Predicting the distribution of exhaustive inference in a QUD-model*

Wataru Uegaki

Massachusetts Institute of Technology

1. Exhaustive inference and polarity-matching

EXHAUSTIVE INFERENCES (ExhInf) of question answers have been a locus of much discussion in the semantics and pragmatics of interrogatives and scalar implicature (e.g., Groenendijk and Stokhof 1984; Sauerland 2004; Schulz and van Rooij 2006; Spector 2007). Despite the abundance of literature on the topic, however, one particular aspect of ExhInfs has attracted relatively less attention: ExhInfs are conditioned by whether the *polarity* of the answer matches that of the question (Schulz and van Rooij 2006; Spector 2007, *pace* von Stechow and Zimmermann 1984), as shown below.

(1) Who among Ann, Bill and Carol will you invite?
   a. I will invite Ann. $\rightsquigarrow$ **ExhInf**: Ann is the only person I will invite.
   b. I won't invite Ann. $\overset{??}{\rightsquigarrow}$ **ExhInf**: Ann is the only person I won't invite.

(2) Who among Ann, Bill and Carol will you not invite?
   a. I won't invite Ann. $\rightsquigarrow$ **ExhInf**: Ann is the only person I won't invite.
   b. I will invite Ann. $\overset{??}{\rightsquigarrow}$ **ExhInf**: Ann is the only person I will invite.

The basic generalization here is that an ExhInf is available if and only if the polarity of the answer matches that of the question. (See Hirsch 2014 for experimental support for this generalization; We will see a refined version of the generalization that takes intonation into account in Section 3.) To capture this generalization, we need a suitable constraint on the set of ALTERNATIVES in the current theories of ExhInf, whether it is a Gricean pragmatic theory or a grammatical theory. However, it is not obvious how such a constraint can be accurately formulated in the current theories of alternatives. In the next section, we will see problems for the two existing theories of alternatives: the formal alternatives theory by Katzir (2007) and Fox and Katzir (2011) and question-based theory along the lines of Groenendijk and Stokhof (1984) and Spector (2007).

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The goal of this paper is to supplement the question-based theory of alternatives with the theory of discourse structure consisting of Questions under Discussion (QUDs; Roberts 1996; Büring 2003). The resulting theory will correctly account for the generalization about the interaction between ExhInf and polarity-matching mentioned above, including a more detailed data point concerning intonation. Also, I will discuss the advantage of the current theory to the alternatives proposed by Schulz and van Rooij (2006) and Spector (2007).

2. Problem with the common theories on alternatives

In this section, after briefly reviewing the existing theory of ExhInf based on the notion of alternatives, we present the problem of polarity-matching with respect to two common theories of alternatives, i.e., structural alternatives theory and question-based theory.

2.1 Derivation of ExhInf using alternatives

The basic data of ExhInfs is accounted for either by the Gricean theory or by the grammatical theory of quantity implicature. Since the page space is limited and the two theories do not make distinct predictions with respect to the empirical scope of the current paper, I will only review the grammatical theory of ExhInfs along the lines of Fox (2007) and Chierchia et al. (2012). See Sauerland (2004), Schulz and van Rooij (2006) and Spector (2007) for the treatment of ExhInf in a Gricean theory of quantity implicature.

In a grammatical theory, an ExhInf is derived by the application of the operator Exh, which is defined as in (3a), where Innocent Exclusion, IE, is defined in (3b) (Fox 2007).

(3) a. $[\![\text{Exh}]\!]^w(Q_{\langle st,t\rangle})(p_{\langle s,t\rangle})(w) \overset{\text{def}}{\Leftrightarrow} p(w) \wedge \forall q \in \mathsf{IE}(p,Q)[\neg q(w)]$

b. $\mathsf{IE}(p,Q) := \bigcap\{ Q' \subseteq Q \mid Q' \text{ is maximal s.t., } \bigwedge_{p' \in Q'}[\neg p'] \cup \{p\} \text{ is consistent}\}$

In the case of (1a), the argument p corresponds to the prejacent proposition 'I will invite Ann', and Q corresponds to the set of alternatives as follows, where A, B and C denote the propositions 'I will invite Ann', 'I will invite Bill' and 'I will invite Carol', respectively.

(4) $\{A,\ B,\ C\}$

Applying Exh to the prejacent of (1a) and (4) results in (5), which is precisely the ExhInf observed in (1a) conjoined with the assertion.

(5) $[\![\text{Exh}]\!]^w(\{A,B,C\})(A) = 1 \text{ iff } A(w) \wedge \neg B(w) \wedge \neg C(w)$

In the next two sections, I will review two common theories that constrain the set of alternatives in (4), i.e., the structural alternatives theory and the question-based theory, and point out that both theories have their own shortcomings in dealing with the polarity mismatch data introduced in the previous section.

2.2 Structural alternatives (Katzir 2007; Fox and Katzir 2011)

The STRUCTURAL ALTERNATIVES theory by Katzir (2007) and Fox and Katzir (2011) states that an alternative for S is derived by replacing a constituent of S with either (i) a lexical item, (ii) another subconstituent of S, or (iii) a contextually salient constituent.

This mechanism predicts the set of alternatives for (1a) is (6) by replacing the object DP with other relevant names, i.e., *Bill* and *Carol*.

(6) $Alt((1a)) = \{A, B, C\}$

As we saw in the previous section, this set of alternatives leads to the correct ExhInf. On the other hand, the set of alternatives for the negative answer to the positive question, (1b), will be the following set in (7) since, in addition to replacing the object DP, we also have the option of replacing the VP *won't invite Mary* with *will invite Mary*, which is a subconstituent of the original utterance, (1b).

(7) $Alt((1b)) = \{A, B, C, \neg A, \neg B, \neg C\}$

The set (7) consists of so-called symmetric alternatives i.e., pairs of propositions that contradict each other. This results in there being no innocently excludable alternative in (7) (i.e., $\neg\exists q \in \mathsf{IE}(A, \{A, B, C, \neg A, \neg B, \neg C\})$), which means that no proposition is negated by the application of Exh to (1b) with respect to (7). Thus, the theory correctly predicts that (1b) lacks an ExhInf.[1]

So far, so good. However, the structural alternatives theory makes an incorrect prediction in the case of (2a), the negative answer to the negative question. Here, the mechanism of structural alternatives generates the same set of alternatives as (7), viz, the symmetric alternatives. The only difference between (1b) and (2a) is that the question preceding (1b) is positive while that preceding (2a) is negative, and this difference in the preceding context does not make the alternatives for (2a) more restricted than (1b) according to the mechanism. This leads to an empirically incorrect prediction: the structural alternatives theory predicts that (2a) lacks an ExhInf, contrary to fact. In Section 6, I will consider a refinement of this theory based on the focus structure of the sentence that avoids this initial problem.

2.3 Question-based account (Groenendijk and Stokhof 1984; Spector 2007)

The source of the problem with the structural alternatives theory discussed above is that it does not consider the structure of the question. The question-based theory of alternatives rather states that the alternatives for an utterance is directly constrained by the question to which the utterance is a response to in the given discourse, along the lines of Rooth's (1992) focus interpretation principle: In Rooth's theory, the focus alternatives for focus-sensitive adverbs like *only* are constrained by a contextually salient set of propositions. Similarly, the alternatives for Exh can be constrained by the contextually salient set of propositions provided by the preceding question.

In the context of ExhInf, this line of analysis is proposed by Groenendijk and Stokhof (1984), and formulated more concretely in terms of scalar implicature by Schulz and van Rooij (2006) and Spector (2007).[2] Here, I will discuss the predictions made by the

[1] In a Gricean theory along the lines of Sauerland (2004), the strengthening step from the primary implicature to the secondary implicature is blocked if the alternatives are symmetric. Thus, we derive the same prediction that there is no ExhInf.

[2] Technically, the formulations in Groenendijk and Stokhof (1984) and Schulz and van Rooij (2006) are different from that of Spector (2007) in (among other things) using what they call a QUESTION ABSTRACT of

Exh-operator introduced above if the alternatives are constrained by the denotation of the preceding question. The more refined analysis by Spector (2007) which addresses the problem of polarity mismatch is discussed in Section 6.

The basic idea of the question-based theory is that the first argument of Exh, i.e., the set of alternatives, is provided by the preceding question denotation. Assuming the Hamblin (1973) style question denotation, the positive question (1) has the denotation in (8).[3]

(8) $[\![(1)]\!] = \{A, B, C, A \wedge B, B \wedge C, C \wedge A, A \wedge B \wedge C\}$

Feeding this question denotation to Exh as its first argument, we predict the correct ExhInf for (1a), as follows.

(9) $[\![\text{Exh}]\!]^w((8))(A) = A(w) \wedge \neg B(w) \wedge \neg C(w)$

Similarly, we predict the correct ExhInf for the polarity matching answer in (2a). However, things get tricky if we turn to polarity-mismatching answers. In (1b), the negative answer to the positive question, we make an incorrect prediction by feeding the question denotation (8) to Exh: We predict the ExhInf that no one came, as follows.

(10) $[\![\text{Exh}]\!]^w((8))(\neg A) = \neg A(w) \wedge \neg B(w) \wedge \neg C(w)$

One plausible response to this problem is to say that Exh is simply inapplicable when the focus semantic value of its prejacent would not be a superset of the preceding question, just as in the case of *only* in Rooth's (1992) theory. In other words, Exh is applicable only when Rooth's (1992) QUESTION-ANSWER CONGRUENCE is met. This is the case in (1b) if the focus semantic value of (1b) is as in (11) below, which is not a superset of (8).

(11) $[\![(1b)]\!]^f = \{\neg A, \neg B, \neg C, ...\}$

Nevertheless, this explanation is problematic since a violation of question-answer congruence normally results in infelicity of the sentence rather than the mere lack of ExhInf, as shown in the incongruent question-answer pair below.

(12) Q: Who will you invite? A: # I_F will invite Sue.

Unlike (12A), the negative answer in (1b) *is* a felicitous answer to the positive question in (1) given a suitable intonation. This fact suggests that the question-answer congruence is met in the pair of (1) and (1b) given the intonation. This casts doubt on the account that resorts to the question-answer incongruence in accounting for the lack of an ExhInf in (1b).

To sum up, both the structural alternatives theory and the question-based theory face their own problems in accounting for the interaction between ExhInf and polarity-mismatch. Before proposing a solution to the problems, we will take a closer look at the data with an attention to intonation.

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type $\langle e, st \rangle$ and a Generalized Quantifier denotation of term answers as arguments of the Exh-operator, instead of the set of alternatives of type $\langle st, t \rangle$ and a proposition.

[3]The question denotations here include conjunctive propositions since I assume that the domain of *who* contains pluralities of individuals.

3. A closer look at the data: Intonation and exhaustivity

If we take intonation into account, we see that the interaction between the polarity-matching and ExhInf is more involved than what we saw in Section 1. Below is the relevant examples with C(ontrastive)T(opic) and F(ocus) markings, where CT is typically realized as a fall-rise contour, i.e., Jackendoff's (1972) 'B-accent' while F is typically realized as a falling contour, i.e., Jackendoff's 'A-accent'. Also, '...' indicates a short pause that typically follows a CT-marked constituent.

(13) Q: Who among Sue, Bill and Mary will you invite?
A: I will invite [Sue]$_F$. $\rightsquigarrow$ **ExhInf**: I won't invite Bill and Mary.
A' I [will]$_F$ invite [Sue]$_{CT}$. $\overset{??}{\rightsquigarrow}$ **ExhInf**: I won't invite Bill and Mary.
A": ?? I [will]$_{CT}$ ... invite [Sue]$_F$.

(14) Q: Who among Sue, Bill and Mary will you invite?
A: ?? I won't invite [Sue]$_F$.
A': I [won't]$_F$ invite [Sue]$_{CT}$. $\overset{??}{\rightsquigarrow}$ **ExhInf**: I will invite Bill and Mary.
A" ?? I [won't]$_{CT}$ ... invite [Sue]$_F$.

(15) Q: Who among Sue, Bill and Mary will you not invite?
A: ?? I will invite [Sue]$_F$.
A' I [will]$_F$ invite [Sue]$_{CT}$. $\overset{??}{\rightsquigarrow}$ **ExhInf**: I won't invite Bill and Mary.
A": ?? I [will]$_{CT}$ ... invite [Sue]$_F$.

(16) Q: Who among Sue, Bill and Mary will you not invite?
A: I won't invite [Sue]$_F$. $\rightsquigarrow$ **ExhInf**: I will invite Bill and Mary.
A': I [won't]$_F$ invite [Sue]$_{CT}$. $\overset{??}{\rightsquigarrow}$ **ExhInf**: I will invite Bill and Mary.
A" ?? I [won't]$_{CT}$ ... invite [Sue]$_F$.

The pattern can be summarized in the following way.

(i) If there is a polarity-mismatch, an intonational prominence (whether it is F or CT) on the auxiliary is obligatory. (14A) vs. (14A', A"); (15A) vs. (15A', A")
(ii) Sentences with a CT-marking on the auxiliary are degraded. (13B", 14B",15B",16B")
(iii) An ExhInf arises if the constituent corresponding to the *wh*-word in the question is Focused while it is absent if the constituent is CT-marked. (13A) vs. (13A'); (16A) vs. (16A')

Given these patterns, the generalization that an ExhInf is absent in the case of polarity-mismatch can be made sense in the following way: the preferred way in which answers with a polarity mismatch are pronounced is the aux-F/*wh*-correspondent-CT (hereafter F-CT) intonation as in the A' examples above. This preferred intonation does not induce an ExhInf independently of whether there is polarity-matching or not. The combination of these two facts leads to the absence of an ExhInf in polarity mismatch examples. Thus, the problem

of ExhInf and polarity-mismatch can be broken down to the following two sub-problems: why the intonations other than the F-CT intonation are dispreferred in polarity-mismatching cases, and why this intonation does not induce an ExhInf. In the rest of the paper, I will address these problems by refining the question-based theory of alternatives using Büring's (2003) theory of intonation-discourse interface.

4. Büring's (2003) theory of intonation-discourse interface

In Büring's (2003) theory of d(iscourse)-trees, a discourse is represented as a tree (referred to as a D-TREE) consisting of DISCOURSE MOVES as its nodes. Here, each utterance in a discourse, whether it is an assertion or a question, maps to a discourse move in its associated d-tree. The structure of such a d-tree represents a 'discourse strategy' consisting of QUDs (Roberts 1996). Discourse moves in a d-tree are represented as semantic objects rather than linguistic expressions. More specifically, assertions are represented as propositions while questions are represented as Hamblin (1973)-style sets of propositions.

Below, I will review some of the well-formedness conditions of a d-tree some of which are modified from Büring's (2003) original conditions.[4] The first condition is that of attachment, i.e., when a node can be a daughter of another node:

(17) **Attachment**: M can be a daughter of Q only if the following conditions are met:
   a. If M is an assertion, M GIVES AN ANSWER TO Q.
   b. If M is a question, M is a PROPER SUBQUESTION of Q.

The relations of 'giving an answer to' and 'being a proper subquestion of' are defined in the following way:

(18) **Answerhood**: p GIVES AN ANSWER TO Q iff there is a proposition $p' \in Part(Q)$ such that p contextually entails $\neg p'$ (Groenendijk and Stokhof 1984).
   a. $Part(Q) := \{[w]_{\equiv_Q} | w \in W\}$
   b. $w \equiv_Q w' \overset{\text{def}}{\Leftrightarrow} \forall p \in Q[p(w) = p(w')]$

(19) **Subquestionhood:** Q' IS A SUBQUESTION OF Q iff for every $p \in Part(Q')$, p gives an answer to Q.

(20) **Proper Subquestionhood:** Q' IS A PROPER SUBQUESTION OF Q iff Q' is a subquestion to Q, but Q is not a subquestion of Q'

What the above definitions amount to is the following: an assertion can be a daughter of a question only if the assertion contextually entails a partial answer to the question. Also, a question can be a daughter of another question only if every complete resolution of the daughter contextually entails a partial answer to the mother, *but not vice versa*.

[4]One modification is in the answerhood condition. Although Büring (2003) defines the answerhood condition in probabilistic terms, here I follow a non-probabilistic answerhood condition from Groenendijk and Stokhof (1984) for simplicity. Also, the requirement for proper subquestionhood follows from Büring's Minimality Condition

An important consequence of this requirement for our purpose is that the following d-tree is *ill*-formed. (I write the discourse moves in a d-tree in the sans serif font to indicate that they are semantic objects rather than linguistic expressions.)

(21) Who will you invite? $\{A, B, C...\}$

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Who will you not invite? $\{\neg A, \neg B, \neg C\}$

This is because the two questions in (21) are equivalent in their partitions (although they are distinct in their Hamblin denotations), and a complete resolution of one question gives an answer to the other question and vice versa. The daughter in (21) is not a *proper* subquestion of the mother question.

The crux of Büring's (2003) theory is in precise specifications of the interface constraints between surface intonations and d-trees. Below are the list of relevant constraints.

(22) **Question-answer congruence:** (after Rooth 1992 and Büring 2007) An utterance U can map onto a move M_U within a d-tree only if the mother Q of M_U satisfies the following:

a. $Q \subseteq [\![U]\!]^f$, and

b. there is no focusing U' of U such that $[\![U']\!]^f \subset [\![U]\!]^f$ and satisfies (22a).

(23) **CT-congruence**: (Büring 2003) An utterance U containing a contrastive topic can map onto a move M_U within a d-tree D only if the mother of M_U and its sisters form a non-singleton set $\mathscr{Q}$ of questions such that $\mathscr{Q} \subseteq [\![U]\!]^{ct}$.

(24) **Preference**: (Büring 2003) CT-marking is preferred over F-marking, where possible.

Here, $[\![\varphi]\!]^{ct}$ is the set of proposition-sets derived by abstracting over the CT-meaning from the Focus-value of φ.[5]

The CT congruence constraint in (23) is designed to capture the distribution of CT and F markings as exemplified in the following contrast from Jackendoff (1972).

(25) Q: Who ate what? What did Fred eat?

A: [Fred]$_{CT}$... ate the [beans]$_F$.

A': #[Fred]$_F$ ate the [beans]$_{CT}$.

The way the question in (25) is formed indicates the following d-tree.

[5]More formally, $[\![\varphi]\!]^{ct}$ can be recursively defined as follows.

(1) $[\![\text{A}]\!]^{ct}$ equals

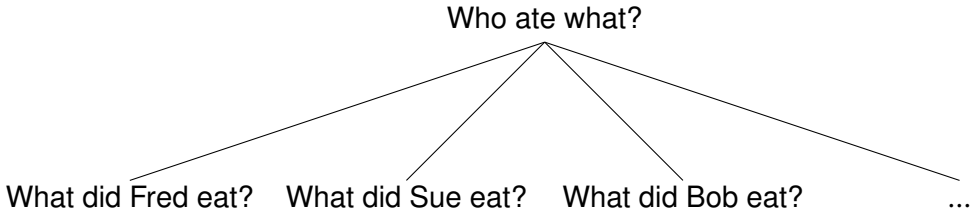
a. $\{[\![\text{A}]\!]^f\}$ if A is F-marked

b. $\{\{\alpha\} \mid \alpha \in [\![\text{A}]\!]^f\}$ if A is CT-marked

c. $\{\{[\![\text{A}]\!]^o\}\}$, if A is a terminal that is neither F- nor CT-marked

d. $\{b + c \mid b \in [\![\text{B}]\!]^{ct}, c \in [\![\text{C}]\!]^{ct}\}$ if A is the mother of two nodes B and C, where $b + c$ denotes the result of the Point-wise Functional Application of b and c.

(26)



The CT congruence then dictates that (25A) is a felicitous answer to the question while (25A') isn't. This is so because the set of subquestions in (26) is a subset of $[\![(25A)]\!]^{ct}$ but not of $[\![(25A')]\!]^{ct}$, as can be seen from the CT-denotations below.

(27) a. $[\![(25A)]\!]^{ct} = \{ Q \mid \exists x[Q = \{p \mid \exists y[p = \lambda w.\mathbf{ate}(x,y,w)]\}] \}$
b. $[\![(25A')]\!]^{ct} = \{ Q \mid \exists y[Q = \{p \mid \exists x[p = \lambda w.\mathbf{ate}(x,y,w)]\}] \}$

Another important feature of the system in this connection is that some discourse moves in a d-tree can be *accommodated* even though it is not overtly pronounced in the discourse. For instance, even if the second question in (25Q) is not uttered, the answer in (25A) can be felicitous since the d-tree in (26) can be accommodated by the hearer without the overt counterpart of the questions 'What did Fred eat?'.

5. Analysis of the data

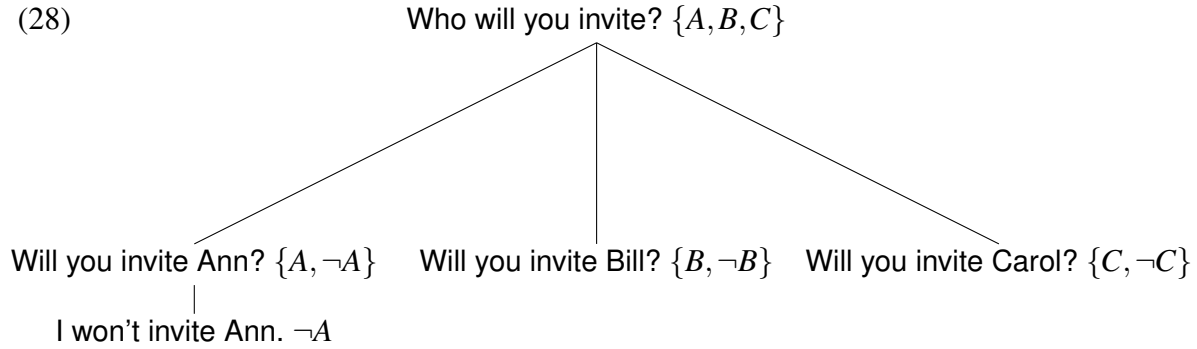
Given the theory outlined in the previous section, a question-based theory of alternatives provides solutions to the problems mentioned in the end of Section 3. I will first address why certain intonations are dispreferred in the polarity-mismatch answers, and then move on to the question of why the sentence in the preferred intonation lacks an ExhInf.

5.1 Dispreference for specific intonations

First of all, the fact that polarity-mismatch answers need some intonational prominence on the auxiliary is accounted for by the Question-Answer Congruence (QAC) requirement in (22). If the auxiliary, which includes the polarity, bears neither F nor CT, the focus-semantic value of the polarity-mismatching answer will not be a superset of the question denotation, violating QAC. For example, the focus-semantic value of *I won't invite [Ann]$_F$* is not a superset of the Hamblin-denotation of *Who will you invite?* as discussed in Section 2.3.

On the other hand, when the answer is pronounced as *I [won't]$_F$ invite [Ann]$_{CT}$*, the CT congruence forces an accommodation of a d-tree as follows.

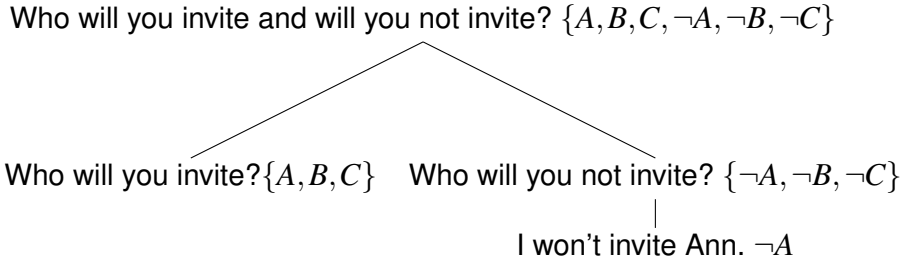
(28)



Given this d-tree, QAC is satisfied since the focus-semantic value of *I [won't]$_F$ invite [Ann]$_{CT}$* i.e., $\{A, \neg A\}$ is a superset of (in fact, equivalent to) its (accommodated) mother question Will you invite Ann?.

Another way in which QAC can be satisfied is the intonation *I [won't]$_{CT}$ invite [Ann]$_F$*. In this case, the CT congruence forces the accommodation of a d-tree of the following form.

(29)



Here again, QAC is satisfied since the focus-semantic value of *I [won't]$_{CT}$ invite [Ann]$_F$*, i.e., $\{\neg A, \neg B, \neg C...\}$ is a superset of Who will you not invite?. However, the d-tree in (29) violates another problem: the subquestions Who will you invite? and Who will you not invite? are not *proper* subquestions of the mother question Who will you invite and who will you not invite?. This is so because the partition derived from the mother question is equivalent to the partition derived from each of the daughter questions.[6] This accounts for the fact that this particular intonation is degraded, as we observed in Section 3.

Finally, the intonation in which both the auxiliary and the wh-correspondent are focused as follows is degraded compared to the F-CT intonation.

(30) ?I [won't]$_F$ invite [Ann]$_F$.

This can be accounted for by the Preference Principle in (24): Since (28) is the only licit d-tree in which QAC is satisfied and the F-CT intonation is possible given this d-tree, the F-F intonation is dispreferred due to (24).

5.2 Lack of an ExhInf in the preferred intonation

In this section, I show that a simple question-based theory of alternatives explains why the F-CT answers lack an ExhInf regardless of the polarity matching. I will assume that the alternatives for sentence S is constrained by the Hamblin denotation of its immediate QUD, following Groenendijk and Stokhof (1984), Spector (2007) and many others. In the d-tree model, this constraint can be represented as follows:

(31) **Constraints on alternatives:** $Alt(S) = Mother(S)$

Given this assumption, we can account for the lack of an ExhInf in the F-CT answers such as *I [will]$_F$ invite [Ann]$_{CT}$*. Recall that the d-tree associated with this utterance is the one in (28). In this tree, the mother question of the answer is Did you invite Ann, i.e. $\{A, \neg A\}$.

[6] Technically, the mapping from the CT-F intonation to the d-tree with the specific mother question in (29) requires the assumption that the conjunction of the complete answers of subquestions resolves their mother question. This assumption leads to the general consequence that when a d-tree involves a question whose subquestions are equivalent in their partitions, the d-tree violates the requirement for proper subquestionhood.

This set consists of symmetric alternatives, which leads to the lack of an ExhInf both in the neo-Gricean theory and in the grammatical theory. Intuitively, the answer in (28) only addresses a question about Ann and 'leaves open' the questions about other people. The same explanation applies to the polarity-matching answers with the same intonation. Thus, the current theory correctly predicts the lack of an ExhInf in the F-CT answers.

In sum, Büring's (2003) d-tree theory together with the question-based theory of alternatives provides solutions to the two questions discussed in Section 3, i.e., why the intonations other than the F-CT intonation are dispreferred in polarity-mismatching cases, and why this intonation does not induce ExhInf. The first question is answered by the well-formedness constraints and the intonation-discourse interface conditions. The second question is answered by the constraint on alternatives: Since the mother question of a F-CT answer is a polar question of the form $\{A, \neg A\}$, no ExhInf is predicted regardless of polarity-matching.

6. Alternative approaches

In this section, I compare the current account with three alternative accounts of the problem of polarity mismatch. Two of them are existing accounts by Schulz and van Rooij (2006) and Spector (2007) while the other is a slight variation of the structural alternatives theory in terms of focus alternatives.

Schulz and van Rooij's (2006) formulation of the exhaustification operator utilizes the question abstract of type $\langle e, st\rangle$ instead of a set of alternatives. ExhInfs in the case of polarity-matching question-answer pairs are captured by the assumption that the preceding question in the discourse supplies the type $\langle e, st\rangle$ argument. For example, the question *Who came?* supplies the $\langle e, st\rangle$ argument $\lambda x \lambda w.\mathbf{came}(x, w)$. In the case of polarity-mismatching answers, the authors simply stipulate that the exhaustification is optional. However, this stipulation does not follow from their general theory of ExhInfs.

Spector's (2007) theory of ExhInfs utilizes neo-Gricean Quantity Maxim with alternatives constrained by the preceding question. ExhInfs in the case of polarity-matching pairs are accounted for in the same way as the theory outlined in Section 2.1. On the other hand, in the case of polarity-mismatching answers, the alternatives are restricted to be the closure under conjunction and disjunction of the atomic propositions that the answer FAVORS, where the notion of favoring is defined as follows.

(32) A (possibly complex) proposition p FAVORS an atomic proposition p' iff there is a world w such that $p(w) = p'(w) = 1$ and $p(w_{-p'}) = 0$, where $w_{-p'}$ is defined as the world which is identical to w except for the value it assigns to p'.

This results in the correct prediction that polarity-mismatching answers lack an ExhInf since any proposition p does not favor logically independent propositions. However, Spector's analysis faces the same problem as Schulz and van Rooij (2006). The treatment of polarity-mismatching answers do not follow from his general theory of ExhInfs and alternatives.

Finally, let us consider a focus-based refinement of the structural alternatives theory. In this refined version, the replacement of a constituent is restricted to focused constituents in the sentence. Given this restriction on the domain of replacement, the problem for the simple structural alternatives theory discussed in Section 2.2 can be remedied. Recall the

problem for the simple theory is that the alternatives for a negative answer to a negative question are predicted to be symmetric, leading to the incorrect prediction that the answer lacks an ExhInf. However, if the replacement is restricted to focused constituents, this problem is avoided. This is so because a negative answer to a negative question can have a focus structure in which only the wh-correspondent is focused as in (16A), resulting in the set of alternatives $\{\neg A, \neg B, \neg C\}$. Given these alternatives, a correct ExhInf is predicted for a negative answer to a negative question. As for the polarity-mismatching cases, the predictions are correct given the F-CT intonation.

Of course, this account has to be supplemented with an independent theory about how the focus structure of an answer is determined given its preceding question. In such a theory, the refined structural alternatives theory makes exactly the same predictions as the proposed theory at least for the data set considered in this paper. The difference is only theoretical: the question-based theory discussed in the previous section directly looks at the immediate QUD to determine alternatives while the focus-based theory constrains alternatives in terms of the focus structure, which in turn is constrained by the QUD.[7] Thus, in this paper, I will remain neutral as to the choice between the question-based theory and the focus-based theory. The claim of the current paper still stands: To deal with the problem of polarity-mismatch, we have to consider the structure of QUDs to constrain the set of alternatives, whether directly as in the question-based theory or indirectly as in the focus-based theory.

7. Conclusions and remaining issues

In this paper, I presented a solution to the problem of exhaustive inference and polarity mismatch. By looking at the role of intonation in the data, the problem was broken down to two problems: why the F-CT intonation is preferred in polarity mismatching answers, and why the answer with this intonation lacks an ExhInf. I presented a solution to the first problem in terms of Büring's (2003) d-tree theory while the second problem is solved by the question-based constraint on alternatives together with the consequence of the d-tree theory that the immediate QUD of a F-CT answer is a polar question.

Before ending, I point out two remaining issues. One problem is how the current analysis carries over to fragment answers such as *Ann* and *Not Ann*. It is plausible that these cases can be reduced to the sentential cases in terms of focus movement and ellipsis, however it is not obvious how the reduction can be made compatible with the theory of Focus and CT assumed in this paper. Another problem is the gradability of the judgment. Some speakers detect an ExhInf in polarity-mismatching answers especially when the domain of the wh-item is large (cf. von Stechow and Zimmermann 1984). Although this tendency is not experimentally validated by Hirsch (2014), it is conceivable that the requirement for

[7] Groenendijk and Stokhof (1984: 276-277) consider these two accounts and claim that a case where the question-denotation is a proper subset of the focus-value of the answer favors the question-based analysis.

(i) Q: Which man walks in the garden?
A: [John]$_F$ walks in the garden. $\rightsquigarrow$ ExhInf: 'John is the only *man*/**person* who walks in the garden.'

Indeed, this argument is not persuasive if the focus-semantic value can be contextually restricted. In fact, if the restriction on the focus-semantic value has to refer to the contextually available question (e.g., via Rooth's $\sim$-operator), the theory would end up equivalent to the question-based account.

the proper subquestionhood is not categorical, and that it can be overridden if satisfying it requires a violation of Maxim of Manner/Brevity. I leave these issues for future studies.

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