Satisfying Questions*

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Abstract

In this paper we first combine and refine the semantics of questions and answers (Groenendijk and Stokhof 1984) and the logic of interrogation (Groenendijk 1999) in order to deal with topical restriction, constituent answerhood and conditional questions in a compositional way. The proposal builds on insights from the structured meanings approaches to questions (von Stechow 1991; Krifka 1991). We next present a global, pragmatic perspective on the use of such questions and answers, which founds and furthers work of (Büring 1999; Ginzburg 1996; Roberts 1996) on information structure.

1 Introduction

Questions (interrogative utterances) have been studied from both a semantic and a pragmatic perspective, more than indicative sentences have been, and for good reasons. While the interpretation of questions depends on context as much as the interpretation of assertions does, their effects upon the context are more obvious, of course. A question normally wants to be answered. Even so, indicative utterances have also been studied from a combined semantic/pragmatic perspective in recent systems of dynamic semantics and discourse representation theory. Clearly, this suggests a treatment of both types of utterances in tandem.

(Groenendijk and Stokhof 1984) has already given a first, and very appealing, systematic treatment of the semantics and pragmatics of questions and answers. This approach elaborates on the idea that the linguistic content of assertions can be specified in terms of their truth conditions, and the content of questions in terms of their answerhood conditions. Truth conditions are defined by the situations or possibilities in which a sentence counts as true, rather than false, and answerhood conditions are defined by the set of full, and mutually exclusive, possible answers to a question (the partition theory). Building on (Jäger 1996), (Groenendijk 1999) has cast this approach in a dynamic framework, which elaborates that of (Veltman 1996).

These partition theories, however, fail to account for at least two crucial aspects of the interpretation of questions and subsequent assertions. First, elliptical answers to *yes*/*no*-questions and constituent answers to *wh*-questions are not really compositionally dealt with. Second, only direct answers to explicit questions are fully dealt with, not partial or conditional replies, neither conditional questions or questions which do not stand in need of full replies.

With this paper we want to overcome both limitations. We first present a more refined notion of what are satisfying questions and answers (section 2). Our notion of a satisfying question incorporates (empirical) insights from the structured meaning approaches to questions (von

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Stechow 1991; Krifka 1991), while it preserves the logical and conceptual merits of the partition theories (section 3). This semantic system is next lifted to a pragmatic setting, which allows for a contextual definition of what counts as an optimal discourse and what is a reasonable contribution to a discourse (section 4). Basic notions from theories of information structure like that of (Büring 1999; Ginzburg 1996; Roberts 1996) will be given a rational pragmatic explanation. Section 5 winds up the results.

2 Satisfaction Semantics for Questions and Answers

We take our start from a truth-conditional first order semantics in the spirit of Frege and Tarski. Like the latter, we will not say that a formula ϕ denotes **1**, or *true*, relative to some sequence of parameters like that of a model M, a variable assignment g, a sequence of witnesses $\vec{e}$, or a world w, but we will say that such a sequence of parameters *satisfies* ϕ, e.g., $M,g,\vec{e},w \models \phi$. Since our initial investigations are extensional, we will omit reference to the world parameter w in the first half of the paper. Also, since the treatment of indefinites and pronouns is not directly relevant for the issues at stake here, we will generally omit the witness parameter $\vec{e}$.[1] In the first part models M thus consist of a domain of individuals D, and an interpretation function V for the interpretation of the (individual and relational) constants of our language, and we generally write $M(c)$ for $V(c)$ if $M = \langle D,V\rangle$.

The first order language is extended with a question operator ?, which allows us to form inquisitive expressions $?\vec{x}\phi$ which question the value of a possible empty sequence of variables $\vec{x} = x_1 \dots x_n$ in a sentential expression ϕ. A true novelty is that our language is fully recursive: questions may occur in the scope of a negation, conjunction or of other question operators. If an expression ϕ does not contain any question operator we will call it indicative and also write it as $!\phi$; otherwise ϕ is inquisitive. Furthermore, if ϕ is indicative, $?\phi$ is a polar (*yes*/*no*) question; if $\vec{x}$ is non-empty, then $?\vec{x}\phi$ is a constituent (*Wh*-) question. The Language of Questions and Answers *LQA* is defined in Backus-Naur Form:

- $\phi ::= \;\; Rt_1 \dots t_n \mid [\exists\vec{x}\phi] \mid {\sim}\phi \mid \phi \wedge \psi \mid ?\vec{x}\phi$

Expressions ϕ of *LQA* are evaluated relative to a model M, an assignment g and a possibly empty sequence of answers $\vec{\alpha}$ to the questions posed in ϕ. The semantics for inquisitive expressions is built on the classical insight (Hamblin 1958; Karttunen 1977; Groenendijk and Stokhof 1984) that the meaning of a question is its full and complete answer but we combine this with the insight from the structured meanings and the dynamic semantic frameworks that these assertions and answers can be structured objects themselves.

For instance, a question $?\vec{x}\phi$ gets satisfied by the answer to the question which sequences of individuals can be the values of $\vec{x}$ in ϕ. If $\vec{x}$ consists of one variable x only, as in $?xCx$ (*Who come?*), it asks for the extension of C; if $\vec{x} = xy$ consists of two variables, as in $?xy(Bx \wedge (Gy \wedge Sxy))$ (*Which boys saw which girls?*), it asks for the set of pairs consisting of a boy and a girl the boy saw[2]; if $\vec{x}$ is the empty sequence, as in $?p$ (*Does it rain?*) it asks for the truth value of p: it denotes the set $\{\lambda\}$ consisting of the empty sequence $\lambda = \langle\,\rangle$ only, which is the truth value *true* (**1**) by definition, or the empty set $\{\,\}$, the truth value *false* (**0**). (We use capital Λ for the empty sequence of answers, for instance when we specify the satisfaction of indicative expressions.)

As a matter of convention, when we consider the possible answers $\vec{\alpha} = \alpha_1,\dots,\alpha_n$ to a

[1]The basic ingredients of such extensions are discussed in detail in (Dekker 2002a; Dekker 2003).

[2]As we will argue later in this paper, this is not an entirely accurate rendering of the associated natural language question, for *which*-phrases should be taken to presuppose their domain, the denotation of the associated common noun phrase.

question ϕ, we always assume in this paper that ϕ asks n questions $q_1, \ldots, q_n$ and such that each α_i has the same type as q_i. In the semantics we use a product $\prod$ and a complement operator C and the usual interpretation of (individual and relational) constants c and variables x:

- $\prod(\alpha_1 \ldots \alpha_n) = \alpha_1 \times \ldots \times \alpha_n$ (n possibly 0)
  $C(\alpha_1 \ldots \alpha_n) = C(\alpha_1) \ldots C(\alpha_n)$ ($n \geq 1$)
  $[c]_{M,g} = M(c)$ and $[x]_{M,g} = g(x)$

Definition 1 (Satisfaction Semantics for LQA)

- $M, g, \Lambda \models Rt_1 \ldots t_n$ iff $\langle [t_1]_{M,g}, \ldots, [t_n]_{M,g} \rangle \in [R]_{M,g}$
  $M, g, \vec{\alpha} \models \sim\phi$ iff $\forall \vec{\varepsilon}$: if $M, g, \vec{\varepsilon} \models \phi$ then $\vec{\alpha} = C(\vec{\varepsilon})$
  $[M, g, \vec{\alpha} \models \exists \vec{x}\phi$ iff $\exists \vec{e}$: $M, g[\vec{x}/\vec{e}], \vec{\alpha}(\vec{e}) \models \phi]$
  $M, g, \vec{\alpha}\varepsilon \models \phi \wedge \psi$ iff $M, g, \vec{\varepsilon} \models \phi$ and $M, g, \vec{\alpha} \models \psi$
  $M, g, \alpha \models ?\vec{x}\phi$ iff $\alpha = \{\vec{e} \cdot \vec{e}' \mid \exists \vec{\varepsilon}$: $M, g[\vec{x}/\vec{e}], \vec{\varepsilon} \models \phi$ & $\vec{e}' \in \prod \vec{\varepsilon}\}$

We cannot explain this definition in full detail here, but we leave it at a few comments. First, satisfaction of indicative expressions is completely standard, for atomic formulas have their ordinary satisfaction conditions and this property is preserved under the indicative operators:

Observation 1 (Satisfaction of Indicatives)

- $M, g, \Lambda \models \sim!\phi$ iff $M, g, \Lambda \not\models !\phi$[3]
  $[M, g, \Lambda \models \exists x!\phi$ iff $\exists d$: $M, g[x/d], \Lambda \models !\phi]$
  $M, g, \Lambda \models !\phi \wedge !\psi$ iff $M, g, \Lambda \models !\phi$ and $M, g, \Lambda \models !\psi$

The indicative part of our system thus is classical, as it should be. Simple questions are treated in a fairly standard way as well:

Observation 2 (Satisfaction of Simple Questions)

- $M, g, \mathbf{1} \models ?!\phi$ iff $M, g, \Lambda \models !\phi$ iff $M, g, \mathbf{0} \not\models ?!\phi$
  $M, g, \alpha \models ?x!\phi$ iff $\alpha = \{d \mid M, g[x/d], \Lambda \models !\phi\}$
  $M, g, \alpha \models ?xy!\phi$ iff $\alpha = \{\langle d, d' \rangle \mid M, g[x/d][y/d'], \Lambda \models !\phi\}$

Yes is the true and complete answer to a polar question *Does it rain?* if and only if it rains. The true and complete answers to the questions *Which boys come?* and *Which professors failed which students?* consist of a specification of the set of boys who come, and the set of professor-student pairs which stand in the fail relation, respectively.

Indicatives and simple inquisitives are, thus, treated in a standard fashion. What is really new is that questions can be embedded in questions or under other operators. We briefly discuss two very useful applications of this phenomenon. Let us define a conditional $\Rightarrow$ so that $\phi \Rightarrow \psi \equiv \sim(\phi \wedge \sim\psi)$, the difference with classical definitions of material implication residing in the fact that the expressions ϕ and ψ can be inquisitive. Now look at conditional questions of the form $!\phi \Rightarrow ?\vec{x}\psi$. Applying the above definition of our satisfaction conditions we get:

Observation 3 (Simple Conditional Questions)

- $M, g, \alpha \models (!\phi \Rightarrow ?\vec{x}\psi)$ iff if $M, g, \Lambda \models !\phi$ then $M, g, \alpha \models ?\vec{x}\psi$

[3] Since $\overline{\Lambda}$ does not exist $M, g, \Lambda \models \sim!\phi$ iff *nothing* satisfies $!\phi$.

Interestingly, this is the type of interpretation argued for in (Velissaratou 2000). Consider:

(1) If we throw a party tonight, will you come?

Clearly, neither of the answers *Yes* and *No* should entail that we throw a party tonight. Intuitively, the two replies state that, *Yes, if you throw a party tonight I will come* and *No, if you throw a party tonight I will not come*, respectively. This is precisely what we find in observation (3).[4] Something essentially similar goes for conditional constituent questions. Consider:

(2) If it rains, who will come?
(3) John and Mary, but not Dick and Trix.

The answer to the above question should be understood to claim that John and Mary come if it rains, and that Dick and Trix do not come if it rains. Clearly, the answer can be perfectly fine when Dick and Trix do show up, and John and Mary don't, that is, in case it does not rain. The results are again like those argued for by (Velissaratou 2000). The difference is that they are obtained in a direct and compositional fashion here.[5]

The possibility of embedding questions in questions is another useful application of our system. If a formula ϕ is already inquisitive, then $?\vec{x}\phi$ not only queries the possible values of $\vec{x}$, but also the answers to the embedded questions. Thus we find for instance that:

Observation 4 (Question Aborption)

- $?\vec{x}?\vec{y}\psi \Leftrightarrow ?\vec{x}\vec{y}\psi$
- $?\vec{x}(\phi \wedge ?\vec{y}\psi) \Leftrightarrow ?\vec{x}\vec{y}(\phi \wedge \psi)$

The first equation in observation (4) shows that the polyadic question-operator can be defined compositionally itself, for $?x_1 \ldots x_n\phi \Leftrightarrow ?x_1 \ldots ?x_n\phi$. The second equation shows an even more attractive feature of our system. Question operators absorb embedded questions which is to say that embedded question operators can be 'bound' by embedding ones. This is very attractive. In previous systems like that of, e.g., (Groenendijk and Stokhof 1984), the meaning of example (4) is relatively adequately specified as (5) but it is not compositional since (5) does not really reflect the intuitive syntactic structure of (4):

(4) Which boys saw which girls?
(5) $?xy(Bx \wedge (Gy \wedge Sxy))$

Our system improves on this, since the more compositional analysis of (4) as (6) turns out equivalent with (5):

(6) $?x(Bx \wedge ?y(Gy \wedge Sxy))$

The fact that we can appropriately analyze (4) as (6) clearly draws from two innovations. First, we allow questions to figure in conjunctions and in the scope of other question operators; sec-

[4] A persistent number of authors claims that conditional sentences ought to address a strict, rather than a weaker, material, notion of implication. This issue is orthogonal to the present discussion. Even if we favor a strict interpretation of conditional sentences, saying *Yes* to question (1) says that our throwing a party tonight strictly implicates that you will come, whereas saying *No* says that it strictly entails that you will not come. Replying with *No* certainly does not mean that our throwing a party tonight does not strictly implicate that you will come.

[5] As observed by Velissaratou $!\phi \Rightarrow ?!\psi$ can be answered by both *Yes* and *No* provided, of course, that $!\phi$ is false. As a matter of fact, $!\phi \Rightarrow ?\vec{x}!\psi$ can be answered by *any* answer α of the right type. This means that a conditional question becomes totally useless if its antecedent turns out to be false. The truth of the antecedent clause thus is a pragmatic, and cancelable, presupposition.

ond, our semantics of embedded questions is adequate in the sense that (6) is equivalent with the intended interpretation (5), as observation (4) shows.[6]

3 Logic and Pragmatics of Questions and Answers

The system discussed in the previous section is innovative because of its successful compositional treatment of conditional and constituent questions, but it still contains all the goodies of the standard theories of questions. As we will see, all important notions of the standard theory of questions can be derived. Apart from this, the additional underlying structure which we assume has the type of structure required to solve some basic problems for the classical theories: the treatment of elliptical and constituent answers.

We build on the relatively standard idea that contents of assertions and information states can be characterized by means of sets of possibilities, those possibilities compatible with these assertions or states, and that questions can be taken to (pseudo-)partition these states. The elements of such partitions indicate the relevant distinctions. Agents are interested in knowing which of the elements of a partition correspond to the real world, and they are supposed to be insensitive to differences between possibilities which reside in one block.

Talk about possibilities requires us to generalize the extensional models we used above to intensional models $\mathcal{M} = \langle W, D, V \rangle$ consisting of a set of worlds W, a domain of individuals D, and an interpretation function V for the constants of our language, and such that for any world $w \in W$: $\mathcal{M}_w = \langle D, V_w \rangle$ is an extensional model. Structured information states are rendered as satisfaction sets S which consist of sequences of answers $\vec{\alpha}$ plus worlds w such that w is conceived possible and $\vec{\alpha}$, in w, provides the complete answers to outstanding questions. Satisfaction sets allow us to define relatively standard notions of content, answerhood and indifference:

Definition 2 (Content, Answerhood, and Indifference)

- $[\![\phi]\!]_{\mathcal{M},g} = \{\vec{\alpha}w \mid \mathcal{M}_w, g, \vec{\alpha} \models \phi\}$ (content of ϕ)
  $D(S) \;\; = \{w \mid \exists\vec{\alpha}\text{: } \vec{\alpha}w \in S\}$ (data of S)
  $A(S) \;\; = \{\ \{w \mid \vec{\alpha}w \in S\}\ \mid \vec{\alpha}v \in S\}$ (possible answers)
  $I(S) \;\;\; = \{\langle v, w\rangle \mid \exists\vec{\alpha}\text{: } \vec{\alpha}v \in S \;\&\; \vec{\alpha}w \in S\}$ (indifference)

The content, or data, $D(S)$ of a satisfaction set S is simply modeled as the set of not (yet) excluded possibilities. Like in (Groenendijk and Stokhof 1984), $A(S)$ groups together possibilities in which the same answer to pertaining questions can be given. Indeed, these groups themselves constitute the propositions (sets of possible worlds) which count as propositional answers to these questions. Like in (Groenendijk 1999), $I(S)$ relates any two possibilities in $D(S)$ the difference between which is considered immaterial.

The classical notions of answerhood and indifference have two major benefits. They combine a fully straightforward logic (Groenendijk and Stokhof 1984) with a strong intuitive

[6] In one respect (5) or (6) do not really capture the intuitive interpretation of (4), in particular the presuppositions associated with *which*-phrases. In (Dekker 2003) I have shown how to lift the present first order system to a system which hosts generalized quantifiers, and which deals with their domain presuppositions. Like all other quantifiers, *which*-phrases as in $WHICH(A)(B)$ can be said to presuppose a witness domain of A's, and to question which individuals in this domain are also B's. In this way we can easily account for the otherwise problematic difference between the following two questions (from Heim 1994):

(7) Which males are bachelor?

(8) Which bachelors are male?

decision-theoretic interpretation (van Rooy 1999). (Jäger 1996; Groenendijk 1999) define a notion of entailment for questions and answers in one gloss:

Definition 3 (Support)

- $\phi \models_{M,g} \psi$ iff $I([\![\phi_{M,g}]\!]) \subseteq I([\![\psi_{M,g}]\!])$

An expression ϕ entails or supports ψ iff it provides more data and poses more questions. For two indicative expressions this boils down to classical entailment, and for two inquisitive expressions ϕ and ψ we find that the former entails the latter iff every complete answer to the first also completely answers the second. But also mixtures as possible. For instance, an indicative expression $!\phi$ entails an inquisitive expression $?\vec{x}\psi$ iff it fully answers the question. The following observation summarizes the results:

Observation 5 (Answerhood and Entailment)

- $$\begin{array}{rr} p \wedge q \models p & \forall xCx \models Ca \\ ?p \wedge ?q \models ?p & ?xCx \models ?Ca \\ p \wedge q \models ?p & \forall xCx \models ?xCx \end{array}$$

(If ϕ is inquisitive, and ψ indicative, the first only entails the latter iff the latter is trivially true.) Other interesting mixtures involve conditional questions, which again appear to be fully well-behaved:

Observation 6 (Conditional Entailment)

- $$\begin{array}{rr} ?q \models p \Rightarrow ?q & ?p \not\models p \Rightarrow ?q \\ q \models p \Rightarrow ?q & p \not\models p \Rightarrow ?q \\ \neg q \models p \Rightarrow ?q & \neg p \models p \Rightarrow ?q \end{array}$$

It may be of interest to note that we also have a deduction theorem for conditional questions:

Observation 7 (Deduction Theorem)

- $!\phi \models ?\vec{x}\psi$ iff $\models !\phi \Rightarrow ?\vec{x}\psi$

Not only logically, but also decision-theoretically, answerhood and indifference are intuitively well-behaved. Suppose you want to cycle to the beach if the sun shines, and go to the cinema otherwise. Not knowing what the weather is like, you face a decision problem. What to do? Prepare the bikes or reserve tickets? Indeed, asking whether the sun shines may provide one way towards solving the decision problem. By means of such a question you indicate you are interested in the issue whether the world is like those in which the sun shines, or like those in which it doesn't. Indeed, as soon as you know which of these two ways the world is like, you know what to do. The same goes for constituent questions. Your decision to go to the party tonight may very well depend on who will be there. Some candidate visitors may make it into a great success, while the attendance of certain others may very well guarantee a safe disaster. Thus, the question *Who will visit the party?*—which queries the exact configuration of attending people—is relevant to your decision to go there yourself.[7]

[7] It should be noticed, though, that, strictly speaking, the question should be who would be there if I come, since I have not yet answered that question myself and since I am not interested in who come if I don't come. We will come back to this issue below.

We see that our system inherits the logical and decision-theoretical merits of previous approaches, but indeed we need, and have, more if we want to come up with a pragmatically adequate notion of answerhood. Suppose that all of my background knowledge can be summarized by a theory $!\Phi$, and if, given that background knowledge, I want to know whether q. In that case, of course, my question is not whether $!\Phi \wedge q$ or $!\Phi \wedge \neg q$. My question really is $!\Phi \Rightarrow ?q$, and observation (6) shows that the question $?q$, as well as the possible answers q and $\neg q$, support that question, like, of course, $!\Phi \Rightarrow q$ and $!\Phi \Rightarrow \neg q$ do. This naturally follows from our treatment of conditional questions.

A formal exercise also shows that our notion of content (definition 2) has more structure than the standard notions of answerhood and indifference and it can be argued that it has the additional type of structure which is minimally needed to deal with elliptical or constituent answers. Consider, for instance, the following questions (the second one from Zeevat, p.c.):

(9) Is Harry there?
Is Harry not there?
(10) Who wants an ice-cream?
Who does not want an ice-cream?

These questions are pairwise equivalent from both a logical and a decision-theoretical perspective. Any full answer to the first (second) question of each pair provides a full answer to the second (first) question of that pair. However, practically or pragmatically these questions are different. For instance, if the answer to the first question of (10) is *Rick* it will be taken to mean that Rick wants an ice-cream; as an answer to the second question of (10) it will be taken to mean that Rick does *not* want an ice-cream. Quite a difference indeed.[8] However, if we use our richer notion of content, these examples can be adequately dealt with in a straightforward way. Since our notion of satisfying contents employs the full answers to a pertaining question, it can be used to constrain the interpretation of subsequent constituent answers. In (Dekker 2002b) I have given a fully general definition of topical restriction and constituent answerhood which uniformly deals with answers to (9) and (10). The only, non-trivial, assumption is that topics, or questions, are modeled as abstracts in the way they are modeled here. In reply to a question like (13), the answer (14) can be interpreted fully compositionally as (15):

(13) Who will go to the party?
(14) John.
(15) John will go to the party.

This is certainly not a trivial result, even more, since the very same analysis renders the replies (17) and (19) to (16) directly equivalent with (18) and (20), respectively.

(16) Does Alice want more sandwiches?
(17) Yes.
(18) Alice wants more sandwiches.
(19) No.
(20) Alice does not want more sandwiches.

[8]This example indeed shows a striking resemblance with (a variant of) Partee's famous marble case. While the following two sentences are logically (truth-conditionally) equivalent, they have different pragmatic 'overtones':

(11) Exactly five of the nine soldiers were killed.
Exactly four of the nine soldiers survived.

The difference shows up when the assertion of any one of these examples is followed by the statement that:

(12) They will be buried.

4 Strategic Inquiry with Questions and Answers

Quite a few of the issues discussed above, and certainly the literature about them, directly or indirectly address the question what is a relevant question or assertion. Most of the formal semantic literature addresses this issue from a local perspective, by focusing in on the question what is a direct answer to an explicit question, or on what discourse relations may exist between two immediately successive utterances. In this section we advocate a global perspective which more accurately formalizes the pragmatic program initiated by (Grice 1975).

We think it is dubious theoretic practice to try and study any two subsequent utterances, and define, in terms of them, what discourse relation holds between the two. Of course, stating that *John comes to the party, and no other students do* can be relevant in response to a question *Who will come to the party?*, but almost any other utterance (indicative or inquisitive) can be relevant as well. This has already been noticed in (Groenendijk and Stokhof 1984), and (van Rooy 1999) gives a decision-theoretic explanation of the facts, in quantitative terms. We will argue here that an intuitive, qualitative explanation can be furthered.

One of Grice's aims was to show that certain general principles constrain and guide the intention and interpretation of utterances of (linguistic) agents which are deemed rational and cooperative. The assumption of rational cooperative behaviour advances the agents involved in a conservation to obey, or to pretend to obey, the maxims of quality, quantity, relation and manner. These maxims require a speaker not to say things for which she lacks adequate evidence, not to say more nor less than is required for the purposes of the conversation, to advance relevant propositions, and to be well-behaved.

These maxims can be understood and formalized in the following way. A game of information exchange consist in getting one's questions answered in a reliable and pleasant way. Interlocutors are therefore assumed to produce a multi-speaker dialogue Φ which is deemed optimal iff Φ answers their questions, while its contents are supported by the information the interlocutors have, and Φ is optimal. Grice's maxims can be (partly) formalized as follows:

Definition 4 (Optimal Inquiry) Given a set of interlocutors A with states $(\sigma)_{i\in A}$ a discourse $\Phi = \phi_1, \ldots, \phi_n$ is optimal iff:

- $\forall i \in A$: $D([\![\Phi]\!]) \cap D(\sigma_i) \models \sigma_i$ (relation)
  $\bigcap_{i\in A} D(\sigma_i) \models D([\![\Phi]\!])$ (quality)
  Φ is minimal (quantity)
  Φ is well-behaved (manner)

The maxim of relation requires an optimal discourse to answer all questions of all interlocutors. The information provided by Φ is hoped to answer the questions in any state σ_i. The maxim of quality requires these answers to be supported by the data which the interlocutors had to begin with.[9] The maxims of quantity and manner are deliberately left underspecified.[10]

[9] Some subtle notes should be added to this maxim. First, of course, in the course of a dialogue things happen and change, and these facts should be taken into account. For instance, after I told you that it rains, it is a fact that I have told you so, but it is not a fact I need to report on. Normally I don't need to tell you that I have told you that it rains. Second, in principle I could provide information which other people have themselves, but of course it would be better if they did themselves.

[10] A discourse can be minimal in the sense of digits produced, or in the sense of processing efforts required to generate and understand it, etc. In theory, and in practice, we cannot decide on the precise measures, but we have to negotiate it. For computational purposes, of course, we cannot leave this notion underspecified, but then we have to relate it to the maxim of being well-behaved, which crucially relies on the objectives of the implementation.

When agents engage in a cooperative conversation, it is reasonable that they make clear what questions they have, and that they provide information which they have support for. The above notion of an optimal inquiry accounts for this, but it also serves to guide agents to a dialogue in which the conditions are not guaranteed to be optimal. Let us first look at an optimal situation. Suppose *A* wishes to know whether Sue comes to the party (?*s*), and *B* wants to know whether Tim comes to the party (?*t*), and assume that each of them knows the answer to the other one's question. The two information states can be defined as follows:

- $\sigma = \{\overline{[\![t]\!]} \cap [\![s]\!], \overline{[\![t]\!]} \setminus [\![s]\!]\}$
- $\tau = \{[\![s]\!] \cap [\![t]\!], [\![s]\!] \setminus [\![t]\!]\}$

The following dialogue is optimal then:

(21) *A:* Will Sue come?
B: Yes.
Will Tim come?
A: No.

Both questions are answered, by information which was initially there distributed over the two initial information states.

Example (21) can be used to show that some standard felicity requirements (like informativity, non-redundancy, consistency, and congruence of answers with questions) can be derived from the maxims we have stated above. More interestingly, these maxims can also be used to explain why certain dialogues are perfectly reasonable also if certain expressions are not direct replies to questions posed just before. The examples which we discuss in the remainder of this section fit our notion of an optimal discourse, while they do not comply with notions of relevance or congruence proposed in localistic discourse grammars.

Consider the following sequence of utterances of *A* through *D*:

(22) *A:* Who were at the awards?
...
A: Who of the Bee Gees?
B: Robin and Barry but not Maurice.
A: Who of the Jackson Five?
C: Jackie, Jermain and Michael, but not Marlon and Tito.
A: Who of Kylie Minogue?
D: Kylie Minogue.
A: OK, I know enough!

The main question of our interrogator *A* cannot be fully answered directly by any of the participants. But we see it makes sense for her to cut up her question into subquestions in the sense of (Büring 1999; Ginzburg 1996; Roberts 1996), which, in this case, can be answered. By posing these subquestions the superquestion may get answered, so it is an orderly way of getting to the main goal. Interestingly, subquestions are senseless in a framework like that of (Groenendijk 1999), where they are rendered superfluous, and, thus, impertinent.

Counterquestions, or 'side questions' as Jefferson calls them, also fit neatly in our model. We do not need discourse or answerhood relations to explain why the sequence of the first two of the following four utterances is sensible:

(23) *Waitress:* What'll ya have girls?

Customer: What's the soup of the day?
Waitress: Clam chowder.
Customer: I'll have a bowl of clam chowder and a salad with Russian dressing.

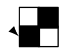
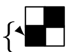
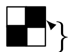
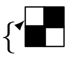
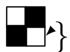
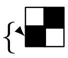
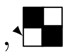
Clearly, the envisaged answer to the customer's question is needed to help the customer to answer the waitress's question. If we take into account what is the information and what are the interests of the interlocutors, this can be readily explained. But surely there is no linguistic relation between the first two utterances here.

We have already discussed conditional questions, and it should be clear what sense they make. Consider:

(24) *A:* Do you like to go to the party?
B: If I go to the party, will prof. Schmull be there?

Clearly, if *B* poses his question *B* wants to know about prof. Schmull's expected attendance in situations where *B* also goes. Apparently, *B* does not presuppose that he is going, assuming that he asks this question in order to motivate his decision whether to go to the party or not. In the model presented above this makes perfect sense, because *B* wants to know whether he is in a situation where prof. Schmull comes if he comes—in case he decides not to go to the party—, or in a situation where this is not so—in case he decides to go. This seems very rational, but indeed it seems very difficult to think of a linguistic or grammatical relation between the two utterances which could explain the relevance of *B*'s question as a reply to *A*'s original invitation.

The most interesting cases are those in which people pose questions which are more specific than the ones they personally face. Formally they ask for more information than they need. Out of the blue one would think that this doesn't make sense, but the general model sketched above suggests and covers cases in which this is perfectly reasonable. We sketch two such case, one more formal, and one more intuitive.

Let the actual world be a simple 2×2 chessboard with agent *A* at position $a1$, as in: . *A* knows she is on the chessboard, but she does not care at which position she is, although she does care whether she is at a black or a white square. Her intentional state can be characterized as follows: $\sigma = \{ \{$, $\}$, $\{$, $\} \}$. Her addressee *B* does know on which position *A* is, but she does not know what the chessboard looks like. Given that *B* does not have any questions himself, his intentional state can be characterized as: $\tau = \{ \{$, $\} \}$. Now the following discourse unfolds:

(25) *A:* Am I on a black square?
B: I don't know.
A: On which square am I?
B: You're on $a1$.
A: Then I am on a black square.

This discourse is perfectly reasonable because *A* first asks what she wants to know, and *B* indicates he doesn't know the answer and then *A* asks something more specific than she wants to know, but something which does entail her question. *B* has a motivated reply to that question, and indeed this turns out to answer *A*'s original question.

The previous example is a bit artificial, and it could be amended. For, as we already remarked above, *A*'s 'real' question is whether, given that she is right, she is on a black square, or more precisely whether she is on $a1$ or $b2$ if these are the black fields indeed. By the same token B could have directly solved A's question by replying that *Yes, if* $a1$ *is black* or with the counterquestion *What colour is* $a1$*, which is your current position?* But in practice it is not always obvious to see what is the optimal reply or question. The following example will show this in some more detail.

Consider the following situation. There is a party which may be visited by, apart from the speaker S, the professors Arms A, Baker B, Charms C, and Dipple D, which gives $2^4 = 16$ configurations. S's decision to go or not will be based on the question whether it is useful to do so, and it is going to be useful if S can speak to professor A or C. So A or C must be there, but there are some further complications. If, besides A, B is there as well she will absorb A if B doesn't absorb C, that is, if C is not absorbed by D; furthermore, if neither B and C are present, D will absorb A. The following table lists the configurations under which it is useful for S to go:

•

	$C\&D$	$C\&\neg D$	$\neg C\&D$	$\neg C\&\neg D$
$A\&\ B$	-	+	-	-
$A\&\neg B$	+	+	-	+
$\neg A\&\ B$	-	-	-	-
$\neg A\&\neg B$	-	+	-	-

Our speaker S only wants to know if she is in a $+$ or $-$ situation, and she could ask:

(26) Will it be useful to go to the party?

but probably her addressee T does not know about which configuration is useful. So S can formulate the contents of the above table in the form of a polar question, a positive answer to which would mean that she is in a $+$ type world, and a negative answer the opposite. Indeed something like the following yes/no question would do:

(27) $(A\ AND\ [(B\ AND\ C\ AND\ \neg D)\ OR\ (\neg B\ AND\ (D \rightarrow C))])\ OR$
$(C\ AND\ \neg B\ AND\ \neg D)$?

Apparently, this is somewhat cumbersome question. Alternatively it would do to simply ask:

(28) Who come?

Any full answer to this question would answer S's main question, but notice that this question (28) is more specific than the question she has. Nevertheless (28) is a much more efficient means than (27) for S to solve her decision problem.

Interestingly, if the addressee T understands a question like *Who come?* as a superquestion of the real question *Will S have reason to go?* he can attune his answer to the real one. That is, in stead of providing a full (exhaustive) answer to the explicit question, he might give one which he thinks suffices to solve S's basic question. This, we suggest, makes up the reason and rationale for providing non-exhaustive answers, and, therefore, for posing non-exhaustive questions.

5 Conclusion

In this paper we have proposed a minimal satisfaction semantics for a language with indicatives and interrogatives. It is new because it is fully recursive and allows us to deal with conditional questions and elliptical answers in a fully compositional way. We have next indicated how to employ this system to understand informative or inquisitive dialogues. The main conclusion is that such dialogues should be apprehended from a global perspective, which takes into account the information and intentions of the dialogue participants, rather than from a local perspective, which focuses on local discourse relations only.

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