A Formal Semantics of the Final Rise*

Julian J. Schlöder

Institute for Logic, Language & Computation
University of Amsterdam
julian.schloeder@gmail.com

Abstract. This paper presents a formally precise model of how the final rise affects the discourse structure of a dialogue. Our account makes precise the informal claims from previous discussions which have characterised the final rise as signalling 'incompleteness,' 'uncertainty' or 'insufficiency' in various senses (*e.g.*, Pierrehumbert and Hirschberg [11], Hobbs [8], Bolinger [3], Westera [19]). Inspired by their analyses, we give a formal semantics in the SDRT framework (see [1]) that models 'incompleteness' as an underspecified notion that is resolved to specific interpretations in context.

1 Introduction

In this paper, we give a formal semantics of the final rise in spoken English dialogue, as part of our ongoing work on pitch contours. Our general claim is that the pitch contour of an utterance perturbs the standard inferences from surface form to illocutionary force and perlocutionary effect. Hence, by computing these perturbations, we can derive the implicatures that a final rise is usually taken to convey. The following examples (adapted from [15]) are cases in point:[1]

(1) A: You're a millionaire.

a. B: I'm a MILLIONAIRE. H* LL%
'Yes, I am.'

b. B: I'm a MILLIONAIRE. H* LH%
'Really?'

(2) A: Are you rich?

a. B: I'm a MILLIONAIRE. H* LL%
'In particular, I'm rich.'

b. B: I'm a MILLIONAIRE. H* LH%
'Does that count?'

The utterance in (1a) and (2a) is intonated in the standard 'high focus, final fall' contour (H* LL%), leading to the usual effects of indicatives: It commits B to the proposition *'B is a millionaire,'* and therefore in (1a) establishes a shared public commitment (*i.e.*, agreement) on that proposition, and completes

* The research presented in this paper has been funded by the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 567652 *ESSENCE: Evolution of Shared Semantics in Computational Environments* (http://www.essence-network.com/).

[1] To describe our examples, we use the ToBI annotation scheme for pitch contour (see [14]). An asterisk (*) marks the focus accent, and a final rise is denoted by LH%.

a question-answer pair in (2a). In contrast, the same utterance with a final rise (LH%) in (1b) does *not* make any such commitment (*cf.* [6]). Therefore, there is no established agreement between A and B in (1b) and B's utterance functions as a clarification request. Then again, in (2b), B *does* make the commitment to *'B is a millionaire,'* but does not commit to this necessarily answering A's question, *i.e.*, the illocutionary force of an answer does not immediately obtain, and it is left open whether it does (pending A's response).

Based on these and similar examples, a body of work has described the final rise in English as marking an utterance as 'incomplete,' broadly construed. In particular, Pierrehumbert and Hirschberg in [11] gloss this as 'to interpret an utterance with particular attention to subsequent utterances,' which Hobbs in [8] plainly calls 'open.' Westera in [19] characterises a final rise as indicating the failure of a Gricean maxim, which corresponds to our intuition that standard perlocutionary inferences do not obtain. Our goal in this paper is to give a fully formal model of these effects.

We proceed as follows. In the next section, we expand our informal discussion above to additional examples. Along the way, we further discuss earlier treatments of their effects and start motivating the choices we made for our formal account. We motivate our choice of SDRT as our formal framework and give a brief introduction into that formalism in Section 3. In Section 4, we present our formal theory in and show that its results correspond to our discussion from Section 2. We conclude with some pointers towards further work in Section 5.

2 Informal Discussion

In this paper, we are primarily interested in the effects of a final rise (LH%) in colloquial English and ignore the effects of nuclear pitch accents (*e.g.*, the high focus accent H*). We consider 'high focus, final fall' (H* LL%) to be the default contour (for indicatives) and contend that it has conversational significance only in non-standard situations. The data and analysis presented here are not new in themselves. The following discussion merely rehearses previous accounts to motivate our formal model.

In (2b), the final rise indicates that the utterance is not necessarily an answer to the preceding question. Such utterances allow the dialogue to proceed in two different ways: either the addressee confirms (or rejects) that they take up the answer, or the speaker continues to supply more information. In either case, it can be said that the final rise utterance itself is not a complete answer. Hence, we follow the literature in characterising the final rise as signalling 'incompleteness,' but we consider incompleteness itself to be an underspecified property. Put simply, an incomplete utterance needs to be addressed—the incompleteness needs to be resolved—in the dialogue, but it is left open *how*. Which resolutions are possible depends on the context, and the speakers negotiate online which possible resolutions are adequate. The following two possible continuations of B's utterance (adapted from [7]) exemplify the effect:

(3) A: Where are you from?
B: I'm from SKOKIE.
H* LH%
B: That's in Illinois.

(4) A: Where are you from?
B: I'm from SKOKIE.
H* LH%
A: Okay, good. / Where is that?

In both examples, B's first utterance can be considered incomplete in the sense outlined above. In (3), B is expressing by way of a final rise that *'Skokie'* is not the full answer, but that it is *'Skokie, Illinois.'* In (4), B isn't sure whether the answer *'Skokie'* is sufficient, and hence leaves the answer open for confirmation or further questions. As analysed by Hirschberg and Ward in [7], the incompleteness of the final rise utterance in (3) and (4) lies in B being unsure whether A can resolve the proper noun 'Skokie' in a meaningful way. Note that B is inviting a response from A in (4): an appropriate gloss of the incompleteness in B's utterance is *'does this answer your question?'* However, while this means that the utterance has question force, in some sense, a reading as a polar question (*'am I from Skokie?'*) is inappropriate.

In contrast, there is an apparent tendency to infer polar clarification requests (requests for confirmation or elaboration) from a final rise intonation, as in (1b) where the gloss *'am I a millionaire?'* is appropriate. So in some contexts, it is licensed to interpret a final rise utterance in indicative mood with propositional content p as having the conversational effect of the question $?p$ (*'Is it the case that p?'*). As mentioned already, part of our solution is to leave the incompleteness of the final rise underspecified. We merely stipulate that it *projects a follow-up*, but leave open what speech act precisely is being projected. First of all, this neatly captures the use of a final rise in 'list intonations' as in the following example: (cited from [19]):

(5) A: What did you do today?
B: I sat in on a history class.
LH%
B: I learned about housing prices.
LH%
B: And I watched a cool documentary.
LL%

In Example (5) and similar ones, a speaker simply provides the follow-up projected by the final rise utterance themself, and we can gloss the contribution of the final rise as *'I am not done.'* If this is not the case, the onus to provide the projected follow-up is on the addressee of the final rise utterance. We assume that, by default, this projection corresponds to a polar clarification question wherever the context allows this, *i.e.*, that the speech act projected is an answer to a polar question. But we also explicitly leave room for other possible continuations, *e.g.*, elaborations (as in 3) or acknowledgements (as in 4). This defaulting to polar questions can be abused for comedic effect, as in the following example:[2]

[2] The example is taken from the TV show *The Big Bang Theory*, but anyone who has participated in an oral exam should be familiar with utterances like B's.

(6) a. A: What's the sixth noble gas?
b. B: Uh, RADON?
H* LH%
c. A: Are you asking me or telling me?
d. B: TELLING you?
H* LH%

B's utterance in (6b) taken on its own admits different interpretations: it might be taken to express the polar question *'Is it Radon?'* or that B is unsure whether the answer is adequate w.r.t. A's intentions. The speaker A is apparently (or purposefully pretending to be) unsure of the right interpretation. This further shows the inherent underspecification in interpreting a final rise.

Aside from this influence on the discourse structure, there are also accounts that characterise 'incompleteness' as displaying an 'uncertain attitude' of the speaker (*cf.* [18], [7]). Westera in [19] has given a compelling account of such uncertainty in terms of the Gricean maxims: by intonating an utterance with a final rise, a speaker announces that they cannot vouch for the truthfulness (Quality), sufficiency (Quantity) or appropriateness (Relation) of their utterance. Since we do not formalise the Gricean maxims precisely, we take a broader standpoint: in our formal account, the speaker is uncertain regarding the successful uptake of their utterance. For our formalisation, we choose a model that keeps track of discourse structure and cognitive attitudes separately. Hence, our model will describe 'incompleteness' according to both accounts.

The final rise also prominently features in utterances that are correcting or contradicting the previous speaker: the rise-fall-rise contour has been dubbed *contradiction contour* by Liberman and Sag in [10]. This fits into our discussion so far as follows: After a correction, the discourse is in a 'state of crisis' (*cf.* [5]) that needs to be addressed. In that sense, a correction prompts a follow-up, aligning with our characterisation of the final rise. Furthermore, a correcting speaker is almost by necessity uncertain whether their contribution will be taken up cooperatively.

3 Framework

Our theory of pitch contours is implemented in Dialogue Segmented Discourse Representation Theory (DSDRT) (established in [1] and [9]). Our rationale goes as follows. SDRT models back-and-forth information flow between a logic of information content (a dynamic semantics) and a logic for cognitive modelling (modelling beliefs and intentions) by way of the so-called *glue logic* that connects the different sources of information. This allows us to model perturbations of the information flow: by stipulating new glue axioms for the final rise, we can block defeasible standard inferences, and impose novel restrictions on the semantic content. In addition, the glue logic allows for defeasible reasoning, and models underspecified information. We now give a brief overview over the most important concepts.

The SDRT *language of information content* is used to express the (truth-conditional) logical form of a discourse. It consists of the following components:

- A standard first-order alphabet, plus a modal operator ($\Box$), and operators for imperatives (!) and interrogatives (?).
- A set of label variables. We conventionally denote these by Greek letters, $\alpha, \beta, \lambda, \pi_1, \pi_2, \ldots$
- A finite set of predefined discourse relations, *e.g.*, Explanation, Elaboration, Correction.[3]

The well-formed formulae are obtained by the standard syntax on the alphabet without discourse relations (treating labels as variable symbols), then adding formulae of the form $R(\pi_1, \ldots, \pi_n)$ where R is an n-ary discourse relation and π_i are labels, and then closing under booleans and quantification (of first order variables, label variables, and discourse relations).[4] These formulae are given a dynamic semantics that also associates pre-defined truth-conditions with every discourse relation. For instance, the truth of $\mathit{Elaboration}(\pi_1, \pi_2)$ must also render π_1 and π_2 true.

A logical form in SDRT is a segmented discourse representation structure (henceforth, SDRS). An SDRS consists of a set of labels Π and a function F mapping labels from Π to formulae in the logic of information content (sometimes we write K_π for $F(\pi)$). Intuitively, the labels of an SDRS mark discourse segments that can be connected by discourse relations. These relations are also represented in the language of information content. Hence, we can use F to define a order on Π: $\pi_1 > \pi_2$ iff either $R(\lambda, \pi_2)$ or $R(\pi_2, \lambda)$ appear in $F(\pi_1)$ for some R and λ. We write $\pi_1 \geqslant \pi_2$ for the reflexive and transitive closure of $\geqslant$ and read this as π_1 *outscopes* π_2. Intuitively, π_1 outscoping π_2 means that π_2 is a subsegment in the larger discourse segment labelled by π_1. On well-formed SDRSs, this order is additionally required to be anti-symmetric, *i.e.*, $\geqslant$ is a partial order.

Outscoping, together with the discourse relations, is used to reason about the *structure* of a discourse and not just its contents. We allow the outscoping relation $\geqslant$ (with the above truth-conditions) to be used in the logic of information content.[5] DSDRT extends this model to dialogues where the information content of the two interlocutors might differ. In a dialogue, every interlocutor vouches for the truth of certain logical forms, *i.e.*, a speaker makes commitments to SDRSs. The logical form of a dialogue turn is a set of SDRSs (one for each interlocutor), and the logical form of a dialogue is the sequence of the logical forms of its

[3] See [1, Appendix D] for a list.

[4] Such quantification is a slight deviation from the presentation in [9] where only first-order variables are quantified. The change is made here to model a public commitment to a yet unknown discourse relation in a transparent way: by existential quantification. This is a conservative extension. Since the logic of information content includes an event calculus that allows us to quantify over speech events, this changes neither the proof-theoretic properties of the logic nor its expressiveness. The equivalent construction in standard SDRT would use the '?' variables of the glue logic to express unknown relations and labels.

[5] Again, a slight deviation from the norm, but also with no further consequences.

turns. Thereby, each interlocutor's commitments over the course of a dialogue are recorded individually. The following example (from [2]) is a simple DSDRS:

(7) A: Max fell.
B: John pushed him.

Turn	A's SDRS	B's SDRS
1	$\pi_1 : \mathit{fall}(e, m)$	$\varnothing$
2	$\pi_1 : \mathit{fall}(e, m)$	$\lambda : \mathit{Explanation}(\pi_1, \pi_2)$ $\pi_2 : \mathit{push}(e', j, m)$

We gloss the assignment function F in each individual SDRS by a colon (so $F(\pi) = K$ is $\pi : K$). In Example (7) above, π_1 labels the information content of *'Max fell'* and π_2 that of *'John pushed Max'* and the speakers are committed to their individual utterances. However, by general principles of dialogue coherence, we also infer that B meant to *explain* the event described by A, which is recorded by the contents of λ. The dynamic semantics of $\mathit{Explanation}(\pi_1, \pi_2)$ entail the contents of π_1 and π_2 and that π_2 answers *'why* π_1*?'* Hence we can infer from the SDRS in (7, turn 2) that B is *also* committed to the proposition that *'Max fell.'* This means that we can read off the logical form in (7) that A and B agree on that proposition, despite this not being linguistically explicit in B's utterance.

The inferences used to *construct* logical form—particularly which discourse relations connect which labels—are not drawn in the logic of information content, but in the *glue logic*. Such inferences are by their very nature defeasible, as novel information could change the interpretation of the dialogue at any time. Hence, the glue logic has a defeasible conditional $>$ which we read as 'normally.' To be precise, from φ and $\varphi > \psi$ we infer ψ only if that conclusion is not blocked by other information in the current context.[6] In addition, glue logic formulae can use a special variable '?' to denote elements of the logic of information content that are not yet fully specified, but whose structural properties can already be circumscribed. The derivation of discourse relations is facilitated by stipulating axioms in the glue logic of the following form:

$$(\lambda{:}\,?(\alpha, \beta) \wedge \mathit{Info}(\alpha, \beta)) > \lambda : R(\alpha, \beta)$$

This schema reads as: "if α and β are rhetorically connected *somehow* to form a part of the (extended) discourse segment λ, and their contents satisfy *Info*, then normally, they are connected by R." These axioms are used to construct the *form* (structure) of a logical form. The following concrete axiom is used to derive the SDRS in (7, turn 2) and stipulates that if it is known that β attaches to α (by a yet unknown discourse relation), and there is evidence that β can cause α, we (defeasibly) infer that β attaches as an explanation to α.

Explanation Axiom.
$(\lambda : ?(\alpha, \beta) \wedge \mathit{cause}_D(\beta, \alpha) > \lambda : \mathit{Explanation}(\alpha, \beta)$.

Finally, the separate *cognitive modelling logic* is used to model the speakers' cognitive states. It includes a number of modal operators (see [2] for details):

[6] This leads the glue logic to admit a nonmonotonic proof theory which is detailed in [1, Chapter 5].

– KD45 modal operators for beliefs: B_S for a speaker S.
– K45 modal operators for public commitments: P_S for a speaker S.
– Modal operators for intentions: I_S for a speaker S.

Glossing over some details, we write $I_A P_B \varphi$ if A wants B to commit to φ and $I_A B_B \varphi$ if A wants B to believe that φ holds. The cognitive modelling logic interfaces with the glue logic: facts from the cognitive modelling logic can block inferences using the defeasible conditional $>$ in the glue logic. For instance, if $P_S \neg \varphi$ in the cognitive model, then the glue logic cannot infer a discourse relation in S's SDRS that would entail φ. Conversely, information from information content can be used to infer cognitive states, *e.g.*, if A has asserted that p, then the glue logic infers that $B_A p$—but this inference too can be defeased if it is known that A is being insincere. For ease of notation, we will also use functions $S(\pi)$ and $H(\pi)$ mapping a label to its speaker and hearer, respectively.

4 A Formal Model of the Final Rise

Based on our informal discussion in Section 2, we claim that the final rise has an influence both on the *structure* of the dialogue (incompleteness) and on the *displayed attitudes* of its speaker (uncertainty). To formalise incompleteness, we assign the following semantics to the final rise in the logic of information content:

Semantics of the Final Rise.
$LH\%(\pi) \mapsto \exists R, \pi', \pi''\ (R(\pi', \pi'') \wedge \pi' \succcurlyeq \pi)$.

That is, the final rise does not affect the information content of the utterance itself, but it enforces that there is a yet unknown follow-up response that stands in some yet unknown discourse relation to the current dialogue. We also leave it underspecified what label this relation attaches to on the left side, only that the current utterance (labelled π) is in its scope. This underspecification is necessary because the continuation can attach both to the current utterance itself or to a wider discourse relation, when it is that relation itself that is uncertain. For example, in (3) the follow-up attaches directly as an elaboration, but in (4) the follow-up attaches to the whole question-answer pair consisting of the first two utterances; see Figure 1 below. We consider this model to be a rather faithful formalisation of the informal discussion in [11].

These semantics account for the forward projecting function of the final rise, *e.g.*, in list intonations as (5). However, we also observed a backward looking property: asking for clarification, thereby indicating uncertainty regarding an earlier utterance. We model this effect by stipulating an appropriate glue logic axiom. The following rule, if it applies, turns a proposition p in indicative mood into the polar question $?p$ as in Example (1b). For the sake of exposition, we shorthand the above semantics of the final rise as '$\pi : LH\%$' (read as: the label π includes the final rise semantics). We also use a function *prop* that maps a polar question $?p$ to its propositional content p.

(Ax1) **Clarification from Final Rise.**
$(\pi : LH\% \wedge \lambda : ?(\alpha, \pi) \wedge \Box(K_\alpha \rightarrow prop(K_\pi))) > (\lambda : \mathrm{CR}(\alpha, \pi))$.
(CR $\simeq$ Clarification Request)[7]

This axiom stipulates that if an utterance has a final rise, and it directly attaches to a previous utterance in some way, then it has the force of a clarifiying polar question *if* this is consistent and the polar question is truth-conditionally appropriate. The appropriateness constraint $K_\alpha \rightarrow prop(K_\beta)$[8] is required to explain the incoherence of (8b):

(8) A: You are rich.
  a. B: I'm rich? (LH%) *'Am I?'*
  b. B: # I'm a millionaire? (LH%)

(9) A: You are a millionaire.
  a. B: I'm rich? (LH%) *'Am I?'*
  b. B: I'm a millionaire? (LH%) *'Am I?'*

Both (9a) and (9b) are licensed because, conventionally, *'millionaire'* implies *'rich,'* hence the question in (9a) is reasonable. Conversely, *'rich'* does not necessarily imply *'millionaire,'* so B's utterance in (8b) cannot be taken to (necessarily) ask for clarification of A's assertion. The only other permissible interpretation of (8b)'s surface form would be one indicating assent, but such interpretations are blocked by (Ax2) below. It is noteworthy that (Ax1) only applies to questions that ask for clarification of an earlier event. Specifically, we require the presence of an appropriate antecedent. We do not stipulate a rule that would infer question force from a final rise *in general*, as such utterances are incoherent when spoken 'out of the blue,' *i.e.*, without an antecedent (see [6, p. 85]):

(10) a. A: Did you go to the cinema last night? (LH%)
  b. A: # You went to the cinema last night? (LH%)

The utterance (10b) is incoherent without an antecedent *despite* the corresponding interrogative mood utterance (10a) being appropriate in the same context. An ancillary conclusion to draw from (10) is that the antecedents α we require for (Ax1) to apply need not be linguistic in nature (*cf.* [17]) as, *e.g.*, an openly visible cinema ticket would render (10b) coherent. This is not to say that utterances with a final rise cannot be uttered out of the blue in general—they can, but then they cannot be interpreted as polar questions.

(11) A: (to a receptionist) My name is Mark Liberman. (LH%)
  # *'Is my name Mark Liberman?'*

[7] We assign the relation *CR* the dynamic semantics of *elaborating questions (Q-Elab)*, see [1, p. 468]. We gloss over more detailed properties of clarification questions (*cf.* [12]), as we are here only interested in the rather simple subset of polar questions.

[8] It is necessary to map K_β to its propositional content, as once question force is inferred, the logic of information content will represent K_β in question semantics.

While (11) *can* be uttered out of the blue, it should not be assigned question semantics. Nevertheless, the utterance expresses a request for a response/follow-up and this expectation of an adjacent action is adequately captured in our semantic postulate for the final rise.[9] Lastly, we also describe the attitude displayed by a final rise, uncertainty, in the cognitive modelling logic:

(Ax2) **Cognitive Contribution of the Final Rise.**
$(\pi : LH\% \wedge \lambda : R(\alpha, \pi) \wedge \neg\pi : ?K_\pi) > P_{S(\pi)}\neg B_{S(\pi)} I_{H(\pi)} P_{H(\pi)} R(\alpha, \pi)$.

This stipulates that if the utterance with the final rise is not a question,[10] and is presumed to directly attach to an antecedent by some relation, then the speaker is usually conveying that they are uncertain whether the hearer is (or should be) willing to commit to that relation. This allows us to account for the uncertain answers (2b) and (4) where the speaker is uncertain whether the hearer is willing to commit to the *Question-Answer-Pair* (QAP) relation. In addition, this applies to utterances correcting or rejecting a previous utterance: typically, the corrected speaker cannot be assumed to accept the correction immediately. In other words, (Ax2) states that the speaker of the final rise utterance displays that they do not assume that normal cooperativity assumptions obtain—because those would usually lead to the addressee taking up the utterance. This is in alignment with Westera's model in [19], but notably different from accounts that put 'epistemic uncertainty' in the spotlight (*e.g.*, [18]). The latter discussions use epistemic uncertainty to account for the lack of commitment to a declarative proposition intonated with a final rise. We achieve this effect instead through (Ax1), as the dynamic semantics of the *CR* relation do not result in any commitments.

Note that (Ax1) and (Ax2) cannot apply simultaneously: (Ax1) infers question force, and (Ax2) explicitly does not apply if this is the case. This property of our formalism allows us to separate the implicatures we associated with our initial minimal pair (1b) *vs.* (2b). The final rise utterance in (1b) satisfies the antecedents of (Ax1) and is thereby rendered in question semantics. Consequently we do not infer a commitment of its speaker to *'B is a millionaire.'* In contrast, the same utterance in (2b) does not satisfy the (context-sensitive) appropriateness constraint of (Ax1), and hence (Ax2) applies. Therefore, the speaker *does* make the usual commitments associated with a declarative utterance, but explicitly displays that they are not sure if the discourse relation of question-answer applies, *i.e.*, if the addressee is willing to take up the utterance as an answer.

As a more verbose application, we present the DSDRT logical forms of (3) and (4) in Figure 1; the final SDRSs contain superfluous conditions that we left in for the sake of clarity. In both cases, A's initial question is resolved by question semantics, and hence projects an answer. Then, in B's first utterance, the final rise semantics stipulate that B's turn is in some sense incomplete, but the available information is not sufficient to make that incompleteness precise. Due

[9] Again, the response might also be a non-linguistic action such as looking up a reservation.

[10] On questions, even when posed in indicative mood, a final rise is part of the default contour and we do not take it to signal a particular attitude in that situation.

Turn	A's SDRS	B's SDRS
1	$\pi_1 : K_{\pi_1}$ $\pi_{1H} : \exists \pi_1'$ QAP(π_1, π_1')	$\varnothing$
2	$\pi_1 : K_{\pi_1}$ $\pi_{1H} : \exists \pi_1'$ QAP(π_1, π_1')	$\pi_2 : K_{\pi_2}$ $\pi_{1H} : \exists \pi_1'$ QAP(π_1, π_1') $\pi_{2S} : \exists R, \pi_2', \pi_2''\ R(\pi_2', \pi_2'') \wedge (\pi_2' \succcurlyeq \pi_2)$
Ex. (3)	Resolution: π_2' is π_2, π_2'' is π_3 and R is Elaboration.	
3	$\pi_1 : K_{\pi_1}$ $\pi_{1H} : \exists \pi_1'$ QAP(π_1, π_1')	$\pi_2 : K_{\pi_2}$ $\pi_{1H} :$ QAP(π_1, π_{3S}) $\pi_{2S} :$ Elaboration(π_2, π_3) $\pi_3 : K_{\pi_3}$ $\pi_{3S} :$ Elaboration(π_2, π_3)
Ex. (4)	Resolution: π_2' is π_{1H}, π_2'' is π_3 and R is Accept.	
3	$\pi_1 : K_{\pi_1}$ $\pi_{1H} :$ QAP(π_1, π_2) $\pi_2 : K_{\pi_2}$ $\pi_{2S} :$ Accept(π_{1H}, π_3) $\pi_3 : K_{\pi_3}$ $\pi_{3H} :$ Accept(π_{1H}, π_3)	$\pi_2 : K_{\pi_2}$ $\pi_{1H} : \exists \pi_1'$ QAP(π_1, π_1') $\pi_{2S} : \exists R, \pi_2', \pi_2''\ (R(\pi_2', \pi_2'') \wedge \pi_2' \succcurlyeq \pi_2)$

Fig. 1. Logical forms of Examples (3) and (4, *'Okay, good'*).

to the appropriateness constraint, (Ax1) does not apply. The cognitive contribution (Ax2) prevents the answer *'Skokie'* to attach to the question answer pair at this point. In the third turn, the logical forms diverge: the incompleteness is resolved to a missing elaboration in (3), and to an acceptance of the answer in (4). The cognitive contribution does not prevent these resolutions: in (3), the full answer is under another label, and in (4), the speaker A's commitments are not subject to the cognitive restriction. In the next turn of (4), B will defease the attitude displayed through (Ax2), as A has now publicly displayed that the uncertainty is resolved.

5 Conclusion

We have presented a formal model that accounts for illocutionary and perlocutionary effects of the final rise in English, modelling in particular the rendering of indicatives to questions, and uncertainty when answering questions. To account for the variety of observable effects, our model postulates strongly underspecified semantics. In connection with SDRT's glue logic, these underspecifications can be resolved in context to make concrete claims that are strong enough to predict incoherence. The particular novel contribution of our model lies in its formality, as we give a fully formal model of previously informal characterisations.

A notable shortcoming of our model, as it is presented here, is that we do not take the focus accent into account. The final rise is a part of some complex pitch contours that have received substantial attention in the literature, *e.g.*,

rise-fall-rise in [7] and [4] or, more generally, the fully compositional system of [15, 16]. However, we believe that the underspecified semantics presented in this paper are sufficiently broad to be *consistent* with these observations and that our formal model can therefore be expanded to cover more specific interpretations of complex pitch contours. This is part of our ongoing work and we address some of these concerns in [13].

References

1. Asher, N., Lascarides, A.: Logics of conversation. Cambridge University Press (2003)
2. Asher, N., Lascarides, A.: Commitments, beliefs and intentions in dialogue. In: 12th Workshop on the Semantics and Pragmatics of Dialogue (LONDIAL) (2008)
3. Bolinger, D.: Intonation and its parts. Language pp. 505–533 (1982)
4. Constant, N.: English rise-fall-rise: a study in the semantics and pragmatics of intonation. Linguistics and Philosophy 35(5), 407–442 (2012)
5. Farkas, D.F., Bruce, K.B.: On reacting to assertions and polar questions. Journal of semantics (2009)
6. Gunlogson, C.: True to form: Rising and falling declaratives as questions in English. Routledge (2003)
7. Hirschberg, J., Ward, G.: The interpretation of the high-rise question contour in english. Journal of Pragmatics 24(4), 407–412 (1995)
8. Hobbs, J.: The pierrehumbert-hirschberg theory of intonational meaning made simple: Comments on pierrehumbert and hirschberg. In: P. R. Cohen, J.M., Pollack, M.E. (eds.) Intentions in Communication, pp. 313–323. MIT Press (1990)
9. Lascarides, A., Asher, N.: Agreement, disputes and commitments in dialogue. Journal of Semantics 26(2) (2009)
10. Liberman, M., Sag, I.: Prosodic form and discourse function. In: 10th Regional Meeting of the Chicago Linguistics Society. pp. 416–427 (1974)
11. Pierrehumbert, J., Hirschberg, J.: The meaning of intonational contours in the interpretation of discourse. In: P. R. Cohen, J.M., Pollack, M.E. (eds.) Intentions in Communication, pp. 271–311. MIT Press (1990)
12. Purver, M.: The Theory and Use of Clarification Requests in Dialogue. Ph.D. thesis, King's College, University of London (2004)
13. Schlöder, J.J., Lascarides, A.: Interpreting english pitch contours in context. In: 19th Workshop on the Semantics and Pragmatics of Dialogue (goDIAL) (2015)
14. Silverman, K.E., Beckman, M.E., Pitrelli, J.F., Ostendorf, M., Wightman, C.W., Price, P., Pierrehumbert, J.B., Hirschberg, J.: ToBI: a standard for labeling english prosody. In: 2nd International Conference on Spoken Language Processing (1992)
15. Steedman, M.: The syntactic process. MIT Press (2000)
16. Steedman, M.: The surface-compositional semantics of english intonation. Language pp. 2–57 (2014)
17. Stojnic, U., Stone, M., Lepore, E.: Deixis (even without pointing). Philosophical Perspectives 27(1), 502–525 (2013)
18. Šafářová, M.: The semantics of rising intonation and interrogatives. In: Maier, E., Bary, C., Huitink, J. (eds.) Sinn und Bedeutung, pp. 355–369 (2005)
19. Westera, M.: Attention, im violating a maxim! A unifying account of the final rise. In: 17th Workshop on the Semantics and Pragmatics of Dialogue (DialDam) (2013)