

# Nuclear Rises in Update Semantics\*

Marie Šafářová  
University of Amsterdam  
`m.safarova@uva.nl`

## Abstract

The main goal of this paper is to argue for an analysis of final rises in American English as ‘intonational adverbs’ expressing epistemic uncertainty. Furthermore, it is suggested that the question-like behavior of declaratives with final rises can be derived as a secondary effect from maxims of rational conversation and is not directly due to their intonational properties. The advantage of this approach is that it allows us to keep the semantics of sentence types uniform. The meaning of final rises is expressed in formal semantic terms as Veltman’s test operator, in the framework of update semantics, enriched with a simple semantics for polar questions. A part of the formalization is also the formulation of Grice’s maxims of quality, quantity and relation.

## 1 Introduction

The semantics of intonation is notoriously difficult to capture formally and it has even been suggested that its meaning is metaphorical, non-denotational and non-compositional (a.o., [Cook, 2002], from the perspective of a cognitive psychologist), and fundamentally related to speaker’s emotions rather than rational linguistic behavior. Since there is no general consensus on what the smallest meaningful intonational units are, it makes sense to focus on sentence melody as a carrier of information. In many languages it is used to express questions and even in languages which possess the means to render questions morphosyntactically (e.g., in English with subject-predicate

---

\*I would like to thank to Marc Pauly, Paul Dekker, Hans-Christian Schmitz, Bernhard Schröder and the audience of *Sinn und Bedeutung 9* in Nijmegen for their helpful comments. All the remaining mistakes are my own.

inversion, or in French, with inversion or the ‘*est-ce que*’ phrase), intonation can still “turn” statements into questions.<sup>1</sup>

In general, *yes/no*-questions are usually reported to be associated with a rising contour, presence of a high pitch and/or a high boundary. Experimental evidence also confirms that rising contours facilitate questions recognition. It is thus rather tempting – and, in fact, common in many typological and semantic studies – to identify rising intonation with question intonation. Undermining this view, however, are the results of corpus studies which show that there are questions (including many declarative questions) without rise, and, crucially, rises which do not express questions. Moreover, final rise in general is associated with a number of other meanings, such as checking whether the audience has understood what is being said, maintaining speaker-hearer solidarity, politeness, tentativeness, non-conduciveness, reservations and conciliatory attitude, friendliness, uncertainty, submissiveness and pleasantness. [Gussenhoven, 2004], following Ohala (e.g., [Ohala, 1984]), considers many of these to be affective meanings of questioning. This view, however, has been disputed by [van Alphen, 2003], on the grounds that questions are normally used as a floor-getting device and their role in a dialogue is to assert a discourse topic and to commit the dialogue participants to its resolution – acts which cannot easily be characterized as submissive or uncertain.<sup>2</sup>

In this paper, I first shortly discuss existing semantic analyses of the rise ([Pierrehumbert and Hirschberg, 1990] and [Gunlogson, 2001], with a reference to [Merin and Bartels, 1997] and [Steedman, 2004]) and subsequently offer an alternative which can reconcile the somewhat conflicting empirical observations regarding the use of rise in questions, as briefly summarized above. Throughout, I make use of the results of the experiments by [Šafářová and Swerts, 2004] and [Šafářová, 2005] which show that while some contours in American English are more likely to be perceived as signaling questions – in particular those described by [Gunlogson, 2001] – they are neither sufficient nor necessary for this end. Combined with the observation that the contours can also appear on statements and that they are associated with a number of other meanings (though not, it seems, continuation, viz below), the idea that their semantics could be expressed solely

---

<sup>1</sup>In a large spoken corpus of American English free conversations, ‘declarative questions’ were counted more frequent than interrogative questions, i.e., questions expressed by means of syntactic inversion. French is even further in that inverted and *est-ce que*-sound unnatural to native speakers outside of high register contexts.

<sup>2</sup>Similarly, [Bartels and Merin, 1998]:98 recall Bolinger’s remark that “questions oscillate between the force of requests and that of orders”.

in terms of questionhood is not tenable. At the same time, however, the semantic analysis has to account for the close association of rises with questions, and for the fact that their meaning is not ‘weaker’ than that of the lexical-pragmatic features of the utterance [Šafářová and Swerts, 2004].

I will suggest that these properties of the final rise can be captured in a uniform way if we take its meaning to be that of a modal expression of uncertainty. Formally, I express the meaning in terms of Veltman’s  $\diamond$ -operator, defined originally for expressions such as *it might be that* as introducing tests on the content of the common ground [Veltman, 1996]. I offer a simple update semantics for both the  $\diamond$  and the  $?$  operators which is a combination of Veltman’s update semantics with a question semantics for propositional formulas and I represent rising declaratives as a  $\diamond\phi$ -type of statements, rising interrogatives as  $?\diamond\phi$  and falling interrogatives and indicatives as  $?\phi$  and  $\phi$ , respectively. One advantage of the proposal is that the relation between syntactic and semantic types is kept uniform, i.e., all syntactic declaratives are analyzed as statements. We can thus do away with the “hybrid” category of declarative questions, utterances with declarative syntax but the contextual behavior of questions. For example, a declarative question like ‘*Those are not all related languages*  $\uparrow$ ’ (where  $\uparrow$  symbolizes a final rise) is semantically analyzed as  $\diamond$  *those are not all related languages*, comparable to the statement ‘It might be that those are not all related languages’. I argue that the fact that this utterance would usually receive a reply from the addressee is due to the maxims of rational conversation which force the participants to address the issue under discussion and to make the strongest possible statement given their state of knowledge. A part of the analysis is a formalization of Grice’s maxims of quality, quantity and relation which I use to explain why statements of the kind  $\diamond\phi$  and questions like  $?\diamond\phi$  are not redundant in discourse, despite their semantics (according to which an update with  $?\diamond\phi$  does not disconnect any worlds in the context and an update with  $\diamond\phi$  does not change the context unless there are no worlds making  $\phi$  true). We can thus account pragmatically for what is sometimes considered a weak point of Veltman’s semantics for possibility. It follows straightforwardly from the analysis that rising declaratives are sometimes interpreted as indicating politeness, tentativeness and other affective states. On a more general level, the approach shows that it is possible to address the semantics of intonation in a formal way without ignoring its ‘emotional’ aspects.

## 2 Empirical Observations

In this section, I sum up the properties of the ‘final rise’ relevant for a semantic account. Hence on, I will use the term ‘final rise’ as defined by [Gunlogson, 2001], i.e., as a nuclear contour which is non-falling and ends higher than the nuclear pitch accent. These contours have been found to be the best predictor of questioning ([Šafářová and Swerts, 2004]). I will symbolize the final rise by  $\uparrow$  and the final fall by  $\downarrow$ .<sup>3</sup>

For details on the empirical claims summarized below, see, among others, [Uldall, 1964], [Fries, 1964], [Pierrehumbert, 1980], [Hirschberg and Ward, 1995], [McLemore, 1991a], [McLemore, 1991b], [Hirschberg, 2000], [Chen et al., 2001], [Chen and Gussenhoven, 2003], [Gunlogson, 2001] and [Šafářová, 2005].

### 2.1 Summary of the facts

(I) Final rise is possible but not necessary with inverted *yes/no*- and *wh*-questions - compare, for instance, the realization of the question ‘*Can I help you?*’ with a high rise in figure 1 and a fall in figure 2.

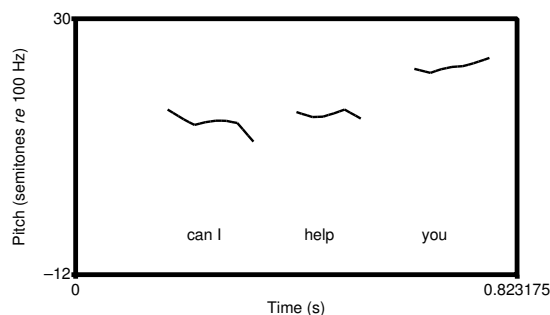


Figure 1: A high-rising question (H\*H-H%) with the nuclear pitch accent on ‘help’. [speaker L.M.]

<sup>3</sup>Note that the definition of final rises I use here excludes fall-rise, as in (i) from [Hirschberg, 1985].

(i) Speaker A: *do you speak Portuguese?*  
Speaker B: *my husband<sub>H\*</sub> does<sub>L-H%</sub>*

For a semantic analysis of fall-rises, see [Bartels and Merin, 1998].

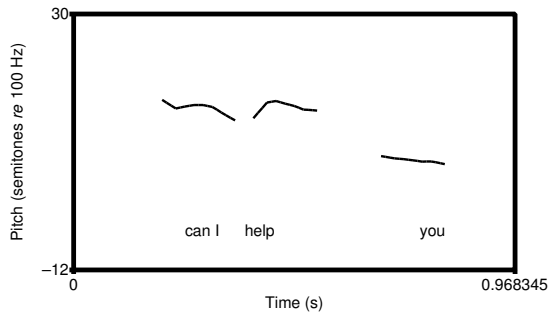


Figure 2: A falling question (H\*L-L%) with the nuclear pitch accent on ‘help’. [speaker L.M.]

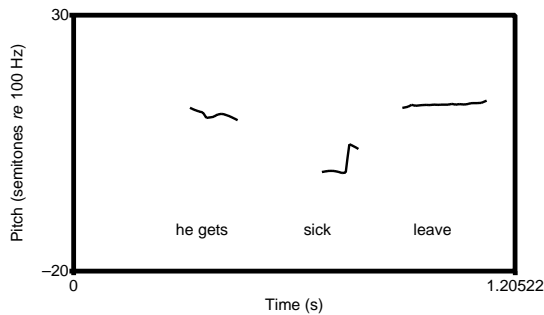


Figure 3: A low-rising declarative with the nuclear pitch accent on ‘sick’ (Santa Barbara Corpus).

(II) Final rise is possible on declaratives, as on the utterance ‘*he gets sick leave*↑’ in figure 3.

(III) Rising declaratives can receive at least three different interpretations:

(i) Some rising declaratives do not result in a commitment from either the speaker or the addressee: e.g., **biased questions**, where the addressee is often considered an expert on the issue, as in (1), or **try-out statements** where the speaker is stating a likely hypothesis, as in (2-b):

- (1) *you’re leaving for vacation today*↑
- (2) a. Speaker A: *John has to leave early*  
b. Speaker B: *he’ll miss the party then*↑

(ii) Some rising declaratives result in speaker’s commitment: e.g., **check-**

**ing statements** where the speaker conveys new information but wants to keep contact with the addressee, as in (3), or **informative statements** expressing polite, submissive and/or uncertain attitude, as in (4-b):

- (3) a. Speaker A: *I put a sign-up sheet over on the board*↑  
b. Speaker B: *it's for Dad's Day*↑
- (4) a. Speaker A: *how did you like the movie?*  
b. Speaker B: *I thought it was good*↑

(iii) Some rising declaratives are only used in case of a previous commitment from the addressee, as in **echo questions**, viz (5-b).

- (5) a. Speaker A: *that copier is broken*  
b. Speaker B: *it is*↑ *thanks, I'll use a different one*

(IV) All these types of rising declaratives usually elicit a response from the addressee or give the impression of the response being welcome, i.e., they are question-like.

(V) However, in context, rising declaratives are not interchangeable with interrogative polar questions because they often convey a certain bias of the speaker, viz (6).<sup>4</sup>

- (6) [as an exam question]  
a. *is the empty set a member of itself?*  
b. *# the empty set is a member of itself*↑

(VI) Rising utterances are considered to be more polite and friendly, but less confident, cmp. the minimal pair below, with a falling (7-b) and its rising version in (7-c).

- (7) a. Speaker A: *what did you think of the movie?*  
b. Speaker B: *I thought it was good*↓  
c. Speaker B': *I thought it was good*↑

(VII) Final rise is not associated with continuations, i.e., it differs from the comma intonation (symbolized here as →) sometimes found sentence-internally on major phrase boundaries, as in (8).

- (8) *I don't want shrimp → I want lobster.*

---

<sup>4</sup>The # symbolizes a semantically anomalous sentence.

(VIII) The meaning of the final rise is not weaker than the lexical-pragmatic features of an utterance. For example, predicates which denote intimate experiences normally match with questions if the subject/experiencer is the addressee (second person singular) and with assertions if the subject is the speaker (first person singular). However, the absence of a final rise on the hetero-cognitive predicate in (9-b) results in an assertive interpretation, while the presence of a final rise on the auto-cognitive predicate in (10-b) creates a questioning effect. This observation suggests that intonational properties can override the conventional interpretation of the predicates (for experimental evidence, see [Šafářová and Swerts, 2004]).

- (9) a. *it's bothering you*↑  
 b. *it's bothering you.*
- (10) a. *it's bothering me.*  
 b. *it's bothering me*↑

In an ideal case, a semantic theory of the final rise should account for all the facts listed above. In the following subsections, I will discuss two existing semantic proposals from this perspective, [Pierrehumbert and Hirschberg, 1990] and [Gunlogson, 2001]. I will also make reference to related proposals by [Gussenhoven, 1984], [Merin and Bartels, 1997] and [Steedman, 2004].

### 3 Existing Proposals

#### 3.1 Pierrehumbert & Hirschberg (1990)

Pierrehumbert & Hirschberg suggest that particular tunes specify the relationship between the propositional content of the utterance over which they are employed and the mutual beliefs of the conversation participants. With the intonation grammar of [Pierrehumbert, 1980] and subsequent work by [Beckman and Pierrehumbert, 1986] at its core, the meaning of individual tones (specified below) combines in a strictly compositional way to give the resulting meaning of a contour. The proposed system is somewhat schematically summarized below.

- H\*** - the accented item should be treated as new in the discourse; instantiated proposition should be added to the mutual beliefs
- L\*** - the accented item should be excluded from the proposition the speaker wishes to add to the mutual beliefs
- L+H\*** - evokes a salient scale and conveys that the accented item should be mutually believed
- L\*+H** - lack of speaker's commitment to the proposed scale

**H\*+L** - support for proposition being true can be inferred from the mutual beliefs  
**H+L\*** - same as H\*+L?  
**H-** - the intermediate phrase should be interpreted together with the following phrase  
**L-** - the intermediate phrase should be interpreted separately from the following phrase  
**H%** - the intonational phrase is forward-looking  
**L%** - the intonational phrase may be interpreted without reference to the following one

Pierrehumbert & Hirschberg’s proposal is interesting in its broad outlines, in that it assumes compositionality of the tone meaning and takes intonation to signal relations to the mutual beliefs of discourse participants, but the exact semantics remains rather informal and is not quite supported by the data. As for H\*H-H%, sometimes referred to as the *high rise*, Pierrehumbert & Hirschberg suggest that it is used in questions which at the same time convey new information, as opposed to L\*H-H%, which, according to the authors, is a question tune that does not convey new information (the L\* tone indicating that the unit carrying the pitch accent is old news). [McLemore, 1991a] and [McLemore, 1991b], however, gives examples from her corpus of checking statements (i.e., statements conveying new information where the speaker uses the final rise because she wants to maintain contact with her audience) with L\*H-H%, as in (11). She notes that “[the speakers] often use L\*[with a high boundary] in the first intonational phrase of a monologue when other participants are assumed to have equal rights to the speaking floor” (p. 79). It is unclear how Pierrehumbert & Hirschberg’s description would apply to these contexts.

(11) *y'all I was gonna tell<sub>L\*</sub>y'all<sub>H-H%</sub>*

As for L\*L-H%, the authors take it to be signaling the continuation rise, an assumption that has not been supported by experimental evidence (viz the references above). They also associate the high boundary tone with a forward-looking function but the boundary tones do not appear to behave uniformly with respect to question identification. The idea of the H% tone having a ‘forward-looking function’ is not unintuitive, but it is not immediately obvious what the function does in a formal semantic or pragmatic sense. One could speculate that a tone with this function should not occur at points of (sub)-dialogue closure (in the sense in which it is discussed, e.g., by [Muller and Prévot, 2003] but there is not enough empirical evidence at this point to prove whether this proposal is sustainable or not. Note also that Pierrehumbert & Hirschberg’s system does not explain why

rising declaratives convey a speaker bias and are not interchangeable with interrogatives.<sup>5</sup>

### 3.2 Gunlogson (2001)

Gunlogson’s proposal is in the spirit of Pierrehumbert & Hirschberg in that it also takes the semantics of intonation to be expressing beliefs and mutual beliefs of participants about the truth of the conveyed proposition. Unlike the authors above, however, she is not concerned with the meaning of individual tones but with the contours of nuclear phrases as a whole. Disregarding interrogatives, Gunlogson focuses on the instances of final rises on syntactic declaratives and makes the following observations:

- Rising declaratives express a bias that is absent with the use of interrogatives; they cannot be used as neutral questions.
- Rising declaratives, like interrogatives, fail to commit the speaker to their content.
- Rising declaratives can only be used as questions in contexts where the addressee is already publicly committed to the proposition expressed (‘Contextual Bias Condition’).

As an illustration of the first point, consider the example in (12): while the interrogative in (12-a) is acceptable in a context that has to be neutral, both the rising declarative in (12-b) and the falling declarative in (12-c) are excluded.

- (12) [on a health insurance form]
- Are you married?*
  - # You’re married?*
  - # You’re married.*

Gunlogson argues that the reason why (12-b) and (12-c) cannot be used in the context of a legal investigation is that they express a bias for the contained proposition being true.

As for the second and third observation, consider the exchange in (13):

- (13) a. Speaker A: *the king of France is bold*

---

<sup>5</sup>[Chen, 2004] summarizes other weak points of Pierrehumbert & Hirschberg’s proposal, such as the independent reality ascribed to H\* and L+H\*, which is highly questionable in intonational practice, and the combination of phrase accents with boundary tones (e.g., H-L% or L-%H), which appears to be difficult to interpret in the proposed system.

b. Speaker B: *France is a monarchy*↑

The rising declarative in (13-b) clearly does not commit the speaker B to the truth of its content, rather, it questions a presupposition to which the speaker A has committed herself by using (13-a).

In the semantics Gunlogson assigns to rises to account for these facts, her approach is closely related to that of [Merin and Bartels, 1997] who propose that rises ‘alienate choices to Alter’ (the addressee), while falls ‘appropriate choices to Ego’ (the speaker), and [Steedman, 2004] for whom the H% versus L% boundary tone distinction correlates with the ‘ownership’ of the content expressed. Specifically, Gunlogson implements the hypothesis that rising declaratives commit the addressee to the proposition expressed, while falling declaratives commit the speaker. First of all, she suggests that the context  $C$  can be viewed as composed of the commitment sets of conversation participants,  $cs$ :

**[Context]**

Let a discourse context  $C_{\{A,B\}}$  be  $\langle cs_A, cs_B \rangle$ , where A and B are discourse participants:

$cs_A$  of  $C_{\{A,B\}} = \{w \in W: \text{propositions representing A's public beliefs are all true of } w\}$

$cs_B$  of  $C_{\{A,B\}} = \{w \in W: \text{propositions representing B's public beliefs are all true of } w\}$

The meaning of a rising declarative,  $\uparrow S_{decl}$  is defined in terms of its context changing potential as:

**[Meaning of the Rise]**

$C + \uparrow S_{decl} = C'$  such that:

a.  $cs_{spkr}(C') = cs_{spkr}(C)$

b.  $cs_{addr}(C') = cs_{addr}(C) + S_{decl}$

For falling declaratives, its context changing potential is defined as follows:

**[Meaning of the Fall]**

$C + \downarrow S_{decl} = C'$  such that:

a.  $cs_{spkr}(C') = cs_{spkr}(C) + S_{decl}$

b.  $cs_{addr}(C') = cs_{addr}(C)$

Note, however, that Gunlogson’s description of the rise in terms of changing the commitment set of the addressee, does not really capture the observation made with respect to (13), that rising declarative can question a commitment

already made by the addressee in the context. But even that condition is in general too strong; rising declarative questions are also used and recognized in contexts where the addressee is not publicly committed *to the truth* of the expressed proposition, but at most to *knowing whether* the proposition is true or not, given that he or she is regarded as an expert on the issue (14-b).<sup>6</sup>

- (14) a. Speaker A: *he had a lot of real wacky ideas on big levels... he wanted a world power system, that you could tap into the air basically, and get power anywhere on earth...*  
 b. Speaker B: *that's what the Tesla coil was about*↑  
 c. Speaker A: *yeah, the problem was, that it interfered with, well, matter... I mean, it was not a clean broadcast system*

It is also not correct that rising declaratives always fail to commit the speaker to their content. As already noted above, they can be used as a politeness or checking device in situations where the speaker is informed with respect to an issue while the addressee is ignorant, as in (15), adapted from [Pierrehumbert, 1980].

- (15) [to a receptionist] *hi, my name is Mark Liberman*↑

One cannot reasonably claim for cases like (15) that the addressee is either already committed to the truth of the propositions expressed by the speaker, or becomes so committed after they have been uttered (while the speaker does not). In fact, it turns out that rising declaratives can also be used without a prior or a subsequent commitment from either the speaker or the addressee: this is in case they are used as questions and the addressee chooses to be uncooperative and leaves them unanswered. To illustrate, consider the example in (16): if speaker B would not reply, neither her nor speaker A would be committed to the proposition that ‘B remembers Peggy White’. However, Gunlogson’s description of the context change potential of rising declaratives would predict that the proposition would be in B’s commitment set even without the confirmation in (16-b).

- (16) a. A: *he was going to uh, Peggy ... you remember Peggy White*↑  
 b. B: *yeah*

---

<sup>6</sup>Only a small subset of declarative questions is actually used after the addressee has explicitly committed himself/herself to the proposition expressed – namely, echoic questions – and their main function in the dialogue seems to be asking for additional evidence in support of the proposition expressed, rather than asking for a simple confirmation.

This brings us to our final objection to Gunlogson’s approach, which is that the analysis does not explain why rising declaratives are usually responded to by the **addressee** as if they were questions. Gunlogson stipulates that uninformativeness with respect to the addressee is a necessary condition for an utterance to qualify as a polar question, but not that it is a sufficient condition. Given that the correct use of rising declaratives is presumably a part of the rules of rational conversation exchange and thus mutual knowledge, Gunlogson’s analysis would predict a response from the addressee neither in case she disagrees with the proposition – because she would be inconsistent with herself, nor if she agrees with it – because she would be agreeing with what she is already publicly committed to, which is superfluous.<sup>7</sup> If we accept Gunlogson’s setup and make the natural assumption that the goal of the conversation is to exchange information and thus create shared commitments, it should make perfect sense that the **speaker** states whether she agrees or disagrees with the proposition. However, neither seems to be the case in conversation: rising declaratives usually elicit a confirmation or a disconfirmation from the addressee (be it at least in terms of a nod or a short backchannel) and are not commented upon by the speaker.

To sum up, Gunlogson’s proposal cannot account for a prevalent number of rising declarative usage types. Specifically, it cannot deal with examples where a rising declarative is used not because the addressee is committed to its content but rather because he or she is regarded as an expert on the issue, examples where it commits the speaker to its content, as well as those where neither the speaker nor the addressee become committed. Also, the approach does not offer a plausible explanation as to why rising declaratives in all of these cases tend to elicit a response from the addressee.

### 3.3 Final Rise as a Modal Expression

#### 3.3.1 General Remarks

In my proposal, I follow the approaches described above in that I take intonation use to reflect the status of propositions in the set of mutual beliefs/common ground in the conversation. I suggest that the crucial properties of rising declaratives can be captured in a uniform way if we take

---

<sup>7</sup>As a matter of fact, Gunlogson would allow for the second case because for her, a sentence is informative if it is informative at least with respect to one commitment set. Note, however, that this has the unwanted consequence that a participant in a dialogue could repeat a sentence for as long as the addressee does not explicitly agree or disagree with it and still be informative.

the meaning of the final rise to be that of a modal expression of epistemic uncertainty.<sup>8</sup>

The connection between final rises and uncertainty has been noted in several studies in the past ([Uldall, 1964], [Chen and Gussenhoven, 2003], [Chen et al., 2001], [Gussenhoven, 2004]) and other attitudes usually associated with the rise like tentativeness, submissiveness or conciliatory attitude can be seen as secondary derivatives of ‘uncertainty’. In many contexts, expressing uncertainty may also sound more polite than a direct statement or a question (cmp. the examples below) because it helps to preserve the addressee’s face by giving him more space to refuse a request (e.g., for information), or an update of the mutual knowledge state.

(17) *Could you maybe tell us when you’ll be arriving?*

(18) *Maybe we could leave now.*

In earlier proposals, uncertainty and lack of confidence was considered to be a secondary attitude accompanying the primary meaning of rising declaratives, typically taken to be ‘questionhood’. I will suggest that uncertainty is the primary meaning associated with the rises, and questioning comes as a derived pragmatic effect. In particular, I will analyze the final rise as a kind of an ‘intonational adverb’, comparable, for instance to *it might be that*. This allows for an analysis that stays “true to form” at least with respect to declaratives, i.e., it represents all declaratives as statements. It only follows from pragmatic reasoning about the content of the rising declarative that the addressee should comment on it.

### 3.3.2 The Proposal

In order to be able to translate both falling and rising statements and questions into the formal language, I combine Veltman’s update semantics with a simple semantics for questions. Due to the semantics of the  $\diamond$ , it is not possible to make direct use of the partition semantics for questions (e.g.,

---

<sup>8</sup>Interestingly, apart from the language internal data discussed in this section, there seems to be cross-linguistic evidence in support of the connection between questions and an expression of epistemic uncertainty (albeit of a morphological type): As noted by [Palmer, 1986], there are languages that use a ‘dubitative’ or ‘uncertainty’ morpheme to turn statements into questions: for example, in Hixkaryana, there are two ways to express non-past - certain and uncertain - and when the ‘non-past uncertain’ is used alone (without other modal particles), it expresses a question. What is relevant about these and other cases given by Palmer is that in various languages, questions appeared to be expressed with the help of a modal expression which, however, does not express interrogativity by itself or in general.

[Groenendijk and Stokhof, 1996]) but I will make use of the idea that questions disconnect worlds in an information state. With respect to the language with the  $\diamond$  operator,  $L_\diamond$ , I stick to Veltman’s original definition: the  $\diamond$  operator can be stacked but cannot be embedded under negation or in conjunction/disjunction. In  $L_?$ , the  $\diamond$  can be embedded under  $?$  but stacking and embedding of the  $?$  operator is excluded. Hence, we can now have both statements with a  $\diamond$ ,  $\diamond\phi$ , as well as questions,  $? \diamond \phi$ , in other words (because I analyze the rise as  $\diamond$ ), we have both rising statements (declaratives), as well as rising questions (interrogatives).<sup>9</sup>

**Definition 1. [Language]**

Let us define the language  $L$  as the set of formulas  $\phi ::= p | \neg\phi | \phi \wedge \psi | \phi \vee \psi$ , where  $p$  ranges over atomic propositional formulas. Then  $L_\diamond = L \cup \{\diamond\phi | \phi \in L_\diamond\}$ , and  $L_? = L_\diamond \cup \{?\phi | \phi \in L_\diamond\}$ .

**Definition 2. [Context]**

Let  $W$  be the set of possible worlds and  $V$  a valuation function which in all  $w \in W$  assigns to each propositional letter a truth value 0 or 1. Then a context  $\sigma$  is an equivalence relation on a subset of  $W$ ,  $\sigma \subseteq W \times W$ , and  $dom(\sigma)$ , the domain of a context is the set of possible worlds in  $\sigma$ ,  $dom(\sigma) = \{w \in W | (w, w) \in \sigma\}$ .

I will write  $\sigma/X$ ,  $X \subseteq W$  for a restriction of a context, such that  $\sigma/X = \{(w, w') \in \sigma | w, w' \in X\}$  and I will call  $\sigma^0 = W \times W$  the state of complete ignorance and indifference where no statements have been made and no questions asked.

**Definition 3. [Semantics]**

- $\sigma[p] = \sigma / (dom(\sigma) \cap \{w \in W | V(p)(w) = 1\})$
- $\sigma[\neg\phi] = \sigma / (dom(\sigma) - dom(\sigma[\phi]))$

---

<sup>9</sup>[Gerbrandy, 1999] in his dissertation gives a formalization of Veltman’s update semantics which allows for  $\diamond$  being in the scope of negation. The interpretation of the formula one gets with the semantics is, however, not intuitive:  $\neg \diamond \phi$  is interpreted as  $\sigma - \sigma[\diamond\phi]$ , which is  $\emptyset$  if there is at least one  $\phi$  world and  $\sigma$  otherwise. In natural language, however, a statement like ‘It is not the case that he might come’ would rather be interpreted as conveying the information that ‘He is (certainly) not coming’, i.e. as an update with  $\neg\phi$  (or stronger, if possible in the formal language), not as a contradiction if it is not yet known whether  $\phi$  or not.

One could try to give a fixed interpretation to  $\neg \diamond \phi$  formulas as being simply equal to  $\neg\phi$ , but such a system basically collapses to propositional logic. (Thanks to Bernhard Schröder for the argument.)

- $\sigma[\phi \wedge \psi] = \sigma / (\text{dom}(\sigma[\phi]) \cap \text{dom}(\sigma[\psi]))$
- $\sigma[\phi \vee \psi] = \sigma / (\text{dom}(\sigma[\phi]) \cup \text{dom}(\sigma[\psi]))$
- $\sigma[\diamond\phi] \equiv \sigma$  if  $\text{dom}(\sigma[\phi]) \neq \emptyset$  and  $\emptyset$  otherwise
- $\sigma[?\phi] = \{(w, w') \in \sigma \mid w \in \text{dom}(\sigma[\phi]) \text{ iff } w' \in \text{dom}(\sigma[\phi])\}$

**Definition 4. [Common Ground and Information States]**

The common ground,  $\sigma_{CG}$  is a context representing the shared beliefs of the speaker and the addressee in the discourse.  $\sigma_S$  is the speaker's information state and  $\sigma_A$  is the addressee's information state.

**Definition 5. [Discourse and Updates]**

A discourse  $\Delta$  is a sequence of formulas  $\phi_1, \dots, \phi_n \in L?$  where with each formula  $\phi_i$  we associate a state of the common ground  $\sigma_{CG}^i$ , a state of speaker's belief state  $\sigma_S^i$  and a state of the addressee's belief state  $\sigma_A^i$ , such that  $\forall i : \text{dom}(\sigma_S^i) \subseteq \text{dom}(\sigma_{CG}^i)$  and  $\text{dom}(\sigma_A^i) \subseteq \text{dom}(\sigma_{CG}^i)$  and  $\sigma_{CG}^i[\phi_i] = \sigma_{CG}^{i+1}$ ,  $\sigma_S^i[\phi_i] = \sigma_S^{i+1}$  and  $\sigma_A^i[\phi_i] = \sigma_A^{i+1}$ . We write  $\phi_1 \prec \phi_2$  for  $\phi_1$  precedes  $\phi_2$  in  $\Delta$ .

With respect to answers, the aim is to have a definition which assigns to the question  $?\phi$ ,  $\phi$  and  $\neg\phi$  as its possible answers (same for  $?\neg\phi$ ) and to the question  $?\diamond\phi$ ,  $\diamond\phi$ ,  $\phi$  and  $\neg\phi$  as its possible answers. This effect does not come out straightforwardly with partition semantics of questions (as in [Groenendijk and Stokhof, 1996] because, e.g.,  $?\diamond\phi$  does not introduce a partition based on its 'yes' and 'no' answers (one, elements of a partition cannot be empty, and two, there is no  $\neg\diamond\phi$  in our language). Therefore, I propose a new definition of answerhood below.

**Definition 6. [Syntactic Answerhood]**

A syntactic answer to  $?\phi$  is  $\phi$ .

**Definition 7. [Semantic Answerhood]**

Let  $\phi$  be the syntactic answer to  $?\phi$ , then  $\Upsilon$ , the set of semantic answers to  $?\phi$  is the set such that  $\phi \in \Upsilon$  and for any  $\psi \in L_\diamond$ ,  $\psi \in \Upsilon$  iff  $\neg\exists v \in \Upsilon, v \in L : \text{dom}(\sigma^0[\psi]) \subset \text{dom}(\sigma^0[v])$  and  $\exists v \in \Upsilon, \sigma^0[\psi][v] = \emptyset$ .

Take the simple case of a question like  $?p$ . Then  $p$  is its answer syntactically and  $\neg p$  is its answer because  $\sigma^0[\neg p][p] = \emptyset$ . Take  $?\diamond p$  as another example. Then  $\diamond p$  is its syntactic answer. Next,  $\neg p$  is its answer because  $\sigma^0[\neg p][\diamond p] =$

$\emptyset$ . Finally,  $p$  is its answer because  $\sigma^0[p][\neg p] = \emptyset$ . Furthermore, the condition  $\neg\exists v \in \Upsilon, \text{dom}(\sigma^0[\psi]) \subset \text{dom}(\sigma^0[v])$  has as its goal to exclude the possibility that  $\neg p \wedge q$  would become an answer to  $?p$  (because  $\sigma^0[\neg p \wedge q][p] = \emptyset$ ) and then  $\neg q$  would become an answer because  $\sigma^0[\neg q][\neg q \wedge q] = \emptyset$  and so on, potentially infinitely. Also, the condition excludes contradictions as possible answers. An update of  $\sigma^0$  (the state of complete ignorance) with a contradiction gives  $\emptyset$ , which would be a proper subset of the state of ignorance updated with, e.g., the syntactic answer to the question. Note that if the question itself concerns a contradiction, this is not the case; e.g., a question  $?p \wedge \neg p$  can have anything as its answer, including contradictions, because its syntactic answer is  $p \wedge \neg p$ .

Given this definition, the question *is Sarkozy a clever man*↓ (with falling intonation) would have in its set of possible answers only (20-a) and (20-b), while the question *is Sarkozy a clever man*↑ (with rising intonation) would have all (20-a), (20-b) and (20-c) as its possible answers.<sup>10</sup>

- (19) a. *Yes. (Sarkozy is a clever man).*  
 b. *No. (Sarkozy is not a clever man).*  
 c. *Maybe. (Sarkozy might be a clever man).*

Based on Grice’s principles of rational conversation, I define four maxims which will restrict the number of eligible discourses, namely Quality, Relation, Quantity (1) and Quantity (2). Note that one of the goals of the analysis is to explain why both  $\diamond$  statements and  $\diamond$  questions are nonredundant. Existing formulations of redundant conversation moves (e.g., [Groenendijk, 1999]) assume that a statement is redundant if updating with it does not change the content of the common ground. Similarly, a question would be redundant if an answer to it would already be known, which technically translates into ‘not disconnecting any possible worlds’ or ‘not creating a (non-empty) partition’ of the common ground. Under this view, both  $\diamond$  statements and  $\diamond$  questions come out as being redundant, which is an undesirable effect. Therefore, I propose a different definition of redundant conversation moves, formulated in Quantity (2).

**Definition 8. [Maxims of Conversation]**

- **Quality:** A discourse  $\Delta$  conforms to Quality iff for every statement  $\phi_i \in \Delta$ ,  $\sigma_S^i[\phi_i] = \sigma_S^i$ .

---

<sup>10</sup>To be precise, given the analysis of rises here, it can also receive (20-a) and (20-b) and (20-c) with rising intonation as an answer.

- **Relation:** A discourse  $\Delta$  conforms to Relation iff for every statement  $\phi_i \in \Delta$ ,  $\phi_i$  is a semantic answer to the most recent unresolved question.  $?\phi_i$  is unresolved in  $\sigma_{CG}^i$  iff  $\exists w, w'$  such that  $w \in \text{dom}(\sigma_{CG}^i)$  and  $w' \in \text{dom}(\sigma_{CG}^i)$  and  $(w, w') \notin \sigma^0[?\phi_i]$ .
- **Quantity (1):** A discourse  $\Delta$  conforms to Quantity (1) iff for every statement  $\phi_i \in \Delta$ , there is no stronger statement given  $\sigma_S^i$ , speaker's knowledge at that point in the conversation.  $\phi$  is stronger than  $\psi$  iff  $\text{dom}(\sigma^0[\phi]) \subseteq \text{dom}(\sigma^0[\psi])$ .
- **Quantity (2):** A discourse  $\Delta$  conforms to Quantity (2) iff for every  $\phi_i \in \Delta$ ,  $\phi_i$  is not redundant in  $\sigma_{CG}^i$ . A question  $?\phi_i$  is redundant with respect to  $\sigma_{CG}^i$  if all its semantic answers are redundant in  $\sigma_{CG}^i$ . A statement  $\phi_i$  is redundant with respect to  $\sigma_{CG}^i$  iff with respect to  $\phi_i^{SUB} \in L$ ,  $\phi_i^{SUB}$  being the largest propositional subformula of  $\phi_i$ ,  $\sigma_S^i[\neg\phi_i^{SUB}] = \sigma_{CG}^i[\neg\phi_i^{SUB}]$ .

By Quantity (2), questions like  $?\diamond\phi$  are only redundant if it is already known whether  $\phi$  or  $\neg\phi$ . A statement  $\diamond\phi$  is not redundant iff the speaker's information state updated with  $\neg\phi$ , would be a proper subset of the common ground updated with  $\neg\phi$ , i.e.,  $\sigma_S^i[\neg\phi] \subset \sigma_{CG}^i[\neg\phi]$ . This will be the case if there are less  $\neg\phi$  worlds in  $\sigma_S^i$  than in  $\sigma_{CG}^i$ , i.e., if the speaker believes  $\neg\phi$  to be less likely.

To see how the proposed theory works in practice, in the next section of this paper, I return to the points (I)-(VIII) from section 2.1.

## 4 Discussion

It is easy to express the observation that inverted *yes/no*-interrogatives can sometimes appear with a rise. If they do, we represent them as  $?\diamond\phi$  and correctly predict that they will be perceived as more polite (but possibly also more hesitant) than the falling  $?\phi$ : they allow for the weak answer  $\diamond\phi$ , while their falling counterparts require a stronger commitment from the addressee.<sup>11</sup>

Similarly, rise on a declarative,  $\diamond\phi$ , is interpreted as a weaker type of statement than a falling declarative  $\phi$ . Using it does not result directly in any commitment (either from the speaker or from the addressee), because an update with a test does not eliminate worlds from the common ground.

<sup>11</sup>Given the semantics I use, I cannot say anything about *wh*-question.

However, by Quantity (2), the addressee can derive that there is at least one world in the common ground in which  $\neg\phi$  holds and in which the speaker does not believe. In a common ground in which there is only *one*  $\neg\phi$  world, uttering  $\diamond\phi$  will thus effectively result in an update with  $\phi$ ! We can thus also account for cases in which uttering a rising declarative results in a commitment by the speaker. As for echo questions, the present setup predicts that using a rising declarative  $\diamond\phi$  directly after  $\phi$  has been uttered by the other participant is redundant. The fact that the speaker uses it nevertheless suggests that for some reason, the update of the common ground with  $\phi$  was not successful and/or the common ground has to be revised. This corresponds to the intuition that echo questions involve disagreement between the participants and can be interpreted as requests for additional information or at least confirmation. Accounting for this process exactly, however, requires a more fine-grained machinery than the one proposed in the present paper.

In general, I assume that uttering a possibility statement, i.e., a  $\diamond$ -statement, accommodates a question to which it is a syntactic answer, i.e.,  $?\diamond p$ , which has  $\diamond p$ ,  $p$  and  $\neg p$  among its answers. In a rational conversation, participants cooperate on finding the strongest possible answers to questions that have been raised (whether overtly or accommodated). Therefore, if a  $?\diamond p$  question has been raised and there is a participant who knows that either  $p$  or  $\neg p$  is the case, she has to say so. Thus, a rising declarative (a  $\diamond$ -type of statement), will frequently be followed by a ‘response’. Crucially, this response is not an answer to the rising declarative but to the question accommodated due to the use of the rising declarative.

The analysis can easily model the fact that rising declaratives are not interchangeable with questions: after all they are assertions, which express a bias also in contexts in which the ratio of worlds making them true and worlds making them false should remain 1:1. For example, used as an exam question, a rising declarative *the empty set is a subset of itself*↑ would swing the odds of the proposition ‘the empty set is a subset of itself’ being true for its favor in a common ground which is supposed to be absolutely neutral.

Similarly to rising *yes/no*-questions, also rising declaratives come out as being more polite than their falling counterparts. If the speaker updates the common ground with a falling declarative  $\phi$  and the addressee believes  $\neg\phi$  to be true, the participants are in an open disagreement and a correction of the common ground may be needed. If, on the other hand, the speaker uses a rising declarative  $\diamond\phi$ , she generally does not eliminate all  $\diamond\neg\phi$  worlds (unless there is only one) and the addressee can still utter the stronger statement  $\neg\phi$ , if she believes it to be true, without overtly disagreeing.

The proposal does not predict any link between final rises and continua-

tions, which is correct, given that in English, empirical studies suggest that different kinds of intonational patterns are involved (see [Šafářová, 2005] and the references cited there). Note also that the meaning of the rise is here treated on the same level as the meaning of the lexical features of the utterance and interacts with them; intonation is not semantically “weaker”.

As a final remark, I would like to stress that in the present proposal, the final rise is not exactly synonymous with a particular lexical adverb and all the translations of the final rise with a lexical expression should be understood very loosely. The syntactic and semantic behavior of lexical adverbial expressions and corresponding adjectival phrases is rather complicated (viz, a.o., [Cinque, 1999], [Nilsen, 2003]): for example, the adverb *possibly* appears to be excluded from some (but not all) interrogatives, while its adjectival counterpart *it is possible that* is not. Also, it is generally assumed that there is a syntactic and presumably also semantic difference between *it might be that*, *maybe*, *possibly* or *perhaps*. In principle, I do not exclude the option of formalizing the meaning of one of these operators with Veltman’s test diamond (the semantics of which I make use does not exclude multiple presence of the epistemic operator which will be represent with a  $\diamond$ , so the option of combining intonational and lexical expressions exists). At least ‘*maybe*’, however, seems to function differently from the rise, as show by the following dialogue:

- (20) a. A: *I lost my ring*  
 b. B: *did you leave it in the bathroom?*  
 c. B’: *maybe you left in the bathroom*  
 d. B’’: *you left in the bathroom*↑

The reply (21-d) patterns with the reply in (21-b) in that a response by speaker A is expected. The relevant difference seems to be that in (21-b) and (21-d), but not necessarily in (21-c), the speaker A is assumed to be knowledgeable with respect to the content of the utterance. Unfortunately, this example cannot be handled by the formalization proposed here, because it lacks the machinery to express propositions of the type ‘A knows that...’.<sup>12</sup>

## 5 Summary and Future Work

The proposal in this paper can be summarized as  $\uparrow = \diamond$ . While it can model a number of facts about the use of rising intonation in American English,

<sup>12</sup>Thanks to David Ahn for bringing this example to my attention.

the formal language is quite simple and cannot express *wh*-questions and propositions of the type ‘A knows that’ or the effect of utterances like ‘*I don’t know*’ on the common ground. Employing a knowledge operator could possibly also help to address the fact that not only rising declaratives, but also falling declaratives are often responded to by the addressee if they concern an issue on which she is an expert.

## References

- [Bartels and Merin, 1998] Bartels, C. and Merin, A. (1998). Towards a formal semantics of English phrasal intonation. In Fujimora, O., Joseph, B., and Palek, B., editors, *Proceedings of LP’98*, pages 91 – 110. Charles University in Prague, The Karolinum Press.
- [Beckman and Pierrehumbert, 1986] Beckman, M. and Pierrehumbert, J. (1986). Intonational structure in Japanese and English. *Phonology Yearbook*, (3).
- [Chen, 2004] Chen, A. (2004). *Universal and Language-specific Perception of Paralinguistic Intonational Meaning*. PhD thesis, LOT dissertation series 102.
- [Chen and Gussenhoven, 2003] Chen, A. and Gussenhoven, C. (2003). Language dependence in the signaling of attitude in speech. In *Proceedings of Workshop on the Subtle Expressivity of Emotion at CHI 2003 Conference on Human and Computer Interaction*.
- [Chen et al., 2001] Chen, A., Rietveld, T., and Gussenhoven, C. (2001). Language-specific effects of pitch range on the perception of universal intonation meaning. In *Proceedings of Eurospeech*, pages 327 – 352.
- [Cinque, 1999] Cinque, G. (1999). *Adverbs and Functional Heads: A Crosslinguistic Perspective*. Oxford University Press, Oxford.
- [Cook, 2002] Cook, N. (2002). *Tone of Voice and Mind*. John Benjamins.
- [Fries, 1964] Fries, C. C. (1964). On the intonation of yes-no questions in English. In Abercombie, D., Fry, D., McCarthy, P., Scott, N., and J.L.M. Trim, L., editors, *In Honour of Daniel Jones*. Longman.
- [Gerbrandy, 1999] Gerbrandy, J. (1999). *Bisimulations on Planet Kripke*. PhD thesis, University of Amsterdam.

- [Groenendijk, 1999] Groenendijk, J. (1999). The logic of interrogation. In *Proceedings of SALT IX*.
- [Groenendijk and Stokhof, 1996] Groenendijk, J. and Stokhof, M. (1996). Questions. In van Benthem, J. and ter Meulen, A., editors, *Handbook of Logic and Language*. Elsevier.
- [Gunlogson, 2001] Gunlogson, C. (2001). *True to Form: Rising and Falling Declaratives and Questions in English*. PhD thesis, UCSC.
- [Gussenhoven, 1984] Gussenhoven, C. (1984). *On the Grammar and Semantics of Sentence Accents*. Foris, Dordrecht.
- [Gussenhoven, 2004] Gussenhoven, C. (2004). *The Phonology of Tone and Intonation*. Cambridge University Press.
- [Hirschberg, 1985] Hirschberg, J. (1985). *A Theory of Scalar Implicature*. PhD thesis, University of Pennsylvania, Published by Garland, New York, 1991.
- [Hirschberg, 2000] Hirschberg, J. (2000). A corpus-based approach to the study of speaking style. In Horne, M., editor, *Prosody: Theory and Experiment*, pages 335–350. Kluwer Academic Press.
- [Hirschberg and Ward, 1995] Hirschberg, J. and Ward, G. (1995). The interpretation of the high-rise contour in English. *Journal of Pragmatics*, 24:407 – 412.
- [McLemore, 1991a] McLemore, C. (1991a). The interpretation of l\*h in english. In *Texas Linguistic Forum - Discourse*, number 32. University of Texas, Austin.
- [McLemore, 1991b] McLemore, C. (1991b). *The Pragmatic Interpretation of English intonation: Sorority Speech*. PhD thesis, University of Texas, Austin.
- [Merin and Bartels, 1997] Merin, A. and Bartels, C. (1997). Decision-theoretic semantics for intonation. Technical Report Bericht Nr. 88, Univ. Stuttgart and Univ. Tübingen.
- [Muller and Prévot, 2003] Muller, P. and Prévot, L. (2003). An empirical study of acknowledgement structures. In *Proceedings of Diabruck*, Saarbrücken.

- [Nilsen, 2003] Nilsen, Ø. (2003). *Eliminating Positions*. PhD thesis, Utrecht University.
- [Ohala, 1984] Ohala, J. (1984). An ethological perspective on common cross-language utilization of f<sub>0</sub> in voice. *Phonetica*, 41:1 – 16.
- [Palmer, 1986] Palmer, F. (1986). *Mood and Modality*. Cambridge University Press.
- [Pierrehumbert, 1980] Pierrehumbert, J. (1980). *The Phonology and Phonetics of English Intonation*. PhD thesis, MIT, distributed by the Indiana University Linguistics Club.
- [Pierrehumbert and Hirschberg, 1990] Pierrehumbert, J. and Hirschberg, J. (1990). The meaning of intonational contours in the interpretation of discourse. In Cohen, P., Morgan, J., and Pollack, M., editors, *Intentions in Communication*, chapter 14, pages 271 – 311. MIT Press.
- [Šafářová, 2005] Šafářová, M. (2005). *Rises and Falls: Studies in the semantics and pragmatics of intonation*. PhD thesis, University of Amsterdam.
- [Šafářová and Swerts, 2004] Šafářová, M. and Swerts, M. (2004). On recognition of declarative questions in English. In *Proceedings of Speech and Prosody*, Nara, Japan.
- [Steedman, 2004] Steedman, M. (2004). Information-structural semantics for English intonation. In *Proceedings of the LSA Workshop on Topic and Focus*.
- [Uldall, 1964] Uldall, E. (1964). Ambiguity: question or statement? or “are you asking me or telling me?”. In *Proceedings of IVth Int. Congr. Phon. Sciences*, pages 779 – 783.
- [van Alphen, 2003] van Alphen, I. (2003). De interactionele kracht van vragen (en vrouwen). In *Artikelen van de vierde sociolinguïstische conferentie*, pages 11 – 21.
- [Veltman, 1996] Veltman, F. (1996). Defaults in update semantics. *Journal of Philosophical Logic*, (25):221 – 261.