LTAG Semantics of Focus[*]

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Abstract

This paper presents LTAG semantics of focus and focus-sensitive quantifiers which adopts alternative semantics of focus (Rooth 1985 and subsequent work). It proposes that focused lexical items make its contribution at the level of elementary trees, so that each elementary tree is associated with two semantic representations: its ordinary semantic representation and its focus representation. Based on the semantic framework, discussed in Kallmeyer and Joshi 2003 and Kallmeyer and Romero 2004, the paper develops a compositional analysis of focus representations, and extends this analysis to focusing adverbs and adverbs of quantification.

1 Alternative Semantics of Focus.

According to alternative semantics, introduced in Rooth 1985, every constituent has two semantic values: an ordinary semantic value, which determines its contribution to the truth conditions, and a focus semantic value, which determines the set of alternatives, or propositions under discussion. The focus semantic value is the set of propositions obtained by making substitutions in the position of the focused phrase. For example, the focus semantic value of the sentence **'Mary dates $[Bill]_F$'** is the set of propositions of the form "Mary dates y", whereas the focus semantic value of '$[Mary]_F$ dates Bill' is the set of propositions of the form "x dates Bill".

The contribution of focus is thus to evoke a set of alternatives, which can be contrasted with the ordinary semantic value. This can be illustrated by the question-answer paradigm. Consider, for example, the question 'Who dates Bill?'. This question determines the set of potential answers 'Mary dates Bill', 'Sue dates Bill', etc, which are alternatives to the actual answer. An appropriate answer to this question is '$[Mary]_F$ dates Bill', where the position of focus correlates with the questioned position in wh-questions. The contribution of focus in an answer is thus to indicate that propositions of the form 'x dates Bill' are alternatives to the actual answer.

Ordinary semantic value is not directly affected by focus, however, focus has a truth-conditional effect in the case of quantifiers like 'only'. Consider the sentences in (1) from Rooth 1985 in the context where John introduced Bill and Tom to Sue, and there were no other introductions. In this context, the sentence in (1a) is false, and the sentence in (1b) is true.

(1) a. John only introduced $Bill_F$ to Sue
    b. John only introduced Bill to Sue_F

The analysis of 'only' proposed in Rooth 1985 assumes that 'only' is a universal quantifier which quantifies over the set of alternatives. The sentence in (2a), for example, is true in case any proposition of the form 'John introduced x to Sue' is a proposition "John introduced Bill to Sue'.

(2) a. John only introduced $Bill_F$ to Sue
    b. $\forall q(q \land \lambda p \ [\exists y \ (p= introduce(j, y, s)](q) ->$
       $q=introduce(j, b, s))$

The main question addressed in the paper is how the set of alternatives can be computed within LTAG-based semantics. The next section introduces the semantic framework adopted in the paper, which is based on semantic feature unification. Section 3 proposes an analy-

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sis of focus which assumes that focused lexical items make its contribution at the level of elementary trees, so that each elementary tree is associated with two semantic representations: its ordinary semantic representation and its focus representation. Sections 4 and 5 extend the proposed analysis to focus-sensitive quantifiers.

## 2   LTAG Semantics with Semantic Unification.

In LTAG framework (Joshi and Schabes 1997), the basic units are (elementary) trees, which can be combined into bigger trees by substitution or adjunction. LTAG derivations are represented by derivation trees that record the history of how the elementary trees are put together. Given that derivation steps in LTAG correspond to predicate-argument applications, it is usually assumed that LTAG semantics is based on the derivation tree, rather than the derived tree (Kallmeyer and Joshi 2003).

Semantic composition which we adopt is based on LTAG semantics with semantic unification (Kallmeyer and Romero 2004). In the derivation tree, elementary trees are replaced by their semantic representations and corresponding feature structures. Semantic representations are as defined in Kallmeyer and Joshi 2003, except that they do not have argument variables. These representations consist of a set of formulas (typed λ-expressions with labels) and a set of scope constraints. The scope constraints $x \leq y$ are as in Kallmeyer and Joshi 2003, except that both x and y are propositional labels or propositional variables.

Each semantic representation is linked to a feature structure. Feature structures, as illustrated by different examples below, include a feature i whose values are individual variables, features p and MaxS, whose values are propositional labels, and a feature S, whose values are situations. Semantic composition consists of feature unification. After having performed all unifications, the union of all semantic representations is built.

Consider, for example, the semantic representations and feature structures[2] associated with the elementary trees of the sentence shown in (3).
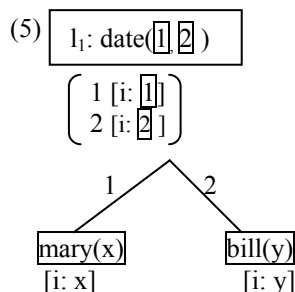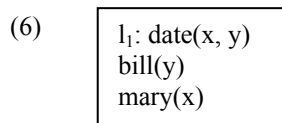
(3) Mary dates Bill
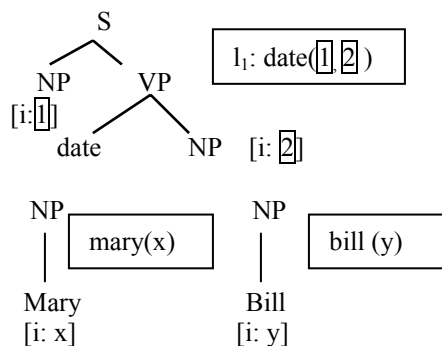
The derivation tree that records the history of how elementary trees are put together is shown in (4):

(4)
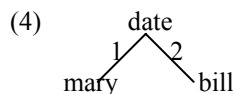
Semantic composition proceeds on the derivation tree and consists of feature unification:

(5)

Performing two unifications, $\boxed{1}$=x, $\boxed{2}$=y, we arrive at the final interpretation of this sentence:

(6)
$$l_1: date(x, y)$$
$$bill(y)$$
$$mary(x)$$

This representation is interpreted conjunctively, with free variables being existentially bound.

3   LTAG based Alternative Semantics.

In order to incorporate the semantics of focus we propose that each elementary tree is associated with two semantic representations, which correspond to its ordinary semantic value and its focus semantic value. The focus semantic value is built parallel to the meaning of questions, where the focused constituent is replaced by a wh-phrase. As in the alternative semantics, ordinary
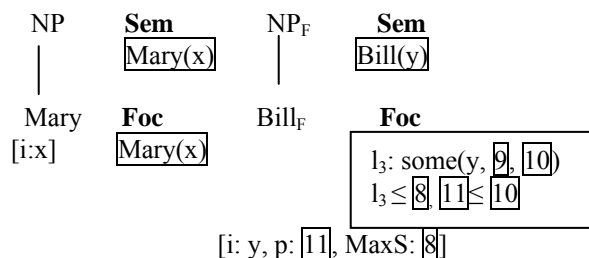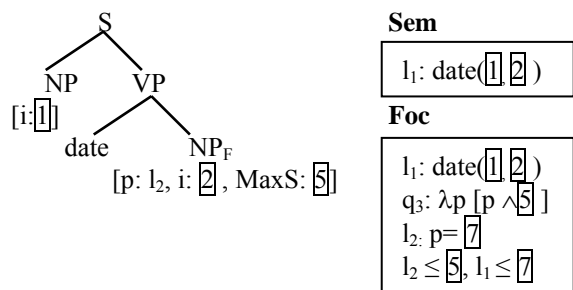
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[2] For simplification, top-bottom feature distinction is omitted.

and focus semantic values are viewed as separate semantic representations.

3.1 Compositional Analysis of Focus

Semantic representations and feature structures for the sentence 'Mary dates Bill', where 'Bill' is focused is given below. As this sentence illustrates, each tree has two semantic representations: which we refer to as *Sem* and *Foc* below, and feature structures shared by the two representations.
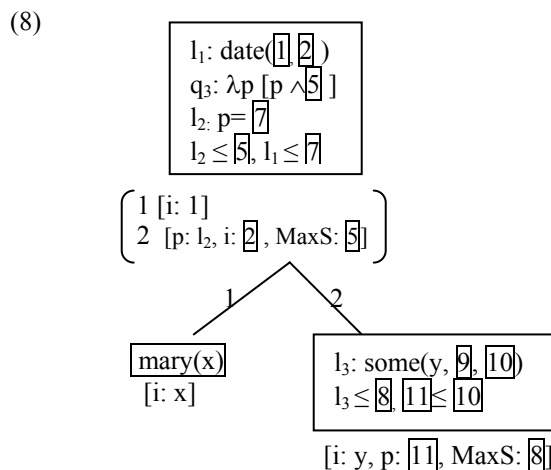
(7) Mary dates Bill$_F$

Sem

l_1: date([1], [2])

Foc

l_1: date([1], [2])
q_3: $\lambda p\ [p \wedge$ [5]]
l_2: p= [7]
$l_2 \leq$ [5], $l_1 \leq$ [7]

NP   **Sem**   NP$_F$ **Sem**
| Mary(x) | Bill(y)

Mary **Foc**   Bill$_F$ **Foc**
[i:x]   Mary(x)

l_3: some(y, [9], [10])
$l_3 \leq$ [8], [11] $\leq$ [10]

[i: y, p: [11], MaxS: [8]]

The focus representation of a non-focused phrase is simply a copy of its ordinary semantic representation, as illustrated by the NP 'Mary' above. The focus semantic value of the S tree corresponds to the semantic interpretation of a question, and is based on the LTAG-semantics of questions discussed in Romero et al 2004. And, finally, the focus representation of a focused phrase, as illustrated by the NP$_F$ 'Bill' above, introduces an indefinite quantifier, where the restricted clause is left as an open variable.

Whereas the present analysis of the focus semantic representation assumes the semantics of questions discussed in Romero et al 2004, it differs in the following respect. Romero et al 2004 assume a multi-component analysis of wh-phrases, which is parallel to quantificational NPs discussed in Kallmeyer and Joshi 2003. Quantificational NPs under these approaches are associated with a multi-component TAG which consists of two elementary trees: S tree, which introduces the proposition containing the quantifier, and NP-tree, which introduces the restrictive clause. In the case of
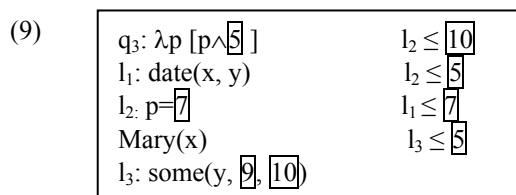
wh-quantifiers, the S tree, or the scope part of the wh-NP, introduces the indefinite quantifier and adjoins to the S' node in the wh-tree. As the representations in (7) show, in the case of focused constituents, both ordinary semantic and focus representations are associated with the same tree. Furthermore, the S tree headed by the verb is not a wh-tree, and does not have an S' node. And, finally, the restrictive clause of the indefinite is not provided by the syntax and is determined contextually. Given these syntactic differences, we suggest that the focus semantic value of a focused phrase is not multi-component, and the indefinite quantifier is part of the focus semantic value of the NP tree.

The use of multi-component representations for wh-phrases is largely motivated by scope constraints. As we will show in section 3.3 below, the present analysis does not present any difficulties for the analysis of scope of focused constituents, given the assumption that the scope feature which is responsible for the right scope interpretations is associated with the focused constituent (such as NP$_F$ in (7) above).

Semantic composition of the focus representation is shown in (8):

(8)

l_1: date([1], [2])
q_3: $\lambda p\ [p \wedge$ [5]]
l_2: p= [7]
$l_2 \leq$ [5], $l_1 \leq$ [7]

$\left[\begin{array}{l} 1\ [i: 1] \\ 2\ [p: l_2, i:\ [2]\ , MaxS:\ [5]] \end{array} \right]$

mary(x)
[i: x]

l_3: some(y, [9], [10])
$l_3 \leq$ [8], [11] $\leq$ [10]

[i: y, p: [11], MaxS: [8]]

Performing unifications leads to the following feature identities: [1]=x, [2]=y, [11]= l_2, [8]=[5]. The feature MaxS, associated with the focused trees, is the scope feature, introduced in Romero et al 2004 to account for the correct maximal scope of quantificational NPs. Given these feature identities, the final representation of the focus semantic value is as follows:

(9)

q_3: $\lambda p\ [p \wedge$ [5]]	$l_2 \leq$ [10]
l_1: date(x, y)	$l_2 \leq$ [5]
l_2: p=[7]	$l_1 \leq$ [7]
Mary(x)	$l_3 \leq$ [5]
l_3: some(y, [9], [10])	

The scope constraints restrict possible assignments for the remaining variables. The only disambiguation (i.e. a function from propositional variables to propositional labels that respect the scope constraints in the sense of Kallmeyer and Joshi 2003) possible in this case is: l_3=5, l_1=7, l_2=10. This disambiguation leads to the desired interpretation, where the label q_3 corresponds to the set of alternatives.
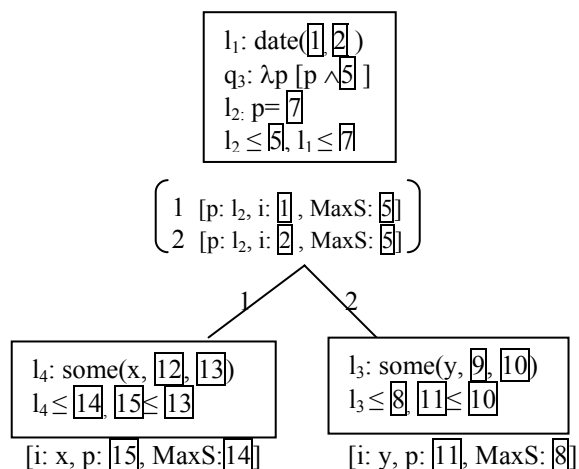
The analysis of focus presented above assumes that composition of ordinary and focus semantic representations uses the same feature structures, specifically the ones shown in (7). This means, for example, that the variable 2 is identified with y in both ordinary semantic and focus interpretations, although in the ordinary semantic representation this variable refers to Bill, and in the focus representation it is existentially bound. This does not present a problem as long as the two final representations are being viewed as separate semantic values, as the present analysis assumes.

The assumption that the same feature structures are being used in the process of composing the two representations also implies that not all variables will get values in the final representation. For example, features p and MaxS, introduced by the NP_F in (7), are only needed for the compositional interpretation of the focus semantic value, but do not play any role for the composition of the ordinary semantic representation.
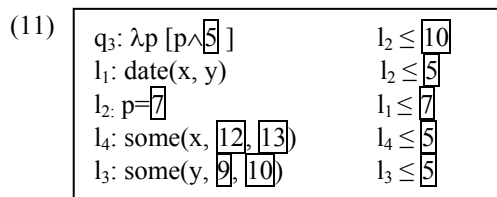
3.2   Multiple Foci

Let us now consider a sentence where two constituents are focused, as in '$Mary_F$ dates $Bill_F$'. According to alternative semantics of focus, both focused phrases are replaced by existentially quantified variables in the focus semantic value, so that the set of alternatives for this sentence is of the form 'x dates y'.

(10) $Mary_F$ dates $Bill_F$

$$l_1: date(1, 2)$$
$$q_3: \lambda p\ [p \wedge 5\ ]$$
$$l_2: p= 7$$
$$l_2 \leq 5,\ l_1 \leq 7$$

$$\begin{pmatrix} 1 & [p: l_2, i: 1\ , MaxS: 5] \\ 2 & [p: l_2, i: 2\ , MaxS: 5] \end{pmatrix}$$

1   2

$$l_4: some(x, 12, 13)$$
$$l_4 \leq 14,\ 15 \leq 13$$

$$l_3: some(y, 9, 10)$$
$$l_3 \leq 8,\ 11 \leq 10$$

[i: x, p: 15, MaxS: 14]   [i: y, p: 11, MaxS: 8]

The composition of the focus semantic value of this sentence is shown in (10). Since both NPs are focused, each of them introduces an existential quantifier in the focus representation. Both NPs also include the feature MaxS in their feature structure, whose value is the propositional variable 5. The following feature identities are being performed: 1=x, 2=y, 11=l_2, 8=5, 14=5, l_2=15, so that the maximal scopes of both existential quantifiers 8 and 14 are identified with the maximal scope of the focused phrases 5. This results in the underspecified representation of scope in the final representation shown in (11):

(11)
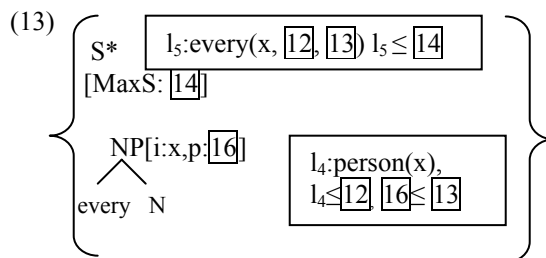|	
$q_3: \lambda p\ [p \wedge 5\ ]$	$l_2 \leq 10$
$l_1: date(x, y)$	$l_2 \leq 5$
$l_2: p= 7$	$l_1 \leq 7$
$l_4: some(x, 12, 13)$	$l_4 \leq 5$
$l_3: some(y, 9, 10)$	$l_3 \leq 5$

The two logically equivalent interpretations which respect scope constraints are given in (12).

(12) $\lambda p[\ p \wedge some(y, 9, some(x, 12, p=date(x, y))]$
    $\lambda p[\ p \wedge some(x, 12, some(y, 9, p=date(x, y))]$

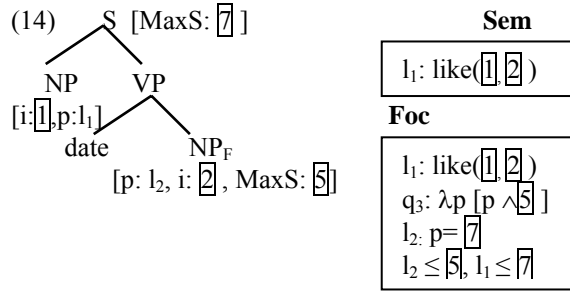## 3.3   Deriving Scope of Quantificational NPs

And, finally, let us consider a sentence with a quantificational NP, such as 'Everybody likes $Bill_F$'. The set of alternatives in this case is the set of propositions of the form 'everybody likes y', where everybody has narrow scope with respect to the indefinite quantifier. The analysis of scope of wh-phrases is discussed in detail in Romero et al 2004, where right scope interpretations are achieved by introducing MaxS features and scope constraints for quantificational and wh-phrases, which are both analyzed as multi-component TAGs. If the focused constituent is not multi-component, and the indefinite quantifier is introduced by a NP tree, as we suggested above, the question which arises is whether we can derive the desired scope interpretations.

The multi-component representation of the quantifier 'everybody' and its semantics[3] is shown in (13):

(13)
$$S^* \quad l_5: every(x, 12, 13)\ l_5 \leq 14$$
$$[MaxS: 14]$$

$$NP[i:x, p: 16]$$
$$l_4: person(x),$$
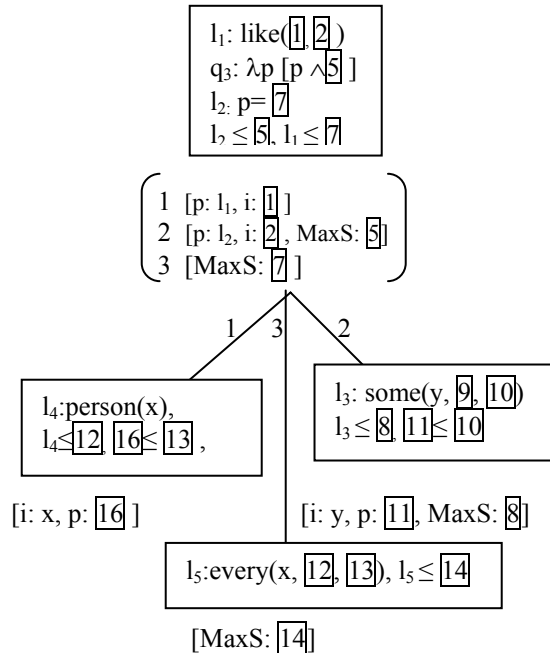$$l_4 \leq 12,\ 16 \leq 13$$

every   N

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[3] Since 'everybody' is not focused, its ordinary and focus representations are the same.

The feature structures associated with the S node and non-focused NP are modified as follows, following Romero et al 2004:
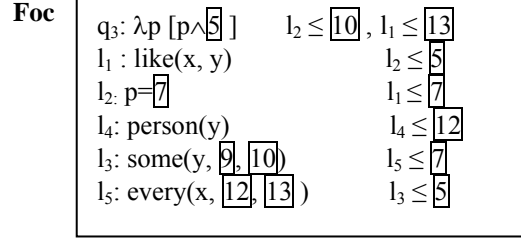
(14)

```
          S [MaxS: 7 ]
         /        \
       NP          VP
   [i: 1, p:l₁]   /   \
              date     NPF
                  [p: l₂, i: 2 , MaxS: 5 ]
```

Sem

l₁: like(1 , 2)

Foc

l₁: like(1 , 2)
q₃: λp [p ∧ 5]
l₂: p= 7
l₂ ≤ 5 , l₁ ≤ 7

Semantic composition of the focus semantic value of the sentence 'Everybody likes Bill$_F$' is shown below. The MaxS feature of 'everybody' is introduced by the S-tree, as previous analyses assume, however, the MaxS feature of the focused phrase is introduced by the NP-tree. Given that the NP$_F$ constituent is semantically composed with the same S tree, this modification will not change the resulting interpretation. Performing feature unifications leads to the following feature identities: 1 =x, 2 =y, 11 =l₂, 8 = 5 , 14 = 7 , 16 =l₁, so that the MaxS feature of the focused phrase is unified with 5 , and the MaxS scope of the quantifier is unified with 7 .

(15) Everybody likes Bill$_F$

l₁: like(1 , 2)
q₃: λp [p ∧ 5]
l₂: p= 7
l₂ ≤ 5 , l₁ ≤ 7

```
1  [p: l₁, i: 1 ]
2  [p: l₂, i: 2 , MaxS: 5 ]
3  [MaxS: 7 ]
```

1 ⟋ 3 ⟍ 2

l₄:person(x),
l₄≤ 12 , 16 ≤ 13 ,

[i: x, p: 16]

l₃: some(y, 9 , 10)
l₃ ≤ 8 , 11 ≤ 10

[i: y, p: 11 , MaxS: 8]

l₅:every(x, 12 , 13), l₅ ≤ 14

[MaxS: 14]

The final focus representation of this sentence is shown below:

Foc

q₃: λp [p∧ 5]   l₂ ≤ 10 , l₁ ≤ 13
l₁ : like(x, y)   l₂ ≤ 5
l₂: p= 7   l₁ ≤ 7
l₄: person(y)   l₄ ≤ 12
l₃: some(y, 9 , 10)   l₅ ≤ 7
l₅: every(x, 12 , 13) l₃ ≤ 5

This representation gives us the desired scope interpretation:

(16) λp[p∧some(y, 9 , p=every(y, person(y) , like(x, y))]

4 Focusing Adverbs.

Let us now turn to sentences with focus-sensitive quantifiers, illustrated in (17a). Given the interpretation of this sentence in (17b), it is true in case any proposition of the form 'Mary dated y' is a proposition 'Mary dated Bill'.

(17)   a. Mary only dated Bill$_F$
       b. ∀q(q ∧ λp [∃y (p= date(m, y)](q) ->
          q=date(m, b))

In Rooth 1985, compositional interpretation of sentences with focus-sensitive quantifiers proceeds in such a way that 'only' takes two arguments: the ordinary semantic value and the focus semantic value of its sister constituent. The ordinary semantic value of the sister of 'only' specifies the nuclear scope of the universal quantifier, whereas the focus semantic value specifies its restrictive clause.
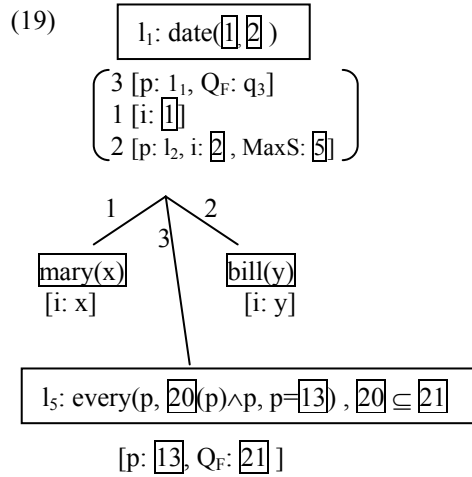
The LTAG based analysis of focus-sensitive adverbs proposed in this section follows this approach in assuming that focusing adverbs like 'only' quantify over sets of alternatives determined by the focus representation. We further assume that this type of quantifiers does not introduce focus semantic values.[4] Specifically, the semantic representation and feature structures associated with the elementary tree headed by 'only' is given in (18):

(18)

```
        VP  [p: 13 , Q_F: 21 ]
       /    \
    only    VP*
```

l₅: every(p, 20 (p)∧p, p= 13) , 20 ⊆ 21

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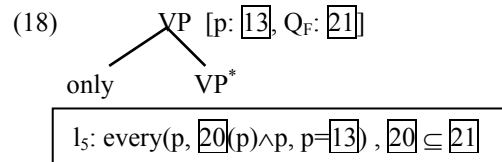
[4] This assumption does not apply to sentences with two or more focus-sensitive quantifiers, in which case we probably need two or more focus representations. The analysis of sentences of this type is left for future research.

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The feature structure of the VP node in (18) introduces a new feature Q_F, which ranges over sets of propositions. Furthermore, we assume that the index 'F' on this feature indicates that its value is a label or a variable in the focus semantic representation.
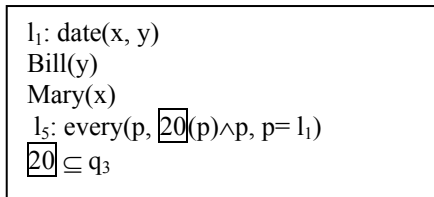
The feature Q_F is also added to the VP node of the S-tree, as part of its 'top' feature structure. Composition of the ordinary semantic representation under these assumptions is shown in (19):

(19)

$$l_1: \text{date}(\boxed{1}, \boxed{2})$$

$$\begin{pmatrix} 3 \ [p: l_1, Q_F: q_3] \\ 1 \ [i: \boxed{1}] \\ 2 \ [p: l_2, i: \boxed{2}, \text{MaxS}: \boxed{5}] \end{pmatrix}$$

```
        1       2
           3
  mary(x)      bill(y)
  [i: x]       [i: y]
```

$$l_5: \text{every}(p, \boxed{20}(p) \wedge p, p = \boxed{13}), \boxed{20} \subseteq \boxed{21}$$

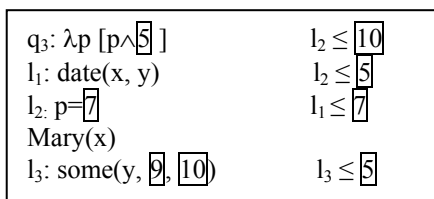$$[p: \boxed{13}, Q_F: \boxed{21}]$$

Performing feature unifications leads to the following identities: $\boxed{1} = x$, $\boxed{2} = y$, $\boxed{21} = q_3$, $\boxed{13} = l_1$, where the label q_3 is part of the focus representation of this sentence (compositional interpretation of the focus representation is shown in (8)).

As the final ordinary and focus semantic representations show, the variable q_3, which corresponds to the set of alternatives is shared by the two representations. This assumption contradicts our original proposal that the two representations are viewed as being completely independent of each other.

Sem:

$$\begin{array}{l} l_1: \text{date}(x, y) \\ \text{Bill}(y) \\ \text{Mary}(x) \\ l_5: \text{every}(p, \boxed{20}(p) \wedge p, p = l_1) \\ \boxed{20} \subseteq q_3 \end{array}$$

Foc:

$q_3: \lambda p \ [p \wedge \boxed{5}]$	$l_2 \leq \boxed{10}$
$l_1: \text{date}(x, y)$	$l_2 \leq \boxed{5}$
$l_2: p = \boxed{7}$	$l_1 \leq \boxed{7}$
$\text{Mary}(x)$	
$l_3: \text{some}(y, \boxed{9}, \boxed{10})$	$l_3 \leq \boxed{5}$

The analysis of sentences with 'only' proposed above follows Rooth 1985 in assuming that the restrictive clause of the focus-sensitive quantifier is identified with the focus semantic value as the result of semantic composition. This approach is known as a semantic theory of focus. On the other hand, Rooth 1992, 1996, von Fintel 1994, Schwarzschild 1997 develop pragmatic theories of focus interpretation, which assume that the restrictive clause of the quantifier 'only' is a pragmatically determined variable, which can be optionally linked to the focus semantic value as the result of pragmatic factors.

The two approaches have different consequences for the present analysis of focus. Under the pragmatic approach, the restrictive clause (i.e. the variable $\boxed{20}$ in (19)) is not identified with the label q_3 as the result of semantic composition, but is left as a free (i.e. pragmatically determined) variable. The semantic and focus interpretations can thus be viewed as being completely separate. The feature Q_F is also not needed in this case. However, this approach is problematic in view of the data discussed in the recent paper by Beaver and Clark 2003, who showed that there is a difference in the interpretation of focus in the case of sentences with 'only' and adverbs of quantification. For example, as illustrated by the data in (20)-(23), presuppositions can override the placement of focus in the interpretation of sentences with 'always', but not in the case of 'only' :

(20) Mary always managed to complete her [exams]_F

Whenever Mary took exams, she completed them
?Whenever Mary completed something, it was an exam

(21) Mary only managed to complete her [exams]_F

*What Mary did when taking exams was completing them
What Mary completed was an exam and nothing else

(22) Mary always remembers to go to [church]_F

Whenever it's time for church, Mary remembers to go
?Whenever Mary remembers to do something, it's always to go to church

(23) Mary only remembers to go to [church]_F

*The only thing Mary does when it's time to go to church, is remember to go
The only place Mary remembers to go is church.

6

Given these data as well as other contrasts in the behavior of 'only' and 'always', Beaver and Clark 2003 suggest that focus-sensitivity of operators like 'only' results from a grammatical mechanism,   whereas quantifiers like 'always' are focus-sensitive as the result of pragmatic factors. In order to distinguish between the two types of focus-sensitivity, we proposed a semantic analysis of focus in the case of 'only', which relies on the assumption that some features allow us to relate a variable in the ordinary semantic representation with a label in the focus representation.

5   Adverbs of Quantification.

Adverbs of quantification are analyzed below as quantifiers over events or situations (Berman 1987, von Fintel 1994 among others).   These quantifiers are focus-sensitive, as the examples in (24)-(25) illustrate. The sentence in (24), with 'John' being focused, has the following interpretation: 'most minimal situations in which Mary took somebody to the movies are situations where Mary took John to the movies'. The sentence in (25), on the other hand, is understood as 'most minimal situations where somebody took John to the movies are situations where Mary took John to the movies'.
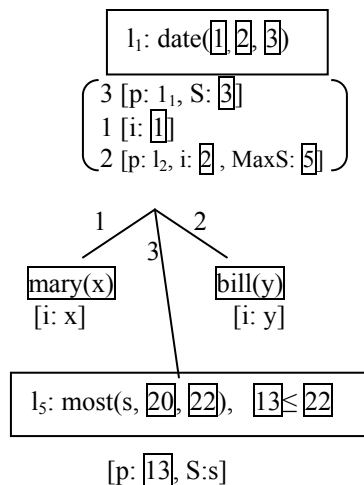
(24)   a. Mary usually took JOHN to the movies.
            b. most(s, $\exists$x (take-to-the-movies(m, x, s)), take-to-the-movies(m, j, s))
(25)   a. MARY usually took John to the movies
            b. most(s, $\exists$x (take-to-the-movies(x, j, s)), take-to-the-movies(m, j, s))

The semantic representation and feature structures of the quantifier 'usually' is given in (26). As in the case of 'only', focus-sensitive adverbs do not have a focus semantic value. Unlike 'only', the restrictive clause of the quantifier is left as a free variable:

(26)   VP [p: [13]]

        usually   VP*

        l_5: most(s, [20], [22]),   [13]≤[22]
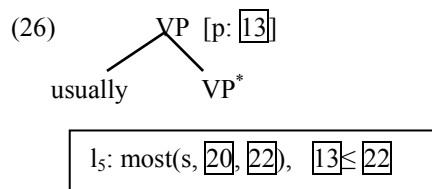
Composition of the ordinary semantic representation of the sentence 'Mary usually dated Bill_F, where 'Bill' is focused, is given in (27). The semantic representations and feature structures in these representations include situation variables (see also Romero et al 2004).

(27) Mary usually dated Bill_F

        l_1: date([1], [2], [3])

        3 [p: l_1, S: [3]]
        1 [i: [1]]
        2 [p: l_2, i: [2] , MaxS: [5]]

                1   2
                       3
        mary(x)   bill(y)
        [i: x]   [i: y]

        l_5: most(s, [20], [22]),   [13]≤[22]

            [p: [13], S:s]

Performing feature unifications leads to the following identities: [1]=x, [2]=y, [13]=l_1 and [3]=s, and results in the following final interpretation:

Sem:

        l_1: date(x, y, s)
        Bill(y)
        Mary(x)
         l_5: most(s, [20], [22])
        l_1 ≤ [22]
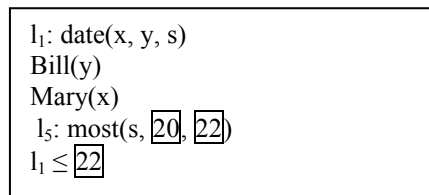
The propositional variable [20], which corresponds to the restrictive clause of the quantifier is left as a free, i.e. pragmatically determined, variable.

6   Conclusion

This paper proposed an analysis of focus which assumes alternative semantics proposed in Rooth 1985 and LTAG semantic unification framework, developed in Kallmeyer and Joshi 2003 and Kallmeyer and Romero 2004. The analysis of focus presented in the paper assumes that each elementary tree is associated with two semantic representations: its ordinary semantic representation and its focus representation, and that the same feature structures are being used for the compositional interpretation of both representations. Whereas the focus representation is analyzed parallel to questions, we have proposed that focused constituents differ from the corresponding wh-phrases in that they are not analyzed as multi-component TAGs, and the existential quantifier is introduced by the NP-tree, rather than the S-tree. We further have shown that given the semantic framework with feature structures, developed in Kallmeyer and Romero 2004, this modification does not present difficulties for the analysis of scope.

The present analysis of focus has also been extended to two types of focus-sensitive quantifiers. Following Beaver and Clark 2003, it assumed that 'only' differs from adverbs of quantifications in that the restrictive clause of the quantifier is linked to the set of alternatives as the result of a grammatical mechanism. Specifically, we proposed to introduce a new feature which allows us to relate a variable in the ordinary semantic denotation with a label in the focus representation. And, finally, we suggested a possible approach to adverbs of quantification, which were analyzed as focus-sensitive quantifiers over situations.

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