Topical Domain Restrictions

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Abstract

We extend Gawron's (1996) dynamic analysis of domain restriction with an analysis of questions. The obtained semantics allows us to account for the impact of questions on subsequent domains of quantification – notably the domain of focusing operators like *only* – improving on existing analyses of interrogative sentences.

1 Introduction

In Rooth's (1985, 1992) semantic theory of focus, sentences in which focused constituents occur are always interpreted relative to a set of alternatives. The set of alternatives for a sentence like (1) can be derived by substituting the meaning of the focused constituent by the meaning of an alternative of the same category.

(1) John introduced $[\text{Bill}]_{\text{F}}$ to Mary.

For our sentence, the alternatives to Bill are the other elements of D and thus the set of alternatives is $\{\{w: \text{ John introduced } d \text{ to Mary in } w\}: d \in D\}$. For bare focus constituents, this alternative set is used to determine the *appropriateness* conditions of the sentence with the focal constituent, while for cases where the sentence contains a focus sensitive operator like *only*, this alternative set can be used to determine the *truth conditions* of the sentence. Sentence (2a) is correctly predicted to entail that John introduced only one person to Mary, whereas sentence (2b) lacks such entailment.

(2) a. John only introduced $[\text{Bill}]_{\text{F}}$ to Mary.

b. John only introduced Bill to $[\text{Mary}]_{\text{F}}$.

But as Von Stechow (1990) has shown, Rooth's account is not flexible enough to determine the right truth conditions of sentence (3b) in the context of question (3a).

(3) a. Which gentlemen did John already introduce to which of their diner partners?

b. John introduced only $[\text{Bill}]_{\text{F}}$ to $[\text{Mary}]_{\text{F}}$.

Rooth (1985) wrongly predicts that (3b) is false if John already introduced the gentlemen of the diner to each other, but has only started introducing the gentlemen to their lady diner partners. The reason for the false prediction is that in Rooth (1985) the quantification involved by *only* is only sensitive to the alternatives determined by the *focus value* of the sentence, and this focus value is determined in a *context-independent* way with the result that the 'diner-partner' relation is ignored. Rooth (1992) responded by saying that focus values can only put constraints on domains of quantification of *only*, but need not determine it. How this domain of quantification is determined is left to pragmatics.

Large parts of pragmatics have become semantics by looking at things from a *dynamic* point of view. Groenendijk (1999) has recently implemented Groenendijk and Stokhof's (1984) partition theory of questions into dynamic semantics. According to their partition theory, the meaning of a question is the set of meanings of its *complete* (possible) answers. Thus, the meaning of a question like (4) is identified with the set of propositions $\{\{v \in W : \{d | d \text{ smokes in } v\} = \{d | d \text{ smokes in } w\} \ \& \ w \in W\}$.

(4) Who smokes?

In Groenendijk (1999), questions partition the context, represented as a subset of the set of relevant alternatives, while answers eliminate cells of this partitioned context. Though appealing, this analysis is not quite satisfactory. First, it fails to account for the intuition that questions influence the domain of quantificational expressions used later on (e.g. *only* in example (3)). Second, if more questions are asked but not yet resolved in the discourse, the partitioned context cannot determine what the influence is of the individual questions, although this is needed to determine whether the answers are appropriate or not. Furthermore, partitions are too *coarse grained* to account for focused and constituent answers. For example, Groenendijk's theory cannot account for the fact that answer (5c) would express a different content as a reply to (5a) than to (5b), for both induce the same partition.

(5) a. Who smokes?

b. Who does not smoke?

c. John

Krifka (2001) has shown that related problems arise also for theories in the Hamblin/Karttunen/Rooth tradition. The standard treatment of alternatives as sets of (propositional) answers is not fined-grained enough and to properly account for questions (and focus) we need something like the *abstracts* that underlie questions: structured propositions. Utilizing the close correspondence between information states in dynamic semantics – sets of world-assignment pairs – and structured propositions, we will show how all the above problems can be solved by introducing questions into Gawron's (1996) dynamic analysis of domain restriction: abstracts correspond to sets of world-assignment pairs associated with variables represented in a Gawronian environment. The obtained analysis of interrogative sentences will combine the empirical strength of the structured meaning approach with the logical appeal of Groenendijk's dynamic theory.

2 Formal Framework

In Gawron's (1996) formalism, the introduction of a quantificational operator is separated by the introduction of the quantificational domain. The latter is allowed to be fixed non locally. The intuition is that domains of quantification are constructed by combining constraints that arise from different sources. These constraints are encoded in so called *environments* which map variables to sets of possible assignments encoding information about which values are possible for them. We propose to interpret the semantic contribution of *questions* in term of extensions of these Gawronian environments. In our formalism an environment will map variables x to sets $e(x)$ of world-assignment pairs. We will take these sets to represent the *topics* under discussion in the current context. Interrogative sentences will be analyzed as setting up new topics, or expanding on previously introduced ones.

On the one hand, these topics correspond to abstracts, therefore our analysis of questions will be fine-grained enough to properly account for phenomena like constituent answers. On the other hand, since from a topic $e(x)$ we can recover the partition it would induce on the information state, we will be able to define all of the logical notions which are relevant for a theory of questions and answers. Finally, since, as in Gawron's original formalism, topics encode domain restrictions we will be able to account for the impact of questions on the domain of subsequent quantificational expressions (like *only* in von Stechow's dining example discussed above).

2.1 The Dynamics of Domain Restrictions

The proposed semantics is an extension of Aloni, Beaver, Clark (1999) (built on Gawron 1996) with an explicit analysis of questions.[1]

The *syntax* of our language is the same as that of standard first-order predicate logic with identity, but with the addition of a question operator '?'. We say that if $x_1, ..., x_n$ is a sequence of variables and ϕ a formula of first order predicate logic, then $?x_1, ..., x_n\phi$ is a formula in our language (see Groenendijk (1998)).

As for the *semantics*, formulae are associated with context change potentials. A context is a pair consisting of an environment e and an information state s. An information state consists of a set of world-assignment pairs, while environments are modeled as partial functions from variables to information states in which these variables are defined. States encode what is known and what antecedents are available for future anaphora; environments encode information about what is merely under discussion. If $c = s_e$ is a context, we will write $S(c)$ for s and $E(c)$ for e.

Elements of a state are called *possibilities*, given a possibility $i = \langle w, g\rangle$, we will write $i(\alpha)$ to refer to the denotation of α with respect to g_i and w_i. As in Dekker (1993), possibilities are ordered by an extension relation $\prec$: j *extends* i, $i \prec j$ iff $w_i = w_j$ & $g_i \subseteq g_j$. This extension relation carries over to an ordering relation between information states: s is a *substate* of t, $s \prec t$ iff $\forall i \in s:\ i \prec t$, where $i \prec t$ iff $\exists j \in t : i \prec j$.

Now we can give a recursive definition of the context-change potential of the formulae of the language. The basic formulae are defined as expected: they can only influence the state parameter s and eliminate possibilities in s in which the formulae are false:

1. $s_e[Pt_1, \dots, t_n] = s'_{e'}$, if $\forall i \in s$ and $\forall k:\ 1 \leq k \leq n \Rightarrow\ i(t_k)$ defined

   (a) $e' = e$

   (b) $s' = \{i \in s \mid < i(t_1), \dots, i(t_n) > \in i(P)\}$

   undefined otherwise.

2. $s_e[t_1 = t_2] = s'_{e'}$, if $\forall i \in s : i(t_1)$ and $i(t_2)$ are defined

   (a) $e' = e$

   (b) $s' = \{i \in s \mid i(t_1) = i(t_2)\}$

   undefined otherwise.

In the interpretation rule of *negation*, we make crucial use of the relation $\prec$. Just like atomic formulae, also negation influences only the state:

3. $s_e[\neg\phi] = s'_{e'}$.

   (a) $e' = e$

[1] Zeevat (1994) and van Rooy (1997) defend similar ideas in somehow different formalisms.

(b) $s' = \{i \in s \mid i \not\prec S(s_e[\phi])\}$

Conjunction is defined as standard in dynamic semantics as sequential update:

4. $s_e[\phi \wedge \psi] = s_e[\phi]\ [\psi]$

Until now the environments played virtually no role. They are crucial, however, for the semantic analysis of *quantified* sentences. If x is already defined in environment e, the update of context with $\exists x\phi$ is defined in terms the *merge* of an information state and the state resulting from applying e to x. The *merging* of information state s with information state s', $s \wedge s'$, is defined as the 'least upper bound' of s and s' (see again Dekker (1993)):

$$s \wedge s' = \{i \mid \exists j \in s : \exists j' \in s' : dom(i) = dom(j) \cup dom(j') \ \&\ j \prec i \ \&\ j' \prec i\}$$

If we define random assignment, $s[x]$, as $\{\langle w, g[x/d]\rangle : \langle w, g\rangle \in s \ \&\ d \in D\}$, we can define the update of s_e with $\exists x\phi$ in terms of this merge-operator as follows:

5. $s_e[\exists x\phi] = s'_{e'}$, if x is not defined[2] in s.

   (a) $e' = e$

   (b) $s' = S((s[x])_e[\phi]) \wedge e(x)$ if $e(x)$ is defined;
   $s' = S((s[x])_e[\phi])$ otherwise.

   undefined otherwise.

Quantificational sentences make use of the environment, but have no influence on these environments themselves. Only *questions* have. The effect of updating context s_e with question $?x\phi$ is that the output environment assigns to variable x a set of possibilities that verify ϕ.[3] Let $e[x_1, ..., x_n]e'$ hold iff $dom(e') = dom(e) \cup \{x_1, ..., x_n\}$ and $\forall x \in dom(e) : x \notin \{x_1, ..., x_n\} \Rightarrow e'(x) = e(x)$.

6. $s_e[?x_1, ..., x_n\phi] = s'_{e'}$

   (a) $e[x_1, ..., x_n]e'$ and $e'(x_i) = S(s_e[\exists x_1, ..., x_n\phi])$ for all $i \in n$.

   (b) $s' = s$

Finally, as in Gawron, we define an operation which copies topics under different labels.

7. $s_e[y \leftarrow x] = s'_{e'}$, if $y \notin dom(e)$

   (a) $e[y]e'$ and $e'(y) = \{i[y/g_j(x)] \mid \exists j \in e(x) \ \&\ i = \langle w_j, g_j \setminus \{\langle x, g_j(x)\rangle\}\rangle\}$

   (b) $s' = s$

Disjunction and implication are defined as standard in terms of conjunction and negation, '$(\phi \vee \psi)$' and '$(\phi \rightarrow \psi)$' stand for '$\neg(\neg\phi \wedge \neg\psi)$' and '$\neg(\phi \wedge \neg\psi)$', respectively. The universal quantifier is defined in terms of the existential quantifier and negation: $\forall x\phi = \neg\exists x \neg\phi$.

[2] As in Heim 1982, variables cannot be reset. So, in addition to formulas containing free variables, quantified sentences are partial updates as well. Since this issue is not directly relevant to the topic of this article, we will pass over it in what follows.

[3] Clause (6) only applies to constituent questions, but our analysis can also be extended to polar questions as shown in Aloni and van Rooy (2002).

Topics and quantification The crucial clauses in the previous definition are the ones of the question operator ? and the existential quantifier $\exists$.

The introduction of a question in a context only modifies the environment parameter. $s_e[?x\phi]$ yields a context $s_{e'}$ where $e'(x)$ is a state which merges the information contained in s and in ϕ with the information possibly contained in $e(x)$. This will be a state in which x is restricted to individuals who are ϕ.

The update of a context with a quantified sentence modifies only the state parameter, but it crucially depends on the value assigned by the environment to the quantified variable. $s_e[\exists x\psi]$ yields a context s'_e where s' depends on $e(x)$ which encodes all of the restrictions previously placed on x.

Topics restrict quantification. In context s_e, question $?xP(x)$ yields a context $s_{e'}$ such that $\langle w, g\rangle \in e'(x)$ only if $g(x) \in w(P)$. After question $?xP(x)$, the update with $\exists xQ(x)$ yields an information state containing only pairs $\langle w, g\rangle$ such that $g(x) \in w(P)$ and $g(x) \in w(Q)$.

2.2 The Logic of Interrogation

Groenendijk (1998, 1999) presents an update semantics for questions. The information change potential of an interrogative is viewed as a way of structuring information (see also Hulstijn (1997)). Questions add structure to an information state by raising an issue. An issue is modeled as an equivalence relation on the possibilities in a state and raising an issue amounts to disconnecting possibilities. Ordinary information states (sets of possibilities) are turned into *structured* states which are equivalence relations on ordinary states. So structured states σ are sets of pairs of possibilities expressing a partition of an ordinary state. If two possibilities i and j are connected in σ this means that the difference between i and j is irrelevant in σ. In this section we will see that topics structure information states. The topics under discussion in a context s_e uniquely determine a partition of the information state s. This fact will enable us to incorporate Groenendijk's logic of interrogation in our framework.

Topics, abstracts and partitions From topics $e(x)$ represented as discourse referents in an environment we can recover both (i) *abstracts*, i.e. functions from possibilities (possible worlds or in our case world-assignment pairs) to sets of (n-tuples of) individuals; and (ii) *partitions*, i.e. equivalence relation over the set of relevant possibilities.

Topics define *abstracts*. Abstracts are functions from states to sets of individuals. The abstract $A_x^{s_e}$ determined by topic $e(x)$ on state s is defined as follows:[4]

Definition 1 [Abstract] Let s_e be a context and x be a variable defined in e. $A_x^{s_e}$ is a function from s into D such that for $i \in s$:

$$A_x^{s_e}(i) = \{g_j(x) \mid i \prec j \ \& \ j \in (s \wedge e(x))\}$$

Intuitively abstract $A_x^{s_e}$ is a function mapping each possibility i in s to the set of individuals which satisfy in i the information encoded by $e(x)$.

From a topic $e(x)$ we can recover the partition $P_x^{s_e}$ it would induce on the current information state s.

Definition 2 [Partition] Let s_e be a context and x be a variable defined in e.

$$P_x^{s_e} = \{\langle i, j\rangle \mid i, j \in s \ \& \ A_x^{s_e}(i) = A_x^{s_e}(j)\}$$

[4]This definition can be easily generalized to the case with n-tuples of variables.

As an illustration consider the topic $e(x) = \{i \mid g_i(x) \in w_i(\text{SPY})\}$ set up by question *Who is a spy?* ($?x$ SPY(x)). The abstract determined by such a topic in context s_e will be the function $A_x^{s_e}$ assigning to each possibility i in s the set of spies in w_i: $A_x^{s_e}(i) = w_i(\text{SPY})$ for all $i \in s$. The partition $P_x^{s_e}$ of s induced by such a topic will contain those possibilities i and j in s such that for all individuals d: d is a spy in w_i iff d is a spy in w_j: $P_x^{s_e} = \{\langle i,j\rangle \mid w_i(\text{SPY}) = w_j(\text{SPY})\}$.

Entailment Building on Groenendijk (1998, 1999), we define entailment in term of subsistence between structured states. By $P(s_e)$ we will denote the partition induced on s by all the topics in e.

Definition 3 $P(s_e) = \bigcap_{x \in dom(e)}(P_x^{s_e})$

Partitions $P(s_e)$ assigned to contexts s_e are equivalent to the structured states σ defined in Groenendijk (1998). Structured states are sets of pairs $\iota = \langle i,j\rangle$ of world-assignment pairs. Groenendijk defines subsistence between structured states in terms of the notion of $\prec$ between world-assignment pairs defined above. A pair $\langle i,j\rangle$ subsists in $\langle i',j'\rangle$, $\langle i,j\rangle \prec \langle i',j'\rangle$ iff $i \prec i'$ & $j \prec j'$. This relation between pairs of possibilities carries over to a relation between structured states: $\sigma \prec \tau$ iff $\forall \iota \in \sigma : \iota \prec \tau$, where $\iota \prec \tau$ iff $\exists \iota' \in \tau : \iota \prec \iota'$.

We can now turn to entailment. We denote by $\min_\phi$ the context of *minimal* information in which an update with ϕ is defined.[5] Following Dekker (1993) we say that a state t is an *update* of s, $s \leq t$ iff $\forall i \in t : \exists j \in s : j \prec i$. This update relation can be carried over to environments and contexts in an obvious way: (i) $e \leq e'$ iff $dom(e) \subseteq dom(e')$ and $\forall x \in dom(e) : e(x) \leq e'(x)$; (ii) $s_e \leq s'_{e'}$ iff $s \leq s'$ and $e \leq e'$. We define $\min_{\phi_1,\ldots,\phi_n} = s_e$ iff $s_e[\phi_1]\ldots[\phi_n]$ exists and $\forall s'_{e'}$: if $s'_{e'}[\phi_1]\ldots[\phi_n]$ exists, then $s_e \leq s'_{e'}$. Entailment between sentences is defined in terms of these minimal contexts.

Definition 4 [Entailment]

(i) $s_e \models \phi$ iff $P(s_e) \prec P(s_e[\phi])$

(ii) $\phi_1, \ldots \phi_n \models \psi$ iff $\min_{\phi_1,\ldots,\phi_n,\psi}[\phi] \models \psi$

A sentence ϕ is entailed in a context s_e iff the structured state induced by s_e survives in the structured state induced by $s_e[\phi]$. While checking on entailment between sentences we only look at the minimal context in which the sentences are defined.

The defined notion of entailment applies uniformly to both interrogative and indicative sentences exactly as in Groenendijk (1998-99). In this section we will use $\phi?$ and $\phi!$ to denote interrogative and indicative sentences respectively.

An indicative is entailed in a context, $s_e \models \phi!$, if it does not bring about new information. An interrogative is entailed in a context, $s_e \models \phi?$, if the issue it raises is already present in the context, although possibly under a different label.

An entailment $\phi \models \psi$ means that ψ is superfluous after ϕ. When applied to indicative sentences, $\models$ corresponds to entailment in D(ynamic) P(redicate) L(ogic) (see Groenendijk and Stokhof (1991)). $\phi! \models \psi!$ means that ψ after ϕ does not bring about new information. The following is a classical example of a valid entailment in DPL: $\exists x P(x) \models P(x)$. *[A man]$_i$ smokes* entails *He$_i$ smokes* since the anaphoric pronoun in the second sentence is co-indexed with the indefinite in the previous sentence.

When applied to interrogative sentences, $\models$ corresponds to the classical Groenendijk and Stokhof's (1984) notion of entailment between questions. $\phi? \models \psi?$

[5] Note that there is always a unique minimal context with this property.

means that whenever the issue raised by $\phi?$ is resolved, the issue raised by $\psi?$ must also be resolved, so answering $\phi?$ yields a complete answer to $\psi?$. An example of a valid entailment between questions is $?xyR(x,y) \models ?yR(y,a)$. If we give a complete answer to question *Who invited whom?* we cannot fail to give a complete answer to the entailed question *Who invited Adam?*. Note further that we have that $?xP(x) \models ?yP(y)$, so the label under which an issue is encoded is irrelevant in this case. It is not irrelevant in general, as it is evident from the following facts which illustrates one of the crucial features of this formal system which will be exploited later on: a quantified sentence is automatically restricted by a preceding question if the two are co-indexed.

(i) $?x\phi \wedge \exists x\psi \ \models \ \exists y(\phi[x/y] \wedge \psi[x/y])$

(ii) $?x\phi_1 \wedge \ldots \wedge ?x\phi_n \wedge \exists x\psi \ \models \ \exists y((\phi_1[x/y] \wedge \ldots \wedge \phi_n[x/y]) \wedge \psi[x/y])$

(iii) $?x\phi \wedge \forall x\psi \ \models \ \forall y(\phi[x/y] \rightarrow \psi[x/y])$

(iv) $?x\phi_1 \wedge \ldots \wedge ?x\phi_n \wedge \forall x\psi \ \models \ \forall y((\phi_1[x/y] \wedge \ldots \wedge \phi_n[x/y]) \rightarrow \psi[x/y])$

Note that $\models$ is not monotonic.

(v) $\forall xPx \models \forall yPy$, but

(vi) $?xPx \wedge \forall xPx \not\models \forall yPy$

Finally, $\phi! \models \psi?$ can be read as $\phi!$ gives a *complete answer* to $\psi?$. For instance $\forall x(S(x) \leftrightarrow x = a) \models ?yS(y)$ is a valid entailment. Sentence *Only Adam smokes* completely answers question *Who smokes?*.

Following Groenendijk (1999) we can also define other logical notions, notably the notion of licensing which applies non-trivially only to indicatives in his system.[6]

Definition 5 [Licensing]

(i) $s_e \propto \phi$ iff $\forall \langle i,j \rangle \in P(s_e) : \langle i,i \rangle \notin P(s_e[\phi]) \Rightarrow \langle j,j \rangle \notin P(s_e[\phi])$

(ii) $\phi \propto \psi$ iff $\min_{\phi\wedge\psi}[\phi] \propto \psi$

An indicative is licensed after a question iff it exclusively addresses the issue raised by the question. Groenendijk uses licensing to characterize Grice's maxim of relation. See van Rooy (1999) and ten Cate (2002) for more sophisticated characterizations of the notion of relevance, which apply to both interrogatives and indicatives and which also could be implemented in the present semantics.

To conclude, since from topics we can recover partitions, we can define, as in Groenendijk (1999), the logical notions which are relevant for a theory of questions and answers. But, since topics correspond to abstracts, we can improve on Groenendijk's theory with respect to a number of phenomena, for instance focused and constituent answers, as we will see in the following section.

3 Applications

In this section, we will show how the formalism presented in the previous section allows us to solve the problems discussed in the introductory part of the present article. The first application concerns constituent answers.

[6]See Aloni & van Rooy (2002) for an extension of this notion which also applies to questions.

3.1 Constituent answers

As already mentioned in the introduction, a partition theory of questions cannot account for the fact that one and the same constituent answer, say *John*, can express different contents if used as reply to different questions like:

(6) Who smokes?

(7) Who does not smoke?

This is because questions (6) and (7) induce exactly the same partition, as it is easily checked. G&S (1984) solved the problem by associating questions with both a partition and an abstract. The formalism introduced in the previous section avoids the problem with no need of this double coding. Let us have a closer look.

We propose to represent a constituent answer as an existential sentence the domain of which is crucially restricted by the preceding question. Constituent answers like (8a) and (9a) are analyzed as in (8b) and (9b):

(8) a. John.

b. $\exists y_x(j = y)$

(9) a. John and Mary.

b. $\exists y_x(j = y) \wedge \exists z_x(m = z)$

where $\exists y_x\phi$ is short for $y \leftarrow x \wedge \exists y\phi$.

It is easy to see that, given this representation, we can account for the fact that constituent answers express different contents if used as reply to questions like (6) and (7) above. This is because although the two questions induce the same partition on the current state, they crucially set up different topics in the environment.

Fact 1

(i) $?xS(x) \wedge \exists y_x(j = y) \wedge \exists z_x(m = z) \models S(j) \wedge S(m)$

(ii) $?x\neg S(x) \wedge \exists y_x(j = y) \wedge \exists z_x(m = z) \models \neg S(j) \wedge \neg S(m)$

In order to account for quantified answers like *all men* or *most men*, which lack a proper first order representation we need a higher order theory exactly as in the structured meaning account of these phenomena.

3.2 Focus

In the present analysis focus expresses conditions on the kind of context in which the associated utterance can occur. Focus is presuppositional (see for instance Roberts (1996)). Focal sentences presuppose questions.

We use Beaver's partial operator ∂ to denote *presupposition*. We extend the language in such a way that only questions can occur in the scope of ∂. As is standard in dynamic semantics (see Stalnaker, Heim and Beaver) presuppositions are analyzed as conditions on the input context which has to be satisfied before the sentence can be interpreted with respect to that context. A presupposed question expresses a condition on the environment part of the context. $\partial[?x\phi]$ expresses the presupposition that the ϕs are among the topics under discussion in the current environment under label x.

Definition 6 [Presupposed topics]

$$s_e[\partial ?x_1, ..., x_n\phi] = s_e \quad \text{iff} \quad (s \wedge e(x_i))_e \models \phi \text{ for all } i : 1 \leq i \leq n$$

$\partial[?x\phi]$ is defined in a context s_e only if the state obtained by merging s with the topic assigned by e to x verifies ϕ. Provided this condition is met, the update of a context with $\partial[?x\phi]$ yields the input context as result.

Accommodation is built in the notion of entailment (see Beaver (1995)). According to the definition given in the previous section, a sentence ϕ entails another sentence ψ iff $\min_{\phi,\psi}$, i.e., the minimal context in which updates with the sentences are defined, updated with ϕ is a context which supports ψ. So while checking on entailment we restrict ourselves to contexts which minimally satisfy the presupposition of the sentences involved. The following are typical examples of valid entailments:

(i) $\partial[?x\phi] \wedge \exists x\psi \models \exists y(\phi[x/y] \wedge \psi[x/y])$

(ii) $\partial[?x\phi] \wedge \forall x\psi \models \forall y(\phi[x/y] \rightarrow \psi[x/y])$

We propose to represent focus in terms of presupposition of topics under discussion which can be accommodated. Focus triggers the presupposition that the so-called 'background' is among the topics under discussion at the moment of the utterance.

A sentence like (10a) with the item 'Mary' in focus is represented as in (10b).

(10) a. John loves $[\text{Mary}]_\text{F}$.

b. $\partial[?xL(j,x)] \wedge \exists x(x = m)$

(10b) presupposes the previous introduction, as topic, of a set of individuals (those loved by John) and, since topics restrict quantification, it asserts that the item in focus (Mary) belongs to that set. A typical example of a sentence introducing such a topic would be the explicit question

(11) Who does John love?

Note that from (10b) we can recover the ordinary meaning of the sentence:

Fact 2 $\partial[?xL(j,x)] \wedge \exists x(x = m) \models L(j,m)$

(10b) entails the ordinary meaning of (10a), but it also represents the information structure of the sentence.

3.3 Association with focus

As in Aloni et al (1999) we assume that focus has two roles: the first role is that of introducing a certain presupposition; the second role is to identify the focused variable to focusing operators such as *only.* We treat *only* as an indexed sentential operator only_x, where x is the associated focused variable. The interpretation of only_x involves a universal quantification automatically restricted by the presupposition expressed by the associated focus.

Definition 7 $s_e[\text{only}_x(\phi)] = s'_{e'}$

1. $e = e'$

2. $s' = \{j \in s \mid \{i \mid j \prec i \;\&\; i \in (s \wedge e(x))\} \subseteq \{i \mid i \prec S(s_e[\phi])\}\}$

As an illustration consider the following example. The sentence in (12a) receives the representation in (12b).

(12) a. John only loves $[\text{Mary}]_F$.

b. $\text{only}_x(\partial[?xL(j,x)] \wedge \exists x(x = m))$

Note that although an existential binds the focused variable x, the operator *only* has the effect of changing the quantificational force, in much the same way as in the standard dynamic analysis of (un)selective binding. (12b) is interpreted as asserting that each x is equal to Mary. Since the sentence is defined only in contexts in which the topic $?xL(j,x)$ has already been introduced, the domain of quantification will contain only individuals who John loves. In a neutral context, (12a) means 'John loves nobody but Mary', as in Rooth (1985).

Fact 3 $\text{only}_x(\partial[?xL(j,x)] \wedge \exists x(x = m)) \models \forall x(L(j,x) \to x = m)$

3.4 Context sensitivity

Among the advantages of a treatment which represents focus by presupposing the background as a domain restriction is that we have a straightforward account of the fact that the quantificational domain of *only* can be further restricted by the context, in particular by a preceding question. Consider the following dialogues:

(13) a. Who is wise?

b. $?xW(x)$

c. Only $[\text{Socrates}]_F$ is wise.

d. $\text{only}_x(\partial[?xW(x)] \wedge \exists x(s = x))$

(14) a. Which Athenians are wise?[7]

b. $?x(A(x) \wedge W(x))$

c. Only $[\text{Socrates}]_F$ is wise.

d. $\text{only}_x(\partial[?xW(x)] \wedge \exists x(s = x))$

The relevant observation due to Gerhard Jäger in (1996) is that the answers in (13) and (14) although identical at the surface have different meanings. (13c) means 'nobody but Socrates is wise'; (14c) means 'there are no wise Athenian but Socrates'. We have a straightforward account of this contrast, as illustrated by the valid entailments in the following fact.

Fact 4

(i) (13d) $\models \forall y(W(y) \to y = s)$

(ii) (14d) $\models \forall y((W(y) \wedge A(y)) \to y = s)$

In the first dialogue, the quantification is automatically restricted to wise men, in the second to wise Athenians. Our system matches Jäger's (1996) predictions on these cases. Example (14) shows that domain restrictions can be constructed by combining constraints that arise from different sources. The restriction on x triggered by the focus is combined with the restriction placed by the which-clause in the preceding question. This same context-dependence of interpretation also allows us to account for Rooth's problem, as noted by von Stechow, discussed in the introduction.

[7] The simple analysis of which-interrogatives assumed in (14) is not satisfactory, but it suffices to make the point here. See the next application for a better analysis.

3.5 Which-questions

In this last section we will discuss a further application of the present semantics which concerns which-questions. According to Groenendijk & Stokhof's (1984) question semantics, a question like (15a) is represented as (15b).

(15) a. Which men are bald?

b. $?x(M(x) \wedge D(x))$

This gives rise to the prediction that (15a) is equivalent to (16):

(16) Which bold persons are men?

However, this seems wrong for *indirect questions*, i.e. questions embedded under verbs like *know*, as observed by Bäuerle & Zimmermann (1991), but also for *direct* questions as illustrated by the following pair due to Stanley Peters (see also Higginbotham (1996)):

(17) Which men are bachelors?

(18) Which bachelors are men?

Intuitively, these two questions are different. While the first question is answered by a characterization of the bachelors among the men, the second is a trivial question. As Groenendijk & Stokhof (1997) note, the 'search routines' for (17) and (18) seem different: whereas (17) suggests to search among the men to find the bachelors, (18) suggests to search among the bachelors to find the men and therefore it is a trivial question. This difference in search procedure is closely related with the syntactic notion of *D-linking* (Comorovski (1985) and Pesetsky (1987)). A Discourse-linked (D-linked) *wh*-phrase is a phrase whose denotation ranges over a contextually given set. It is commonly assumed that *which*-phrases are always D-linked. To account for the difference between (15a) and (15b), we will assume that a D-linked *wh*-phrase – so a *which*-phrases in particular – gives rise to the presupposition that the set over which it ranges is already given as a *topic*. To account for this we will represent *which*-questions as follows:

(19) a. Which men are bald?

b. $?y_x(\partial[?xM(x)] \wedge D(y))$

Where $?y_x\phi$ is short for $y \leftarrow x \wedge ?y\phi$. We can now distinguish between (17) and (18) which are represented as follows:

(20) a. Which men are bachelors?

b. $?y_x(\partial[?xM(x)] \wedge B(y))$

(21) a. Which bachelors are men?

b. $?y_x(\partial[?xB(x)] \wedge M(y))$

Although the two questions determine the same partition, under the assumption that in all worlds all bachelors are men, (21) is vacuous whenever defined. In distinction with (20) which is not a trivial question.

Fact 5

(i) $\not\models ?y_x(\partial[?xM(x)] \wedge B(y))$

(ii) $\models ?y_x(\partial[?xB(x)] \wedge M(y))$

4 Conclusion

In this article we have analyzed within dynamic semantics how questions can restrict the domain of quantificational sentences used later in a discourse. We have done this by extending Gawron's (1996) dynamic model of domain restriction with an explicit analysis of questions. The obtained semantics incorporates Groenendijk's (1999) Logic of Interrogation, but improves on it by introducing (basically) the abstracts underlying the questions to the discourse. In this way we are able to account for the context-dependent meaning of constituent-answers, free focus, association with focus and how the domain of focus sensitive operators like *only* can be determined by a previous question.

Traditionally, linguists have thought in two different ways of a topic: either as the question under discussion, or as the individual talked about. By analyzing questions as discourse referents in an environment, our dynamic analysis suggests that both ways of thinking are two sides of the same coin.

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