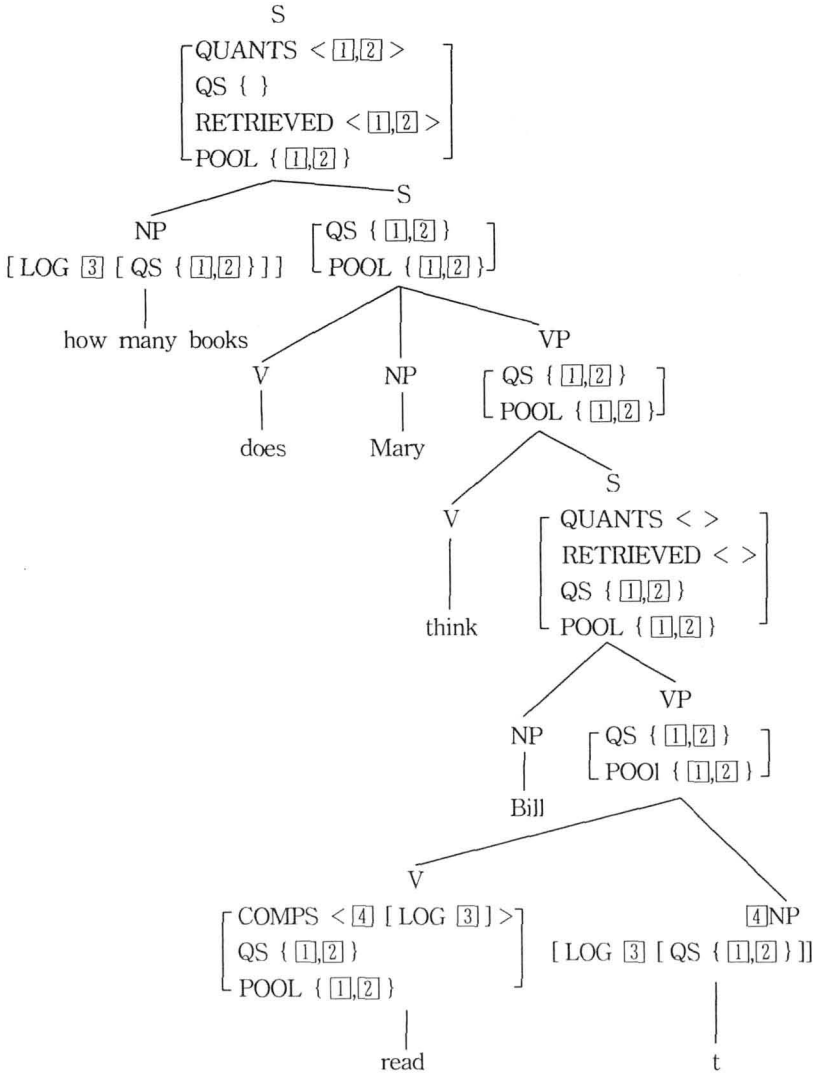


$\boxed{1}$ = [which n | number(n)]

$\boxed{2}$ = [$\exists$x | books(x) $\wedge$ |x| = n]

On the other hand, the wide scope reading in (35b) is obtained by retrieving both the *wh*-operator and the existential quantifier at the higher clause, as in (37):

(37) Wide scope reading



Now our analysis can explain the ambiguity of the examples (6) and (7) that Fiengo *et al.* observed without a precise account. The examples (6) and (7) contain three operators: an interrogative operator and an existential group quantifier associated with *how many students*, and a universal quantifier associated with *every professor*. We showed that how the problematic, narrow scope reading of (7) can be represented under our double quantifier

analysis, in (22c). Likewise, the two readings of (6) that Fiengo *et al.* discusses can be represented as in (38):

(38) a. How many students has every professor taught?
b. [(which n (number'(n))) [(∃x (students(x) & |x| = n)) [(∀y (professor'(y)) has-taught'(y,x)]]]
c. [(which n (number'(n))) [(∀y (professor'(y)) [(∃x (students(x) & |x| = n)) has-taught'(y,x)]]]

In our analysis, the three operators involved in these readings are stored as QSTORE/POOL value of the verb *taught* by (29), since both *how many students* and *every professor* are selected arguments of this verb. Then, this QSTORE/POOL value is inherited to its mother VP, and to the S headed by *has*, by (31), until it is retrieved at the matrix S node. Thus, in our theory, the two readings in (38) is simply the result of more than one possible order of operators in the RETRIEVED list. As was mentioned before, the existential group quantifier cannot appear before the *wh*-operator in the QUANTS list, since it is prohibited by the Quantifier Binding Condition.

4. More on Wh/Quantifier Scope Interaction

In addition to the readings that we considered so far, there is actually another reading that (38a) has. While both the readings we explained involve wide scope of the interrogative operator, it is also possible in (38a) that the universal quantifier takes the widest scope, i.e. a scope over the *wh*-operator and the existential quantifier. In this section, we will discuss our treatment of the examples that involve wh/quantifier interaction.

It has been much discussed in literature that questions such as (39) can be replied with two types of answers as in (40):

(39) What Disney movie does every kid (in the class) like?

(40) a. *Mulan.*
b. Dennis likes *Hercules,* Abby likes *Poccahontas,* …

As May (1985) discusses at length, a question like (39) displays an ambiguity. It may be understood either as a single question, asking for the name of the Disney movie that all the kids (in the class) like, or as a

"distributed" question, asking of each kid (in the class) what Disney movie that kid likes. The answer in (40a) is possible when (39) is interpreted as a single question, and the one in (40b) is appropriate when (39) gets a "distributed" question or "family of question" interpretation.

As in May, we adopt the view that the ambiguity of (39) arises from the more than one possible scope order between an interrogative operator and a quantifier. Accordingly, in (39), the interrogative operator associated with *what Disney movie* can take either wide scope or narrow scope with respect to the quantifier associated with *every kid*. In the former case, (40a) is an appropriate answer; in the latter, (40b).

In our analysis, this is indicated in the CONTENT, by the order of the operators in the QUANTS list. When the *wh*-operator takes scope over the universal quantifier, its CONTENT value is represented as (41), and (39) is interpreted as a question asking the identity of the movie that all the kids in the class like.

(41)
$$\begin{bmatrix} psoa & \\ \text{QUANTS} & \left\langle \boxed{2}\begin{bmatrix} quantifier \\ \text{DET } which \\ \cdots \mid \text{IND } \boxed{1} \end{bmatrix}, \boxed{4}\begin{bmatrix} quantifier \\ \text{DET } forall \\ \cdots \mid \text{IND } \boxed{3} \end{bmatrix} \right\rangle \\ \text{NUC} & \begin{bmatrix} like \\ \text{LIKER } \boxed{3} \\ \text{LIKED } \boxed{1} \end{bmatrix} \end{bmatrix}$$

Another CONTENT value that is available for (39) is represented in (42), wherein the universal quantifier takes scope over the *wh*-operator.

(42)
$$\begin{bmatrix} psoa & \\ \text{QUANTS} & \left\langle \boxed{4}\begin{bmatrix} quantifier \\ \text{DET } forall \\ \cdots \mid \text{IND } \boxed{3} \end{bmatrix}, \boxed{2}\begin{bmatrix} quantifier \\ \text{DET } which \\ \cdots \mid \text{IND } \boxed{1} \end{bmatrix} \right\rangle \\ \text{NUC} & \begin{bmatrix} like \\ \text{LIKER } \boxed{3} \\ \text{LIKED } \boxed{1} \end{bmatrix} \end{bmatrix}$$

(42) yields a "family of questions" interpretation in May's (1985) terms.

Likewise, our theory predicts that the following example (43) is ambiguous, thus both answers in (43b,c) being felicitous:

(43) a. Who recommended every candidate?
b. The chairman did.
c. Prof. Rayner recommended Sally, Prof. Curry recommended John…

By contrast, May claims that in the following set of examples, only (44) has a "family of questions" interpretation, and that the wide scope of the universal quantifier in (45) must be prohibited on syntactic grounds.

(44) What did everyone buy for Max?

(45) Who bought everything for Max?

The existence of such an asymmetry has been accepted in much subsequent literature, and various syntactic conditions have been imposed in order to explain it. In May, the condition that is responsible is the Path Containment Condition of Pesetsky (1982), which May proposes to replace the ECP. In Aoun & Li (1993), it is the Minimal Binding Requirement that blocks the wide scope of a quantifier over a *wh*-subject.[14] In Chierchia (1993), it is explained as an instance of weak crossover.

However, contrary to May's claim, when more examples are considered in various contexts, we find cases where examples of the latter kind are equally ambiguous. Thus we will suggest that it is not appropriate to posit any kind of syntactic constraint for this much discussed phenomenon.

Actually, the status of the examples (44) and (45) with respect to operator scope ambiguity has not been without some disagreements. One kind of objection involves the claim that the two readings in (44) is not a consequence of scope ambiguity; the other kind involves some potential counterexamples on the nonambiguity of (45). We will briefly review the former cases first.

Williams (1986) claims that the (seemingly) wide scope interpretation of *everyone* in (44) is not due to quantification. Rather he argues that it is due to the possible nonquantificational "group" interpretation *everyone/ everybody*, just as the nonquantificational pronominal NPs in (46a,b) can yield a "pair-list answer" in (46c).[15]

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[14] (i) The Minimal Binding Requirement (Aoun & Li 1993: 11)
Variables must be bound by the most local potential $\bar{A}$-binder.

[15] By contrast, May (1985) argues that examples with plural pronouns show the same asymmetry as the one between (44) and (45). That is, *Who did they see at the*

(46) a. Who did they dance with?
b. Who danced with them?
c. John danced with Mary, Same danced with Sue, …

Williams explains that the family of questions reading is not possible in (45) since *everyone/everybody* may receive a group interpretation only in a subject position, but not in an object position. He presents example (47) as supporting evidence, arguing that when a *every* N phrase, which does not have a group reading, is involved, no ambiguity is exhibited:

(47) Who did every girl dance with?

In reply to Williams, May (1988) presents some detailed counterarguments. Crucially, May (1988) points out the claim that *wh*/quantifier interactions are limited to the cases with *everyone/everybody* cannot be maintained, given the numerous instances of the latter type found in the literature. The following (48) is one from Engdahl (1986):

(48) a. Which book did every author recommend?
b. *War and Peace.*
c. Bellow recommended *Herzog* and Heller recommended *Catch-22.*

Lasnik & Saito (1992) also argue that the ambiguity in (44) is not due to relative scope of operators. In contrast with Williams, however, they claim that the putative "narrow scope reading" of *everyone* in (44) results from the group interpretation of *everyone*, while the family of questions reading comes when *everyone* is interpreted as a universal quantifier that takes wide scope over the *wh*-phrase. Such a claim is problematic for the same reason as aforementioned Williams' claim is; as in (48), a narrow scope reading of the QP is possible with a *every* N phrase as well, which does not have a group interpretation.

Moreover, even with *everyone*, Lasnik & Saito's argument is problematic, when we consider the following (49):

Wimbledon finals?, but not *Who saw them at the Wimbledon finals?* possesses the family-of-questions interpretation. May treats plural pronouns (or the plurality feature) as (a kind of universal) quantifiers that undergoes LF movement. Such empirical claim on the asymmetry and the view that plural pronouns are quantifiers are specifically objected to in Krifka (1992) which argues that definite plural NPs, both pronouns and full NPs, do not act as quantifiers with respect to *wh*-phrases.

(49) What recipe can everyone find in a French cookbook?

Example (49) has a reading wherein *everyone* takes scope narrower than *what recipe* but wider than *a French cookbook*. That is, it is possible that each person finds the recipe of the same French dish, say quiche, but in a different French cookbook. If *everyone* is interpreted as a (individual denoting) group, as Lasnik & Saito claims, then it cannot be interpreted as taking wide scope over *a French cookbook*.[16]

On the other hand, regarding the nonambiguity assumed in examples like (45), there have been some discussions of potential counterexamples. First of all, it has been recognized that with an *each* phrase, wide scope over a *wh*-subject is obtained much more easily. Williams (1986) observes that either of the following examples is ambiguous:

(50) a. Who did each boy dance with?
b. Who danced with each boy?

In order to explain this, May (1985, 1988) assumes that *each* is inherently focused and thus, unlike other universal quantifiers, undergoes a different type of adjunction at LF, viz. adjunction to S'.

However, Williams (1988) points out some problems with such analysis. While the S'-adjunction analysis accounts for the wide scope of the universal quantifier in *Who bought each thing for Max?*, S'-adjunction of the *each* phrase in *What did each person buy for Max* violates the PCC (Path Containment Condition). As Williams points out, a violation of the PCC also occurs in a biclausal sentence like (51), in which the universal quantifier undergoes adjunction to matrix S′ in order to get maximally wide scope.

(51) Someone or other knows who each murderer murdered.

Thus May's explanation of the ambiguous status of (50b) is not successful. In a theory that allows either order in operator scope, this example need not be treated exceptionally.

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[16] Both Williams (1988) and Lasnik & Saito pursue the idea that operator scope interaction is constrained by some "rigidity condition" such as those of Huang (1982) and Hoji (1985). The claim that (44) does not involve scope ambiguity is directly relevant to positing such a rigidity condition.

Another case involves complex sentences with an embedded question. The universal quantifier can take scope over the *wh*-operator in (52).

(52) She told me who inspected every school.

Another ambiguous example of the same kind is given in (53).

(53) Before we can pay the subcontractors, we need to know who did everything.

Regarding the wide scope reading of the universal quantifier in (52), May (1985) claims that when *every school* has wider scope than *who*, it also has wider scope than the matrix predicate. Thus he claims that the embedded question lacks a family of questions interpretation.

While it is true that the universal quantifier can have a matrix scope in (52), it is questionable whether its wide scope within the embedded clause is really prohibited as May maintains. Groenendijk & Stokhof (1982) observe that in examples such as *Bill knows whom everyone knows*, wherein the matrix verb is "extensional" (e.g. *tell, know*), the two wide scope readings of the universal quantifier are equivalent.[17] That is, the reading in which the universal quantifier takes wide scope over the matrix extensional predicate is truth-conditionally equivalent to the reading in which the universal quantifier takes wide scope over only the *wh*-phrase. Therefore, May's claim that only the former reading is possible in (52) is not well supported.[18]

Moreover, there seem to be cases wherein the wide scope reading of the universal quantifier is hard to ascribe to its having wide scope over the matrix predicate. Consider (54).

(54) Bill wondered who donated every book in the library.

According to Gronendijk & Stokhof, *wonder* is an "intensional" predicate, and

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[17] They use the term "extensional" to refer to predicates operating on the denotations of their complements (i.e. propositions, in their theory). Those predicates are distinguished from "intensional" ones (e.g. *ask, wonder, guess*, and *depend on*) that operate on the sense of the complement.

[18] By the same reason, May's claim that *John told me which school everybody inspected*, in contrast with (52), may have only the family of questions construal (but not the maximal wide scope of the universal quantifier) is problematic. See also (51), for which the PCC makes a wrong prediction.

the reading in which the universal quantifier outscopes both the matrix predicate and the *wh*-phrase is distinct from the one wherein it outscopes only the *wh*-phrase (See also Karttunen & Peters 1980).

Moreover, May's argument cannot go through when we consider the following exchange:

(55) A : We need to pay the subcontractors.
B : OK, who did everything?

In the second sentence of (55), the universal quantifier is interpreted as having wide scope, even though it is not in an embedded context. Therefore, in (52) and (53), wide scope of the *every* phrase should be permitted within the embedded clause.

In other cases, it has been noted that some examples parallel to (45) have both readings. Chierchia (1993) recognizes that a pair-list answer such as (56b) is available for (56a) when, for example, there is a party and each student has brought a dish.

(56) a. Who put everything on the platter?
b. Bill, the chicken salad, Frank, the chow mein; …
(Chierchia 1993: 183)

However, Chierchia claims that the availability of a pair-list answer in structures like (56a) is due to the property of *who/whom* that can be semantically plural. Thus the reading that yields a pair-list answer in (56a) is made parallel to the interpretation of the following (57): [19]

(57) The kids brought everything for the party. Bill brought the paper cups, John the beer, …

Chierchia claims that once the effects of plurality are factored out, the subject-object asymmetry that May discusses still remains, as in the following pair of examples with *which* N:

(58) a. Which student put everything on the platter?
b. (Not) Bill, the chicken salad; Frank, the chow mein; …
(Chierchia 1993: 184)

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[19] However, a specific mechanism as to how to yield such interpretations is not given.

(59) a. Which dish did every student bring?
b. Bill brought the chicken salad; Frank brought the chow mein; ⋯
(Chierchia 1993: 184)

According to Chierchia (1983: 184), the same asymmetry emerges when the singular interpretation of *who/what* is forced by a bound variable pronoun.

(60) a. Who$_i$ put everything on his$_i$ platter?
b. (Not) John, the chicken salad; Bill, the chow mein; ⋯

(61) a. What$_i$ did everyone return to its$_i$ owner?
b. Bill returned the screwdriver to its owner; John returned the cat to its owner; ⋯

While it is true that *who/what* is tolerant for plurality, and it might play a role in yielding a pair-list answer, we doubt that this is the main force behind the family of questions reading of examples such as (56). Contrary to Chierchia's claim, it seems possible that a subject *which* N is outscoped by a universal quantifier. The following example is from Karttunen & Peters (1980), and has a reading wherein the embedded question has a family of questions interpretation.

(62) Bill wonders which professor recommends each candidate.

If the plurality factor is solely responsible, then it cannot be explained why this example with a singular *wh*-subject allows a family of questions interpretation. The embedded question in (62) is not different from (58) in that it contains a universal quantifier and a *which* phrase.[20] A wide scope inter-

[20] In this connection, it should be noted that Karttunen & Peters (1980) argue that the following pair of examples have the same range of (denotational) meaning, and do not regard them as expressing different questions. (See May 1985: 50-52 for discussion.)

(i) Which customer is each clerk now serving?
(ii) Which clerk is now serving each customer?

They argue, on the other hand, that these two questions are associated with distinct conversational implicatures, so it is odd to use the question (ii) in a situation such as a supermarket, where 1 : 1 clerk-to-customer relationship is normal. According to them, this is because the question (ii), which, with a universally quantified phrase in the object position, presumably presupposes one-to-many relationship, thus implicating that one clerk is serving all the customers.

pretation of the universal quantifier seems also available in the following question, which can be asked in a faculty meeting situation:

(63) Which professor advises every student that we're going to put up for the fellowship?

Some cases with subject *who* that is interpreted as singular also exhibit availability of a family of questions interpretation. Suppose, for example, that a workshop is being organized by graduate students, and student speakers coming from other cities are staying at one or other local students' places. A sign-up sheet has been circulated so that for each outside student some local student can volunteer hosting. Then, the following (64) can be uttered:

(64) Let's find out who$_i$ is putting every student up at his$_i$ place.

In this situation, the wide scope reading of the universal quantifier seems possible. [21]

Consider also the following (65):

(65) Mary wondered [[which of her clients]$_i$ had the most of [every stock]$_j$ in his$_i$ portfolio].

In (65), the *wh*-phrase is forced to get a singular interpretation, and yet the kind of answer that Mary wants is *John has the most Microsoft in his portfolio, Bill has the most Philip Morris in his portfolio, etc.*, which reflects the wide scope reading of the universal quantifier. [22]

Thus the plurality factor cannot explain all the ambiguous cases with *wh*-subject. Then, the most natural and simple assumption that we can make is that examples like (56) actually involve a scope ambiguity, just like (44) does.

In this section, we have seen that various arguments/claims in favor of nonambiguity of (44) and (45) are problematic. Based on the discussions in this section, we conclude that as in the cases with two QPs, scope ambiguity between a *wh*-operator and an ordinary quantifier should not be prohibited by a syntactic constraint.

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[21] Some speakers that I consulted with found that this reading is very difficult to get in (64) while it is more easily obtained in (63).

[22] This example was pointed out to me by Carl Pollard (p.c.).

5. Conclusion

In this paper, we discussed scope properties of cardinality *wh*-phrases, and claimed that they are best analyzed as involving an existential group quantifier in addition to an interrogative operator ranging over numbers. We argued that such decomposition is necessary for the account of scope ambiguity of cardinality noun phrases in general. Since our representation of quantifier scope does not depend on the syntactic positions of QPs in the structure, we can account for the fact that scope of the two operators involved in a cardinality noun phrase, viz. the cardinality quantifier (or cardinality *wh*-operator in the case of a cardinality *wh*-phrase) and the existential group quantifier, can be intervened by another element in the interpretation. In our theory, each operator is stored as a feature value, which can be retrieved at different sites, thus taking different scope.

For the account of ambiguity of a constituent question that involves QPs, we take the widely assumed view that this can be explained in terms of scope ambiguity between quantifiers and interrogative operators. However, we argue against May (1985) with respect to subject-object asymmetry in *wh*/QP scope interaction. By considering various kinds of examples, we claimed that either relative scope order is possible when both a universal quantifier and a *wh*-operator are involved, and that there is no subject-object asymmetry that should be accounted for by a syntactic constraint.

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