Information Structure and the Syntax-Phonology Interface

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The article proposes a theory of grammar relating syntax, discourse semantics, and intonational prosody. The full range of English intonational tunes distinguished by Beckman and Pierrehumbert 1986 and their semantic interpretation in terms of focus and information structure are discussed, including "discontinuous" themes and rhemes. The theory extends an earlier account based on Combinatory Categorial Grammar, which directly pairs phonological and logical forms without intermediary representational levels.

Keywords: intonation, syntax, information structure, combinatory categorial grammar, topic, comment, theme, rheme, focus, phonological form

1 Structure and Intonation

Phrasal intonation in English is frequently orthogonal to traditional notions of surface syntactic structure. For example, the verb group may form an intonational phrase at odds with traditional assumptions about constituency, giving rise to a perceived intonation structure indicated informally by parentheses in (1a) (from Selkirk 1981:127–128). Similarly, a subject and a transitive verb may form an intonational phrase at odds with traditional surface structure for simple transitive sentences, as in (1b) (cf. Selkirk 1984:290–291; Steedman 1991a).

(1) a. (The absent-minded professor)(was avidly reading)(about the latest biography)(of Marcel Proust).
b. (Marcel proved) (completeness).

Numerous effects of intonational boundaries on phenomena such as the Rhythm Rule (Selkirk 1981, Gussenhoven 1983), which applies to move stress from the second to the first syllable of *Marcel* in (1a) and (1b), appear to depend on prosodic domains that are to some degree independent of traditional surface structure. Other examples are *liaison* in French (Selkirk 1972),

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American English flapping (Nespor and Vogel 1986), Bengali /r/ assimilation (Hayes and Lahiri 1991), and Italian *raddoppiamento syntattico* (Napoli and Nespor 1979; Kaisse 1985; Nespor and Vogel 1986; Vogel 1994).

Nevertheless, this apparent independence is quite limited. The intonational devices that give rise to the structures in (1) cannot be used to induce the intonational structures indicated in (2) without absurd results ((2a) and (2b) originate with Mark Liberman).

(2) a. *(Three mathematicians)(in ten derive a lemma).
b. *(Seymour prefers the nuts)(and bolts approach).
c. *(They only asked whether I knew the woman who chaired)(the zoning board).

Selkirk (1984) follows Halliday (1967a) in defining the limits upon the freedom with which intonation can diverge from traditional constituent structure in terms of a semantic condition that she calls the "Sense Unit Condition," defined in terms of head dependencies at the level of Logical Form. Nevertheless, the sensitivity of intonation to such "late" or surface aspects of grammar as coordinate structure, coupled with the fact that one would expect the notion "sense unit" to bear a close relation to the notion "constituent," might lead one to seek a more syntactic solution, according to which the Sense Unit Condition would simply be a corollary of what is perhaps the most fundamental principle of generative grammar, namely the Constituent Condition on Rules.

Selkirk's (1984) proposal to incorporate phrasal phonology in a then-standard Government-Binding (GB) framework thereby gives rise to a theoretical architecture that can be summarized in an extension of the traditional T- or Y-diagram shown in Figure (1) (cf. Selkirk 1984, p.205). In addition to the usual modules of the parent theory, including a level of S-Structure mediating between Phonetic Form (PF) and Logical Form (LF), this architecture postulates an autonomous structural level of Intonational Structure, which also mediates between PF and LF. The responsibility of S-Structure is as usual to define aspects of LF that relate to predicate-argument relations. The responsibility of Intonational Structure is to define those aspects of LF that relate to discourse information structure—that is, to distinctions such as theme (a notion somewhat related to topic, in the sense of the term used by such authors as Reinhart (1981), Erteschik-Sher (1998), and Zubizarreta (1998), among others) and rheme (comment, or in the sense that those authors use the term, focus).

It would be in keeping with other recent developments in generative grammar to reduce the number of modules in the theory, either by eliminating some of them entirely, as Chomsky (1995) has proposed, or (equivalently) by unifying one with another. This article shows how the levels of S-Structure, and Intonational Structure (together with certain syntactic functions that have sometimes been relegated to the module of Phonetic Form, in the rather unusual sense in which that term has been used in GB), can be collapsed into one surface syntactic module.[1] Surface derivations are associated with a compositional semantics that determines both information

[1]PF plays a rather different role in GB from the one its name might suggest. It is the locus of a number of syntactic processes, including some associated with coordination. It is referred to on occasion by Chomsky (1986) as "Surface Structure," a name in keeping with its actual role.

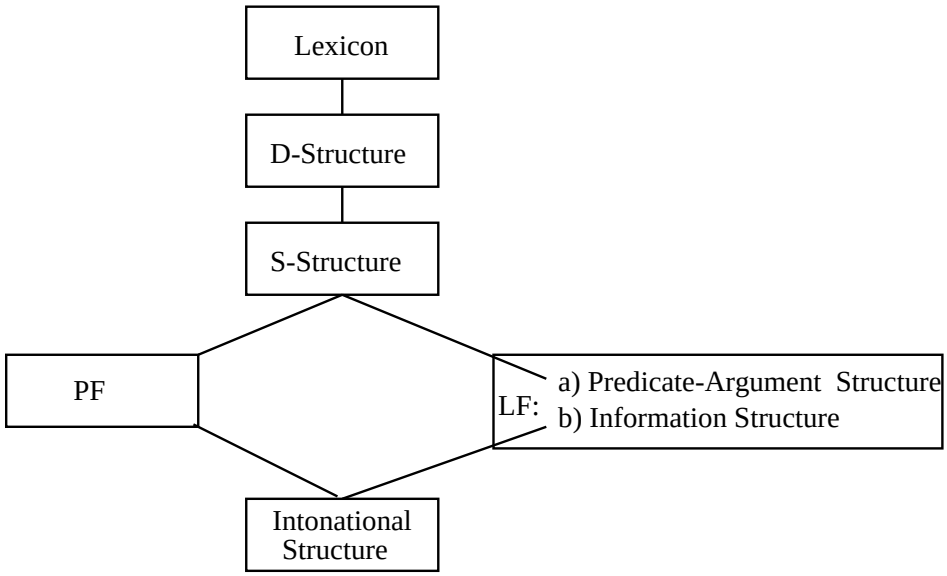


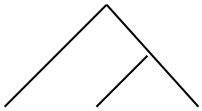
Figure 1
Architecture of a GB theory of Prosody (adapted from Selkirk 1984)

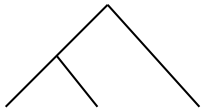
structural and predicate-argument structural aspects of a logical form. The Sense Unit Condition can thereby be eliminated, since the class of possible intonational phrases reduces to the class of interpretable constituents in a syntactic derivation, excluding all examples such as (2a–c) without further stipulation.

2 The Claim

On the basis of evidence from coordination and other constructions involving unbounded dependencies, a number of theories based on Categorial Grammar (CG), including Combinatory Categorial Grammar (CCG) of the kind proposed in Steedman 1987, 1991a, 1996 and 2000 (the latter hereafter *TSP*), make the claim that substrings like *Marcel proved* are possible surface syntactic constituents of sentences. According to these theories, even such minimal sentences as (1b) have two possible surface structures.[2]

[2]Wood (1993) provides a useful review of theories by Ades & Steedman (1982), Bach (1988), Dowty (1988), Steedman (1985, 1987), Oehrle (1988), Hepple (1990), Jacobson (1990, 1992), and Szabolcsi (1989, 1992a), among others, although none of these authors other than the present one should be assumed to endorse all the assumptions of the version that is outlined here. The present proposal is more distantly related to a number of other generalizations of the early categorial systems of Ajdukiewicz, Bar-Hillel, Lambek, Geach, Lewis, Montague, van Benthem, Cresswell, and von Stechow, to many of which the conclusions of this paper also apply. In particular Oehrle (1987, 1991), Moortgat (1988), Morrill (1994), and Hendriks (1999, 1998) explicitly relate Lambek-style categorial grammars to prosody.

(3) a. 
Marcel proved completeness

b. 
Marcel proved completeness

More complex sentences like *Marcel says that Harry proved completeness* may have many surface structures for each reading.

To fly in the face of received linguistic wisdom to the extent of questioning traditional assumptions concerning the most superficial level of syntactic structure may seem absurd. However, it is a curious fact that all of the traditional tests for surface constituency either are incomplete (as are the criteria of representation in the lexicon and susceptibility to movement), or can be interpreted as offering positive support for a more general notion of constituency (as can a third criterion, susceptibility to coordination). I will argue that most traditional tests for constituency other than coordination are expressions of ill-defined intuitions about a level of meaning related to traditional underlying structure or meaning relations, rather than constituting empirical evidence concerning syntactic form—a confusion that Chomsky (1957:chap. 7, passim) has repeatedly warned against.

It is important in assessing this claim to know that the multiple derivations engendered by CCG deliver identical interpretations, which can conveniently be represented as predicate-argument structures or logical forms (in the logicians' sense of that term). Such structures preserve traditional dominance and command relations, including relations of binding and control. All such bounded relations are assumed to be defined via interpretations in the lexicon—a position that seems implicit in work by Hale and Keyser (1993). Such relations are automatically projected onto the unorthodox structures of CCG by the rules of derivation. It is therefore at the level of logical form, rather than that of derivation or surface structure, that the equivalent of c-command must be defined in a CCG (see Steedman 1996).

In earlier work, I have tried to show that the intonational structure of English, essentially as described by Pierrehumbert (1980), Selkirk (1981, 1984), and others, is directly subsumed by surface syntactic structure, as it is viewed in CCG (Steedman 1991a, *TSP*). The interpretations that the grammar assigns compositionally to certain constituents of these nonstandard surface derivations directly correspond to information structure in Selkirk's sense of the term. The present article presents a new version of this theory, covering a wider inventory of prosodic tunes and information categories.

The claim is that surface structure and information structure coincide, the latter consisting in the interpretation associated with a constituent analysis of the sentence. Intonation in turn coincides with surface structure (and hence information structure) in the sense that all intonational boundaries coincide with syntactic boundaries, a position that is to some extent implicit in more recent work by Selkirk (e.g. 1990:195) and others.

Of course, the reverse does not follow. Not all surface syntactic boundaries are explicitly marked by intonational boundaries. Pierrehumbert (1980) has argued that intonational tunes

constitute a language of tone sequences that is merely finite-state. Even in English, the majority of information structural boundaries go unmarked by explicit intonational boundaries.[3]

There is no contradiction here: information structure has to be inferred from the partial specification implicit in the tones in exactly the same sense that predicate-argument relations have to be inferred from that implicit in the sequence of words. The central claim made here is simply that constituents of the derivation and their semantic interpretations provide the logical forms that discourse semantic functions apply to, and that the boundaries of these constituents line up with the intonational structural boundaries, where these are present.

3 Intonation and Information Structure.

It is important to be clear from the outset that there is no single definitive characterization of the components of intonational contour, much less a definitive theory of their information structural meanings. Even within the "autosegmental-metrical" phonological framework stemming from Liberman 1975, Goldsmith 1976, Bruce 1977, and Pierrehumbert 1980, there is still uncertainty on a number of points, including the precise inventory of tone types, the question of whether they are perceptually categorical in the sense that phonemes are, and the role of phrasal tones (see Ladd 1996:98–112 for discussion).

The theory of information structure is similarly fraught: it is still far from clear which aspects of discourse meaning stem from literal meaning and compositional semantics, and which from pragmatics and conversational implicature. Although these uncertainties make it necessary to begin with some descriptive discussion, it is not the purpose of this article to develop a definitive theory of information structure. The point is rather to show that a theory of grammar in which phrasal intonation and information structure are reunited with formal syntax and semantics is not only possible, but much simpler than one in which they are separated.

3.1 The Two Dimensions of Information Structure

The theory proposed below is compatible with any of the standard descriptive accounts of phrasal intonation. However, Pierrehumbert's (1980) notation, as modified in more recent work by Selkirk (1984), Beckman and Pierrehumbert (1986), and Pierrehumbert and Hirschberg (1990), is particularly helpful in defining intonational contours entirely in terms of two components or "tones": the *pitch accent(s)* and the *boundary*. Pitch accents are realized as maxima or minima in the pitch contour and coincide with the perceived major emphasis or emphases of the prosodic phrase; boundary tones mark the right-hand boundary of the phrase. The advantage of Pierrehumbert's notation for present purposes is that it captures in formal terms the fact that the same sequence of pitch accent(s) and boundary can be spread over longer or shorter strings of words.

It will be convenient to refer to any sequence of one or more pitch accents followed by a boundary as an intonational phrasal "tune." (I will define it more precisely later.) The claim will

[3]That is not to claim that they may not be marked by other more subtle articulatory markers. See Fougeron and Keating 1997.

be that phrasal tunes in this sense are associated with specific discourse meanings distinguishing information type and/or propositional attitude.

In assessing this claim and the argument that follows, it will be important to bear in mind that linguistic categories of this kind, besides exhibiting all the ambiguity and context-dependency that ordinary sense semantics is heir to, are also presuppositional in the way that definite expressions like *the man who just walked past the window* are. This means that they may engender conversational implicatures. In particular, they are likely to cause what Lewis (1979) called "accommodation," whereby the listener rapidly and unconsciously adjusts his or her model of the domain of discourse to support the presuppositions of the speaker, provided that those presuppositions do not actually conflict with his or her own knowledge (see Thomason 1990 for discussion). This means of course that it is always necessary to specify a context, in making a claim about the information-structural significance of markers like intonational tones. But since a given context may support more than one information structure, and a given utterance may adjust the context via accommodation, there will frequently be more than one possible utterance that the context can reasonably give rise to.

Consider for example possible prosodies for sentence (1b), *Marcel proved completeness*, in the following pair of discourse settings. (To aid the exposition, words bearing nuclear pitch accents are printed in small capitals, and prosodic phrase boundaries are explicitly marked in the sentences, using parentheses. Pierrehumbert's notation for the tones, which (together with the metrical component) determine this structure, appears beneath each answer.)

(4) Q: I know who proved soundness. But who proved COMPLETENESS?
A: (MARCEL) (proved COMPLETENESS).
H* L L+H* LH%

(5) Q: I know which result Marcel PREDICTED. But which result did Marcel PROVE?
A: (Marcel PROVED) (COMPLETENESS).
L+H*LH% H* LL%

In these contexts, the accented words receive a pitch accent, but a different one. In the answer A of (4), there is a prosodic phrase on MARCEL made up of the sharply rising pitch accent that Pierrehumbert calls H*, immediately followed by an L boundary, perceived as a rapid fall to low pitch. There is another prosodic phrase having the somewhat later-rising and (more importantly) lower-rising pitch accent called L+H* on COMPLETENESS, preceded by null tone (and therefore interpolated low pitch) on the word *proved* and immediately followed by an utterance-final rising boundary, written LH%. (See Pierrehumbert and Hirschberg's (1990:(33)) discussion of a similar example.)[4]

In (5A) above, the order of the two tunes is reversed: this time, the tune with pitch accent L+H* and boundary LH% occurs on the word PROVED in one prosodic phrase, *Marcel* PROVED,

[4]For the moment, I ignore the distinction between the intonational phrase proper, and what Pierrehumbert and her colleagues call the "intermediate" phrase. These categories differ in the way the boundary is annotated.

and the other tune with pitch accent H* and boundary LL% is carried by a second prosodic phrase COMPLETENESS.[5]

There is a further strong effect of intonational phrasing in sentence (5), which has the incidental consequence of confirming that the intonation structure of (5) is indeed as indicated by the parentheses. In dialects of English that exhibit the Rhythm Rule, (5) (in contrast to (4)) causes the lexically specified stress on the final syllable of the word *Marcel* to shift onto the first syllable, because (like the same word in the nounphrase *Marcel Proust* in example (1a)) it is immediately succeeded by a stressed syllable that is within the same intonational phrase. I will return to this point below.

The intuition that these tunes strongly convey systematic distinctions in discourse meaning is inescapable. For example, exchanging the answer tunes between the two contexts in (4) and (5) yields complete incoherence. However, the relevant dimensions of discourse meaning have proved quite hard to characterize. The tunes have variously been associated with social attitude (O'Connor and Arnold 1961 and in a different sense Merin 1983), illocutionary acts (Liberman and Sag 1974; Sag and Liberman 1975; Liberman 1975), propositional attitudes and maintenance of mutual belief (Ward and Hirschberg 1985; Pierrehumbert and Hirschberg 1990); Bartels 1997, and various notions of information structure or packaging (Halliday 1967a, Jackendoff 1972, Schmerling 1976, Ladd 1980, 1996, Gussenhoven 1983, Selkirk 1984, Terken 1984, Terken and Hirschberg 1994, Morel 1995, Rochemont 1986, Steedman 1991a, b, Zubizarreta 1998).

This article concentrates on certain aspects of intonation that primarily have to do with information structure in the sense of that term proposed in Vallduví 1990 and Steedman 1991a, although these proposals differ in detail—see Vallduví and Engdahl 1996 for discussion. The present theory diverges from others mentioned above in following Halliday's (1967b, 1970) assumption that there are two independent dimensions to information structure that are relevant to intonation.

The first of these two dimensions corresponds to the contrast between the theme of an utterance and the rheme that the utterance contributes on that theme. The terms theme and rheme are taken from Mathesius (1929), Firbas (1964,1966), and Halliday (1967b, 1970), (see Newmeyer to appear for a historical review), but I do not assume any prior definition of these terms, which I will define more formally below in terms of both the "structured meanings" approach of Cresswell (1973), von Stechow (1989), and Chierchia (1989), and the "Alternative Semantics" of Rooth (1985) and others.[6] Informally, it is to be thought of as *that part of an utterance which connects it to the rest of the discourse*, a notion that is most unambiguously determined when the preceding utterance is itself a *wh*-question. In English, this dimension of information structure

[5]The reason for notating the latter boundary as LL% rather than L again has to do with a distinction between intonational and intermediate phrases that I will make explicit later. Elsewhere (Steedman 1991a) I examine all possible combinations of these two tunes with a simple transitive sentence.

[6]In particular I follow Lyons (1977) and Bolinger (1989) in reverting to Mathesius and Firbas and rejecting Halliday's requirement that the theme be sentence-initial. I also leave open the possibility that disjoint parts of the utterance might be marked as theme and as rheme, a point to which I return in section 3.4. The theme of an utterance in this sense is sometimes called the "topic" or the "presupposition," but it must not be confused with the overall discourse topic, or with other notions tied to traditional syntactic constituency, or with the entire presuppositional component of the utterance.

contributes among other things to determining the overall shape of the intonational phrasal tune or tunes imposed on an utterance. In particular, I will claim that the L+H* LH% tune (among others) is associated with the theme, whereas the H* L and H* LL% tunes (again among others) are associated with the rheme (cf. Steedman 1991a, p.275, 1991b, p.28, and *TSP*.)

The second dimension of information structure concerns the distinction between words whose interpretations contribute to distinguishing the theme or rheme of the utterance from other alternatives that the context makes available, and words whose interpretations do not, in a sense to be made precise below. Halliday (1967b), who was probably the first to identify the orthogonal nature of these two dimensions, called it "new" information, in contrast to "given" information. The term *new* is not entirely helpful, since (as Halliday was aware), the relevant part of the theme need not be novel to the discourse. I will follow the phonological literature and Prevost (1995) in calling the information marked by the pitch accent the "focus," distinguishing theme-focus and rheme-focus where necessary, and use the term "background" for the part unmarked by pitch accent or boundary. Again there are a number of other taxonomies, with most of which the present proposal is fairly straightforwardly compatible.[7] In English, this dimension is reflected in the position of the pitch accents themselves. The presence of a pitch accent of any shape is generally agreed to assign salience or contrast independently of the shape or contour of the pitch accent or overall phrasal melody (Bolinger 1958, Pierrehumbert and Hirschberg 1990:288–289).

3.2 Theme and Rheme

The effect of the *wh*-question in (4) is to strongly encourage a hearer to regard the theme linking the answer to the discourse as something we might informally think of as *proving completeness*. This is the part of the answer that has the L+H* LH% tune on it. The subject MARCEL is the rheme, the part of the answer that advances the discussion by contributing novel information. It receives the H* L tune.

Similarly, in (5), the *wh*-question tends to establish a theme that we might call *Marcel proving*. It is within this part of the response that the L+H* LH% tune appears, while the rheme-tune H* L appears on COMPLETENESS.

Of course, such flamboyantly informative intonation contours as those in (4) and (5) are exceptional. It is only appropriate to mark the theme with an L+H* pitch accent when it stands in contrast to a different established or accommodatable theme. If the theme is unambiguously established in the context, it is common to find that it is deaccented throughout—in Pierrehum-

[7]The term *focus*, like the term *topic*, is used in the literature in several conflicting ways. The present use is common among phonologists, who use it simply to denote the material marked by the pitch accent(s). This usage is not the same as that of Grosz and Sidner (1986), who use it to denote something like topic, or theme in present terms. Nor is it to be confused with the usage of other authors such as Chomsky (1970), Jackendoff (1972), Gussenhoven (1983), Hajičová and Sgall (1987, 1988), Vallduví (1990), Lambrecht (1994), Erteschik-Shir (1998), and Zubizarreta (1998), who in different ways confine the use of the term focus to the rheme (but cf. Valduvi and Vilkuna 1998). Still other authors, notably Selkirk (1984), Rooth (1985, 1992), Jacobs (1991), Krifka (1992), É. Kiss(1998), and Rochemont (1998), invoke "two levels" of focus, using the term to cover both comment/rheme *and* phonological focus. (On occasion, these two notions of focus are confounded, as in the association of contrastive themes with focus/rheme by Gundel (1977:453), and Carlson (1983:216).) In this article, the term focus is only used in the narrow phonological sense.

bert's terms, without any phonetically realized boundary—as in the following exchange:[8]

(6) Q: Which result did Marcel prove?
A: (Marcel proved) (COMPLETENESS).
H* LL%

We would be missing an important semantic generalization if we failed to note that (5) and (6) are identical in information structure as far as the theme-rheme division goes. We will therefore need to distinguish the "marked" theme in the former from the "unmarked" theme in the latter. Unmarked intonation, unlike the marked variety, is always ambiguous with respect to information structure. In the following context, the same contour gives rise to an information structure in which *Marcel* is an unmarked theme:

(7) Q: What do you know about Marcel?
A: (Marcel) (proved COMPLETENESS).
H* LL%

Unmarked themes do not contrast with any earlier one; that is, they are entirely given or background. This situation is to be contrasted with the application of the same contour to an utterance that is "all-rheme," as when someone announces the following as "hot news":

(8) Guess what? (Marcel proved COMPLETENESS!)
H* LL%

Here the utterance includes no theme at all, and the rheme alternatives set that it restricts is simply the set of possible propositions.

Jackendoff (1972) seems to have been the first to suggest that the theme (which he followed Chomsky (1970) in calling the "presupposition") should be characterized semantically via functional *abstraction*, using the notation of the λ-calculus, as in the following example, corresponding to the theme of (5) and (6):[9]

(9) $\lambda x.prove' x\ marcel'$

The variable-binding operator λ in such expressions identifies a variable (here, *x*), by means of which a value may be substituted into the expression to the right of the dot. It thus defines a *function* or concept, mapping individual arguments onto propositions concerning Marcel's proving them. When the above concept is supplied with an argument in the form of the rheme, *completeness*′, it therefore *reduces* to give a proposition, with the same predicate-argument relations as the canonical sentence.

[8]In this and all examples in the present article, such "backgrounded" elements of the sentence appear without any tonal marking. Such material may include stresses or "secondary" pitch accents, which on occasion phoneticians notate as H* and so on. Secondary accents are distinct from the primary accents that convey focus and contrast and are not of interest in the present context—see Selkirk 1984 and Ladd 1996 for further discussion. The crucial point is that examples (6) and (7) can be uttered with the *same* intonation.

[9]Juxtaposition of terms *A B* indicates the application of a function *A* to an argument *B*, and application "associates to the left"; that is, the formula $prove' x\ marcel'$ is equivalent to $(prove' x)marcel'$. Primes indicate constants, denoting semantic interpretations whose detailed nature is of no direct concern here.

(10) *prove′ completeness′ marcel′*

It is the presence in the context of the abstract proposition in (9) that makes the intonation contour in (5) felicitous.[10] In the case of this example, it is clear that this abstract proposition is explicitly introduced into the context by the *wh*-question Q. That is not to say that the explicit utterance of this question is necessary for interpreting the response. (We have already noted that themes can also in the absence of conflicting information be accommodated or taken on board by the hearer.) But the effect is a strong one: as noted earlier, exchanging the answers to the questions in (4) and (5) yields complete incoherence.

The λ-abstraction operator is closely related to the existential quantifier ∃. It is therefore also natural to associate the notion of theme with a set of propositions among those supported by the conversational context that could possibly instantiate the corresponding existentially quantified proposition. In the case of the exchange in (5), the existential in question is the following:

(11) $\exists x.prove' x\ marcel'$

The propositions that might instantiate the existential might in a particular context of utterance be a set like the following:

(12) $\left\{ \begin{array}{l} prove' decidability' marcel' \\ prove' soundness' marcel' \\ prove' completeness' marcel' \end{array} \right\}$

The "presupposition skeleton" (11) and the set (12) are closely related to Karttunen and Peters' (1979) "secondary denotation" and to the related notion of "alternative set" in the Alternative Semantics of Rooth (1985, 1992) and Kratzer (1991), which these authors used to determine the entailments of utterances, including those associated with presuppositions and focusing particles, and to the related analysis of German intonation by Büring (1995, 1997).[11] Specifically, the alternative set in question is the one that Rooth and Büring call C, the "contextual" alternative set. I will follow *TSP* in referring to it as the "rheme" alternative set, since all alternative sets are in some sense contextual.

Alternative sets are of course in many cases not exhaustively known to hearers, and in practice one would want to compute with something more like the quantified expression (11) or the λ-term itself, as in the structured meanings approach of Cresswell and others. However, alternative sets are easy to grasp and are used here for reasons of exposition.

In semantic terms, the effect of the tunes we have encountered so far can be specified as follows:

(13) Theme tunes *presuppose* a rheme alternative set.
Rheme tunes *restrict* the rheme alternative set.

[10]Such λ-abstractions are also related to what Sperber and Wilson (1982) and Prince (1986) have called the "open proposition" of an utterance.

[11]By this definition, theme is also close to the notion "topic," which Reinhart (1981), Erteschik-Shir (1998), and Zubizarreta (1998), among others, also relate to ideas like secondary denotation. However, such definitions have generally been tied to standard notions of constituency.

The sense in which a theme "presupposes" a rheme alternative set is much the same as that in which a definite expression presupposes the existence of its referent. That is to say, there is a pragmatic presupposition that the relevant alternative set is available in the contextual model or database. This presupposition may in the sense noted earlier be accommodated; that is, such a set may be added by the hearer after the fact of utterance to a contextual model that is consistent with it. (We will see that this property means that on occasion utterances may consist of nothing *but* a theme.) However, we will see that it may not be the *only* presupposition carried by the utterance, and this is a reason to avoid calling it "the" presupposition of the utterance.

The context-establishing questions in the earlier examples (4) and (5) can themselves be analyzed as including a theme and a rheme. As Prevost (1995) points out, a *wh*-item such as *what* or *which result* in a *wh*-question is the theme of the question, albeit a rather unspecific one, associated with a set of propositions concerning things, or sorts of result. (Usually such themes are prosodically unmarked, but they may also bear the marked L+H* LH% theme tune.) The remainder of the *wh*-question, which typically bears the H* LL% rheme tune, restricts this set to propositions relating to one particular predication, such as $\lambda x.prove' x\ marcel'$. It is this set that in turn typically becomes the set of alternatives associated with the theme in the answer.

3.3 Focus and Background

We saw earlier that the position of the pitch accent(s) in the phrase has to do with the further information structural dimension that is here called "focus" (in the "narrow" sense of that term). Within both theme and rheme, those words that contribute to distinguishing the theme and the rheme of an utterance from other alternatives made available by the context may be marked via a pitch accent. The following example adapted from *TSP* shows how this works.

(14) Q: I know that Marcel likes the man who wrote the musical.
But who does he ADMIRE?
A: (Marcel ADMIRES) (the woman who DIRECTED the musical)
L+H*LH% H* LL%
background *focus* *background* *focus* *background*
theme *rheme*

The significance of the presence or absence of primary pitch accents within a theme like *Marcel* ADMIRES seems to lie in the prior existence or accommodatability of a theme differing in its translation only in those elements corresponding to accented items like ADMIRES. (If the theme is unmarked, then as we saw in the case of (6) and (7), the pre-existing or accommodated theme must be identical to the new one.) We can therefore mark the presence of pitch accents in the translation of themes like that in (14) by distinguishing the corresponding constant $admires'$ with an asterisk.

(15) $\exists x.*admires' x\ marcel'$

Unless a compatible prior theme—that is, one that matches the expression in (15) when $*admires'$ is replaced by some other constant, as in (16)—can be retrieved or accommodated, the utterance is simply infelicitous, and the analysis will fail at this point.

(16) $\exists x.likes'x\ marcel'$

The set of alternative themes in this case is the following:

(17) $\left\{\begin{array}{l}\exists x.admires'x\ marcel'\\ \exists x.likes'x\ marcel'\end{array}\right\}$

This set is what Rooth and Büring call Q, the "question" alternative set. I will again follow *TSP* in calling it the theme alternative set, to contrast it with the earlier rheme alternative set.

When a marked theme is felicitously uttered, the old theme is removed from the context and the new theme is added, in a process that I will refer to as "update."[12] The effect of the update is much like that of Jacobs's (1991) and Krifka's (1992:4) *ASSERT* operation over structured meanings. The new theme can also be used as before to generate the related alternative set.

In the case of (14A), the theme $\exists x.*admires'x\ marcel'$ establishes a rheme alternative set such as the following:

(18) $\left\{\begin{array}{l}admires'woman'_1 marcel'\\ admires'woman'_2 marcel'\\ admires'man'_1 marcel'\end{array}\right\}$

The rheme of (14A), which is *the woman who* DIRECTED *the musical*, where only the word DIRECTED is contrasted, then restricts this set to one proposition, just in case the database supports the fact that all individuals in the alternative set have something to do with the musical in question, and the property of directing it uniquely identifies one such individual. (See Prevost and Steedman 1994, Prevost 1995, and *TSP* for further details, including discussion of asymmetries between possibilities for pre- and postnuclear accents, as on *woman* and *musical* in the present example.)

3.4 Discontinuous Themes and Rhemes

The intonational tunes discussed above may also mark multiple disjoint segments of the sentence as either theme or rheme. For example, a discontinuous theme is found in the following exchange:[13]

(19) Q: I know what Marcel SOLD to HARRY. But what did he GIVE to FRED?
A: (Marcel GAVE) (a BOOK) (to FRED).
L+H*LH% H* L L+H*LH%

[12]See Veltman 1983, Heim 1983, Landman 1986, Groenendijk and Stokhof 1990 and Steedman 1997 for discussion of "dynamic" varieties of logic that can be used to formalize the notion of updates and sideeffects.

[13]Once again, in relevant dialects the Rhythm Rule applies to shift stress to the first syllable of *Marcel* because it is immediately followed by an accented syllable GAVE in the same intonational phrase.

The theme established by the question is *what Marcel gave to Fred*—that is:

(20) $\exists x.{*}give'{*}fred'\,x\;marcel'$

We may assume that the rheme alternative set includes things like the following:

(21) $\left\{\begin{array}{l} give'\,fred'\,book'\,marcel' \\ give'\,fred'\,record'\,marcel' \\ give'\,fred'\,biscuit'\,marcel' \end{array}\right\}$

In the answer, the words *gave* and *Fred* get L+H* pitch accents, because the theme alternative set includes the previous theme, *what Marcel sold to Harry*, or $\exists x.sell'\,harry'\,x\;marcel'$. Since elements of the theme are separated by the rheme *a* BOOK (which of course has its own H* pitch accent and boundary), there are two L+H* LH% theme tunes. These fragments work independently to have the effect of a discontinuous theme. The first presupposes that the rheme alternative set consists entirely of propositions of the form $give'\,xy\;marcel'$, whereas the second presupposes that it consists of predications over an indirect object $fred'$. Both presuppositions are compatible with the same rheme alternative set, so together they require that it consist of propositions of the form $give'\,fred'\,y\;marcel'$, just as if they constituted a single discontinuous theme. Similarly, both theme fragments separately evoke theme alternative sets that are compatible with the alternatives introduced by the question, which are of the form *dtv x y* $marcel'$, where *dtv* is a variable over ditransitive verb interpretations.

4 The Compositional Semantics of Tones

The claim that the L+H* LH% tune marks the theme and the H* L% and H* LL% tunes the rheme is implicit in the accounts of Jackendoff (1972), Ladd (1980), Bolinger (1989), and others, but it remains controversial. This section first presents further evidence for the claim, then shows how these discourse functions derive from more primitive compositional discourse-semantic elements associated with the individual tones that make up the tunes, in a system of the general kind proposed by Pierrehumbert and Hirschberg (1990).

Before we proceed, a word of caution is in order. This section will be presented as though the identification of tones were unproblematic. However, as noted earlier, their status is in fact much less clear than this might suggest. Even trained judges find distinctions such as that between H* and L+H*, or between the latter and L*+H, hard to draw, even when explicit phonetic segments or syllable boundaries are available. Many non-native dialects obliterate all distinction between such tones, and/or eliminate high boundaries. Although Pierrehumbert and Steele (1989) offer some support for the claim that such distinctions are perceptually categorical, Taylor (to appear) suggests that they merely represent points in a continuum. We will see in section 5 that the present proposal is compatible with even drastically reduced tone systems in which most distinctions between varieties of pitch accent and boundary are eliminated or held to be perceptually ambiguous between the categories assumed here. In fact, one very strong implication of the present work is that many of these distinctions may need to be redrawn.

4.1 The Tunes H LL%, H* L, and L+H* LH%*

Pierrehumbert and Hirschberg (1990) offer an ambitious proposal for a compositional semantics for tones and intonational tunes. They make no direct reference to notions like theme and rheme (although with some reservations they do invoke a themelike notion of "open expression"; see p. 289 and n. 5). Instead, they propose a compositional semantics for the intonational tunes that is based on scalar dimensions of propositional attitude such as certainty concerning relevance and degree of commitment to belief revision (pp. 294-297). Nevertheless, their account is for the most part consistent with the assumptions that are made here.

According to Pierrehumbert and Hirschberg, the L+H* pitch accent is used "to convey that the accented item—and not some alternative related item—should be mutually believed" (p. 296). In this it contrasts with the rhemelike function of the H* pitch accent, which is used to signal "that the open expression is to be instantiated by the accented items" and that the resulting proposition is to be mutually believed.

These two analyses are compared at some length in *TSP*, where the theme/rheme analysis is shown to offer an alternative analysis for Pierrehumbert and Hirschberg's examples. However, the following minimal pair of dialogues appears at first glance to raise problems for both accounts of the L+H* LH% tune:

(22) Q: Does Marcel love opera?
A: Marcel likes MUSICALS.
H* LL%

(23) Q: Does Marcel love opera?
A: Marcel likes MUSICALS.
L+H* LH%

In both cases, the initial question can be assumed to establish a set of alternatives containing the proposition in question and its negation, and in both cases the answer states a proposition that is not among those alternatives.

In (22), the response is marked with the H* LL% tune that I have identified as marking the rheme. Depending on the context, the speaker may thereby be committed by the usual Gricean principles to a number of conversational implicatures. For example, if it is mutually believed that liking musicals entails hating opera, then this response implicates denial. If on the other hand liking musicals is mutually believed to entail loving opera, then affirmation is implicated. Either way, the speaker's intonation only commits him or her to the claim that his or her utterance is a rheme—that is, that it restricts the set of alternatives established by the question, rather than to a particular change in belief.

(23) is of a kind discussed by Jackendoff (1972:264–265), Liberman and Sag (1974), and Ladd (1980:146–148) (see also Ward and Hirschberg 1985, discussed below) and might appear at first glance to be almost equivalent to (22). In particular, the possibilities for conversational implicature, whether of affirmation or denial, seem identical. There is a temptation to believe

that the L+H* LH% tune in this case might mark a rheme, rather than a theme, differing from the standard H* LL% rheme tune in terms of the degree of conviction or commitment to whether it does in fact answer the question.

In *TSP*, I argue that, on the contrary, the entire answer (23A) states a theme, and that what the respondent has actually done is to offer a new theme, and hence a new rheme alternative set, replacing the one established by the question, without stating a rheme at all. On this view, the lack of commitment to whether the utterance actually answers the question is explained, since that is exactly what a theme does not do. It is also likely, among other possibilities, that the effect of not taking responsibility for a rheme in this utterance will be that of *conversationally implicating* a lack of confidence in either the relevance of the theme or the certainty that a particular inference can be drawn. For similar reasons, a lack of commitment to any particular change in belief might be implicated. But neither implicature would be a matter of literal or conventional meaning of the utterance itself.

This is essentially the analysis proposed by Ladd (1980:152–156), who relates "fall-rise" contours to the function of evoking a set of alternatives established by the preceding context—a notion that has here been identified with the notion of theme, interpreted in terms of the alternative semantics of Karttunen and Peters (1979), Rooth (1985) and Büring (1995:51).

In the case of answer (23A), the new theme is simply the following:

(24) $like'^{*}musicals'marcel'$

Since this is a fully saturated proposition, with no λ-bound variables, the corresponding rheme alternative set is a singleton.

(25) $\{like'musicals'marcel'\}$

Since it contains only one member, it will in fact lead to an answer to the question via exactly the same chain of inference from shared beliefs as in (22), although the speaker does not actually commit to that belief. It is for this reason that theme-only propositions end up having much the same illocutionary force as rheme-only propositions. This analysis will be supported by a closer examination of the individual tones.

4.2 The Compositional Semantics of Pitch Accents and Boundaries

Examples like the following, as well as numerous examples cited by Pierrehumbert and Hirschberg 1990, suggest that the H* accent yields a rheme not only in combination with LL%, but also with an LH% boundary.

(26) There's ORANGE juice, and APPLE juice.
H* LH% H* LL%

The H* LH% and H* LL% tunes seem to be more or less freely interchangeable in listing offers of this kind. Both tunes seem to mark rhemes, in the sense that they restrict the rheme alternative

set.[14]

A related example of the H* LH% tune is (27a), adapted from Pierrehumbert and Hirschberg (1990:293–294).

(27) a. Your LUNCH is ready! b. Your LUNCH is ready!
H* LH% H* LL%

It is quite hard to pin down the precise contribution of the LH% and LL% boundaries in these examples. Example (27a) appears to differ from the parallel H* LL% utterance (27b) only in explicitly entertaining the possibility of a response, including demurral—hence the greater politeness of the former. This property seems related to the use of the H* LH% contour in British (but not American) English for polite yes-no questions (Ladd 1996:122), and to Pierrehumbert and Hirschberg's claim (1990:304–308) that high boundaries mark discourse units that are to be interpreted in relation to a succeeding phrase that may be from either speaker (see Brown 1983). One conjecture that is consistent with these observations and with all the examples considered here is that H% boundaries mark themes and rhemes alike as the *hearer's* theme or rheme, whereas L% boundaries mark them as the speaker's. (In section 5.2.2 the idea of ownership of information units will be related to the logical notion of *modality*.) The suggestion is that the rather diverse collection of speech acts such as questioning, polite requesting, ceding or holding the turn, and the like, which have been imputed to H% boundaries, arise by implicature from the marking of information units as the hearer's. As a consequence, the H* LH% tune can be used to mark polite declarative rhemes like those in (26) and (27), in circumstances where the hearer can accommodate the suggestion that it is his or her rheme. But it cannot be used to mark the rheme in the answer to a *wh*-question, as can be established by trying its effect in contexts like (4) and (5), since by definition such a rheme cannot be the hearer's.

This conjecture is supported by the observation that the L+H* pitch accent is similarly free to occur with LL% as well as LH%.[15]

(28) a. Q: Why did Marcel want to prove completeness?
A: THAT was the whole POINT of the exercise!
H* L L+H* LL%

b. Q: I know that the result of the exercise was to prove completeness. But what was the whole point of the exercise?
A: THAT was the whole POINT of the exercise!
H* L L+H* LH%

The claim is that the tune L+H* LL% is again a theme, differing only from the L+H* LH% theme in (28b) in being marked by the LL% boundary as the answerer's own, and (since it bears

[14]As in the case of the multiple theme tunes in (19), these two rhemes independently restrict a (possibly accommodated) rheme alternative set of available beverages and thereby have the effect of a disjoint rheme.

[15]Example (28a) is adapted from Ladd 1996:97–98, although it is not clear that this is the context that Ladd has in mind.

a pitch accent) as contrasting with the theme of the question (28a).[16]

It is because the high boundary in the L+H* LH% tune marks the theme as the hearer's responsibility that it implicates the lack of commitment on the part of the speaker discussed earlier in connection with (23), in contrast to the same response with L+H* LL% intonation. For identical reasons, the following combinations of otherwise well-formed theme and rheme tunes are infelicitous in the contexts used in (4) and (5):

(29) Q: I know who proved soundness. But who proved COMPLETENESS?
A: #(MARCEL) (proved COMPLETENESS).
H* LH% L+H* LL%

(30) Q: I know which result Marcel PREDICTED. But which result did Marcel PROVE?
A: #(Marcel PROVED) (COMPLETENESS).
L+H* L H* LH%

These responses are infelicitous on two counts. First, the H* LH% tune on the rhemes MARCEL and COMPLETENESS is infelicitous for the same reason that it would be if those rhemes were stated in isolation as answers: the rheme of the answer to a *wh*-question cannot under normal circumstances be the responsibility of the original questioner. Similarly, marked L+H* LL% themes are inappropriate in answers to *wh*-questions unless they offer a contrast to the theme of the question.[17]

These observations point the way to two generalizations. First, the theme/rheme distinction seems to be projected from pitch accents onto prosodic phrases by the boundary. Second, the distinctive role of H% boundaries seems to be to indicate ownership of, or responsibility for, the information unit by the other party to the discourse, whereas L% boundaries indicate ownership by the speaker.

4.3 The Generalization to other Tunes

These observations appear to generalize across the remaining pitch accent and boundary tones in Pierrehumbert's system (Beckman and Pierrehumbert 1986.) The reader is urged to consult Pierrehumbert and Hirschberg 1990, especially figure 14.14, for identification of the exact contours in question.

L* seems to mark rhemes in a similar way to H*, from which it seems to differ mainly in terms of involving an associated speech act of denial (cf. Liberman and Sag 1974). For example, in English questions like (31) (from Pierrehumbert and Hirschberg's ex. 16) the discourse meaning of L* seems parallel to that of the Latin particle *num*, whose inclusion implies that the questioner believes the answer to be negative. No such implicature inheres to H* in example

[16]The claim is supported by the observation that the answer in (28b) is not an appropriate response to the question in (28a), since the theme of that answer clearly isn't that questioner's theme. Conversely, the answer in (28a) is inappropriate as a response to question (28b), because the theme in the answer is already the questioner's theme.

[17]I am grateful to one of the referees for calling for an account of examples like (29)–(30), and of the incoherence of simply exchanging the tunes within the answers to (4) and (5), which follows from the same principles.

(32).

(31) Do PRUNES have FEET? (Surely not!)
L* L*LH%

(32) Do PRUNES have FEET? (How wonderful!)
H* H*LH%

Although this distinction can be used to signal affirmation versus denial, it can also be used indirectly, in polite offers of alternatives, as can be seen from the increased diffidence that the following exhibits in comparison with the earlier version (26):

(33) There's ORANGE juice, and APPLE juice.
L* LH% H* LL%

As Pierrehumbert and Hirschberg suggest in somewhat different terms, this contrast between H* and L* in terms of positive and negative presuppositions appears to generalize to the other pitch accents. The two accents H*+L and H+L* mark rhemes, much like particularly emphatic or theatrical versions of H* and L*.[18]

(34) JEREMY!
H*+L LH%

(35) Do PRUNES have FEET? (I really can't believe this!)
H+L* H+L* LH%

The remaining pitch accent, L*+H, is a more difficult case. It is claimed here to pattern with the L+H* pitch accent in marking a theme. Ward and Hirschberg (1985) discuss the following example, which is closely related to (23) (see Pierrehumbert and Hirschberg 1990:295, (26)):

(36) A: Harry's such a klutz.
B: He's a good BADMINTON player.
L*+H LH%

Pierrehumbert and Hirschberg describe the L*+H LH% tune in this example as expressing "uncertainty about whether being a good badminton player provides relevant information about degrees of clumsiness." However, the example is also consistent with an implicature along the same lines as (23), in which B's response acts as a theme establishing a rheme alternative set such as the following, the single member of which entails denial under usual assumptions about requirements for good badminton players.

(37) $\{good'\,badmintonplayer'\,harry'\}$

Any implicature of uncertainty about the relevance of the information arguably results from the fact that the LH% boundary in (36) marks the contrastive theme as the hearer's, rather than the

[18]Given the uncertainty in the theory concerning the location of phrasal tones, it seems possible that H*+L and H+L* could eventually be subsumed to H* and L*, respectively.

speaker's, responsibility. This is clear from the effect of substituting an LL% boundary, which is to entirely remove the uncertainty by implicating speaker responsibility, as in (38).

(38) A: Harry's such a klutz.
B: He's a good BADMINTON player.
L*+H LL%

The L+H* and L*+H pitch accents are hard to tell apart, both subjectively and instrumentally—although Pierrehumbert & Steele 1989 claim experimental evidence for the categorical nature of the distinction. Pierrehumbert and Hirschberg note (1990, p.296) that the discourse functions of these accents are closely related, and indeed it seems quite possible to produce an utterance equivalent to (38) and parallel to (23) using L+H*:

(39) A: Harry's such a klutz.
B: He's a good BADMINTON player.
L+H* LH%

The effect of substituting an LL% boundary is much the same as in (36)—cf. (38). Although I will not attempt to formalize the notion of speech act in what follows, any difference seems to lie in the fact that L*+H is only really compatible with a speech act involving contradiction, whereas L+H* is neutral in this respect. For this reason, L*+H does not seem to work in simple direct answers to *wh*-questions like *Who is a good badminton player?* Nevertheless, it does seem to be possible as a theme marker in responses where contradiction is involved.

(40) A: I can't believe I ate the whole thing!
B: RALPH ate MOST of it.
H* L L*+H LH%

Although I will not go into examples in detail, the HH% boundary seems to pattern with the LH% boundary when substituted in the above examples, as does HL% with LL%.

5 Grammar and Intonation

Apparently "nonconstituent" intonational units—such as the intonational phrase *Marcel proved* in (1b) and (5)—are very widespread and can coincide with all of the intonational tunes considered above. The following sections extend the argument of earlier papers that such fragments are not only prosodic constituents but surface syntactic constituents, complete with interpretations.

5.1 Combinatory Grammars.

The following is the briefest possible sketch of Combinatory Categorial Grammar (CCG) of the kind presented at greater length in *TSP*. As in other varieties of Categorial Grammar, elements like verbs are associated with a syntactic category that identifies them as *functions* and specifies the type and directionality of their arguments and the type of their result. A "result leftmost" notation is used, in which a rightward-combining functor over a domain β into a range α is

written α/β, and the corresponding leftward-combining functor is written $\alpha\backslash\beta$.[19] α and β may themselves be function categories. For example, a transitive verb is a function from (object) NPs into predicates, which are themselves functions from (subject) NPs into S:

(41) proved := $(S\backslash NP)/NP$

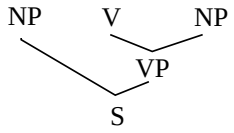
Such functor categories can combine with their arguments by the following rules:

(42) *Forward Application* (>)
$X/Y \quad Y \quad \Rightarrow \quad X$

(43) *Backward Application* (<)
$Y \quad X\backslash Y \quad \Rightarrow \quad X$

Derivations are written as in (44a), with underlines annotated with arrows denoting application of forward and backward rules, rather than as conventional phrase structure derivations like (44b).

(44) a.
$$\dfrac{\dfrac{\underline{NP} \quad \underline{(S\backslash NP)/NP} \quad \underline{NP}}{S\backslash NP}\,>}{S}\,<$$

b.


The lexical categories can be augmented with an explicit identification of their semantic interpretation, here associated with the category via a colon operator.

(45) proved := $(S\backslash NP)/NP : prove'$

In this notation, the rules of functional application must be expanded with an explicit semantics in the same way. For example:

(46) *Forward Application:* (>)
$X/Y : f \quad Y : a \quad \Rightarrow \quad X : fa$

The semantic interpretation of this and all other combinatory rules is completely determined by its syntactic form under the following principle:[20]

(47) *The Principle of Type Transparency*
All syntactic categories reflect the semantic type of the associated logical form, and all syntactic combinatory rules are type-transparent versions of one of a small number of simple semantic operations over functions including application, composition and type-raising.

This principle entails that *fa* is the *only* interpretation permitted for the result *X* of the rule, given those inputs. Alternatives like *faa* and *af* are not allowed, because they would require one or both categories to be non-type transparent.

[19] There is an alternative "result on top" notation due to Lambek (1958), in which the latter category is written $\beta\backslash\alpha$.

[20] This principle is differently stated in earlier papers. The word *including* is to license the coordination rule used here and to allow one further combinatory operator type in CCG that is not discussed here, called "substitution."

Derivations can then be written as follows:

(48)
$$\dfrac{\dfrac{\underline{\text{Marcel}}}{NP : marcel'} \quad \dfrac{\dfrac{\underline{\text{proved}}}{(S\backslash NP)/NP : prove'} \quad \dfrac{\underline{\text{completeness}}}{NP : completeness'}}{S\backslash NP : prove'completeness'}>}{S : prove'completeness'marcel}<$$

The derivation yields an S with a compositional interpretation, equivalent as usual under the convention of left associativity to $(prove'completeness')marcel'$.

Coordination of constituents of like type to yield a single constituent of the same type is permitted by the following polymorphic rule schema, in which X is variable over categories, and whose semantics is discussed in *TSP*.

(49) *Coordination* (<&>)
$$X \quad conj \quad X \quad \Rightarrow \quad X$$

One of the original motivations behind CCG was to account for coordination of contiguous strings that do not constitute traditional constituents, as in (50).

(50) I predict and *will prove* completeness.

Rather than invoking rules of deletion or movement, CCG allows certain further operations on functions related to what Curry called "combinators" (Curry and Feys 1958), including the following rule of functional composition, indexed $>\mathbf{B}$ in derivations (because Curry called his composition combinator **B**):

(51) *Forward Composition* ($>\mathbf{B}$)
$$X/Y \quad Y/Z \quad \Rightarrow \quad X/Z$$

Since *will* is $(S\backslash NP)/VP$ and *prove* is VP/NP the rule yields the transitive verb category $(S\backslash NP)/NP$ for *will prove* in (50), which may therefore coordinate with *conjectured*.

The Principle of Type Transparency (47) means that the semantic effect of this rule is as follows, yielding an interpretation $\lambda x.\lambda y.will'(prove'x)y$ for the same fragment:

(52) *Forward Composition* ($>\mathbf{B}$)
$$X/Y : f \quad Y/Z : g \quad \Rightarrow \quad X/Z : \lambda x.f(gx)$$

Combinatory grammars also include type-raising rules, which turn arguments into functions over functions-over-such-arguments. These rules allow arguments including subjects to compose, and thereby take part in coordinations like the following:

(53) *Marcel proved*, and I disproved, completeness.

(54) *Forward Type-raising* ($>\mathbf{T}$)
$$X : a \quad \Rightarrow \quad \mathrm{T}/(\mathrm{T}\backslash X) : \lambda f.f\ a$$

(55) *Backward Type-raising* (<**T**)

$$X : a \quad \Rightarrow \quad \mathrm{T}\backslash(\mathrm{T}/X) : \lambda f.f\ a$$

X ranges over argument categories such as NP and PP. T is a metavariable that schematizes over a number of instantiations subject to a restriction that the functions T/X and $\mathrm{T}\backslash X$ must be categories consistent with the parameters of the language in question. For example, English NPs can raise over $S\backslash NP$, $(S\backslash NP)/NP$, S/NP, and so on, but not $(S\backslash NP)\backslash NP$. (See *TSP* for discussion. This restriction is in keeping with a general resemblance between type-raising and the traditional notion of case—see Steedman 1985, 564; 1990, 221—and with the possibility that type-raising should be treated as a morpholexical rule rather than a syntactic one.) The rules have an "order-preserving" property. For example, (54) turns an NP into a *rightward* looking function over *leftward* functions and therefore preserves the linear order of subjects and predicates. The interpretation of such rules is again entirely determined by the Principle of Type Transparency (47).

Since sentential complement-taking verbs like *think*, VP/S, can in turn compose with fragments like *Marcel proved*, S/NP, we correctly predict that right-node raising is unbounded, as in (56a), and also provide the basis for an analysis of the similarly unbounded character of leftward extraction, as in (56b) (see Steedman 1996 for details, including Empty Category Principle effects, and various extraction asymmetries), and of a variety of coordination phenomena (see *TSP*):

(56) a. [I disproved]$_{S/NP}$ and [you think that Marcel proved]$_{S/NP}$ completeness.
b. The result that [you think that Marcel proved]$_{S/NP}$.

The significance of this theory for present purposes is the following. If in order to account for coordination and relativization we take strings like *you think that Marcel proved* to be surface constituents of type S/NP, then they must also be possible constituents of non-coordinate sentences like *Marcel proved completeness*, which must permit derivation (57), as well as the traditional derivation (48), which with type-raising appears as in (58). These derivations correspond to the trees in (3b) and (3a), respectively.

(57)

$$\dfrac{\dfrac{\dfrac{\text{Marcel}}{NP : marcel'}}{S/(S\backslash NP) : \lambda f.f\ marcel'}{>}\mathbf{T} \qquad \dfrac{\text{proved}}{(S\backslash NP)/NP : prove'}}{S/NP : \lambda x.prove'\,x\ marcel'}{>}\mathbf{B} \qquad \dfrac{\dfrac{\dfrac{\text{completeness}}{NP : completeness'}}{S\backslash(S/NP) : \lambda p.p\ completeness'}{<}\mathbf{T}}{S : prove'\,completeness'\,marcel'}{<}$$

(58)

Marcel	proved	completeness
$NP : marcel'$	$(S\backslash NP)/NP : prove'$	$NP : completeness'$
$S/(S\backslash NP) : \lambda f.f\ marcel'$ (>T)		$(S\backslash NP)\backslash((S\backslash NP)/NP) : \lambda p.p\ completeness'$ (<T)
	$S\backslash NP : \lambda y.prove'\,completeness'\,y$ (<)	
$S : prove'\,completeness'\,marcel'$ (<)		

These derivations correspond to the trees in (3). It is important to notice that once we simplify or "normalize" the interpretations by β-reducing λ-abstracts with arguments, as I have tacitly done throughout these and earlier derivations, both yield the same appropriate proposition *prove′ completeness′ marcel′*.[21]

The Principle of Type Transparency guarantees that all such non-standard derivations yield identical interpretations, over which such c-command-dependent relations as the binding conditions can be defined as in any other grammar framework (see Steedman 1996). In more complex sentences than the above, there will be many such equivalent derivations for each distinct interpretation. Hence, this property has been rather misleadingly referred to as "spurious ambiguity."

The relevance of the nonstandard surface structures that were originally introduced to explain coordination in English will be obvious. The claim is simply that they subsume the intonation structures that are needed in order to explain the possible intonation contours for sentences of English discussed earlier. Intonational boundaries, when present as in spoken utterances like (4) and (5), contribute to determining *which* of the possible combinatory derivations such as (57) and (58) is intended. The interpretations of the constituents that arise from these derivations, far from being "spurious," are related to semantic distinctions of information structure and discourse focus.

That is not of course to claim that information structure is invariably (or even usually) disambiguated by prosodic information. As should be evident from the earlier discussion of unmarked themes like those in (6) and (7), listeners seem to be able to cope with as much ambiguity in this component of the grammar as in any other. The claim is merely that where intonational boundaries are present, they will contribute to disambiguation in this way. Conversely, any such boundaries must be consistent with *some* syntactic derivation, or ill-formedness will result. It follows, as we will see, that the examples (2) are excluded under the CCG notion of syntactic and semantic constituency, without an independently stipulated Sense Unit Condition parallel to that in Selkirk 1984.

[21] It is in terms of this level of representation, a logical form preserving traditional notions of dominance and command, rather than in terms of derivation, that the phenomena that in GB are covered by the binding theory can be most straightforwardly defined within the present theory (see Chierchia 1985, 1988, 1989). Szabolcsi (1989), Jacobson (1990), Hepple (1990), and Dowty (1982, 1992), discuss a number of ways to do this without the mediation of predicate-argument structure within closely related categorial frameworks, to which the present analysis of intonation structure also in principle applies.

5.2 Combinatory Prosody

In order to formalize this idea within the CCG framework, I build here on a sketch developed in *TSP*. Where earlier analyses used an autonomous "autosegmental" phonological categorial grammar, with its own combinatory operations of application and composition, locked to syntactic derivation by a "Prosodic Constituent Condition," the grammar presented here uses a much simpler set of phonological types, and uses this information to directly limit the syntactic derivation (and hence information structure).[22]

5.2.1 The Pitch Accents It has already been noted that the focus-marking property of pitch accents seems to belong at the level of the word, whereas the theme/rheme-marking property seems to belong at the level of phrasal constituents. The latter property can be "projected" from the former by the grammar as follows.

First, Beckman and Pierrehumbert's (1986 six pitch accents are distinguished as markers either of theme (θ) or of rheme (ρ).[23]

(59) θ-markers: L+H*, L*+H
ρ-markers: H*, L*, H*+L, H+L*

This partition is controversial. Many accounts such as Halliday's (1967a), Jackendoff's (1972), Ladd's (1980), and Bolinger's (1989) do not explicitly distinguish L+H* and H* pitch accents at all, whereas we have seen that Pierrehumbert and Hirschberg explicitly contrast the roles of L+H* and L*+H. Nevertheless, most if not all of Ladd's examples of fall-rise evoking contextual alternatives appear to involve the L+H* LH% tune (1980:152–162), and the similarity of function to the L*+H LH% tune noted by Pierrehumbert and Hirschberg (1990) and exemplified above in minimal pairs like (36) and (39) strongly suggests that L*+H should be in the same theme-marking group. Similarly, minimal pairs like (26) and (33) above seem to require H* and L* to be in the same rheme-related class, whereas the respective similarity between them and H*+L and H+L* exemplified by minimal pairs like (31) and (35) seems to place them in the same category as H* and L*.

We will further assume that pitch accents affect both the syntactic category and (some element of) the interpretation of the words they occur on. If the syntactic category is a basic type such as *NP* then the effect of a θ- or ρ-marking accent is to associate with the category a value of θ or ρ on a feature we might call *INFORMATION*, which we will notate as a subscript, as in NP_{ρ}. If the syntactic category is a function type, such as $S\backslash NP$ then the effect of a θ- or ρ-marking accent is to θ- or ρ-mark the domain and range of the function, as in $S_{\rho}\backslash NP_{\rho}$, $(S_{\rho}\backslash NP_{\rho})/NP_{\rho}$,

[22]The theory's main claim concerning the isomorphism between the constituents of surface syntactic derivation and their semantic interpretations with information structure and the associated intonational boundaries would in fact hold for many different choices of intonational categories and information structural functions—for example, in theories or dialects in which the catalogue of pitch accents is much reduced, or in theories where the boundary rather than the pitch accent is the "head" of categories like theme and rheme, as hypothesized in Prevost and Steedman 1994.

[23]Of course, these categories simplify considerably in omitting any finer distinctions within the classes θ and ρ of theme accents and rheme accents. The symbols θ and ρ should be regarded as placeholders for more specific bundles of feature values distinguishing the individual theme and rheme pitch accents on further dimensions such as involvement of negative presuppositions and other factors identified above.

$S_\rho/(S_\rho\backslash NP_\rho)$, and so on. In effect this imposes a requirement that any argument that combines with such a function has to be compatible with its theme- or rheme-hood.

Although eventually we will certainly want to do this by rule, for purposes of exposition I will follow Bird 1991, Prevost 1995, and *TSP* in regarding this as happening presyntactically, at the level of lexical categories like the following for the verb *proved* bearing an H* pitch accent.

(60) proved := $(S_\rho\backslash NP_\rho)/NP_\rho : \lambda x.\lambda y.{*}prove'xy$
H*

The semantic interpretation of the word is also marked as focused using an asterisk notation.

I will assume that all lexical items in the sentence are similarly associated either with a pitch accent or with a phonological category corresponding to the absence of any tone in Pierrehumbert's system. This "null tone," which I will follow Pierrehumbert in leaving without annotation in sentences, similarly marks the syntactic category with a null *INFORMATION* feature value η (for "eme"), which is a variable unique to each particular occurrence of the null tone, that ranges over the theme and rheme markers θ and ρ and nothing else except η itself (although I have suppressed explicit typing of variables in the notation). For example:[24]

(61) proved := $(S_\eta\backslash NP_\eta)/NP_\eta : \lambda x.\lambda y.prove'xy$

Naturally, the null tone does not mark any element of the interpretation as focused.

It will reduce notational clutter to suppress the η-marking of categories like (61), writing them as before as $(S\backslash NP)/NP : \lambda x.\lambda y.prove'xy$. Nevertheless, the variable feature value is there, and is crucial in projecting θ- and ρ-marking correctly when such categories combine with a θ- or ρ-marked one.

Under the standard unification-based interpretation of the combinatory rules (see Shieber 1986 and *TSP*), and in particular of the variable accent value η, these phonologically augmented categories allow intonational tunes to be spread over arbitrarily large constituents.

For example, in analyzing the first two words of the sentence *Marcel proved completeness* with the intonation in (5), the following partial derivation is allowed (the η values on categories for words bearing null tone are omitted by convention as previously stated):

(62)

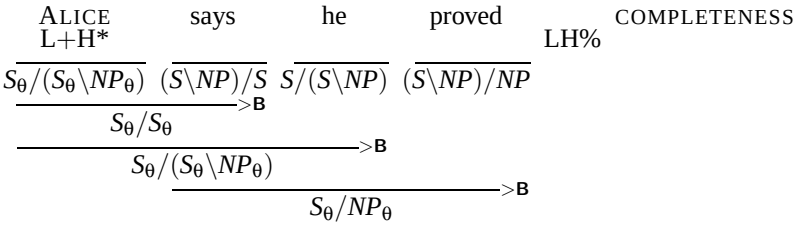
Marcel	PROVED L+H*	COMPLETENESS LH%
$S/(S\backslash NP) : \lambda p.p\ marcel'$	$(S_\theta\backslash NP_\theta)/NP_\theta : \lambda x.\lambda y.{*}prove'xy$	
	$S_\theta/NP_\theta : \lambda x.{*}prove'x\ marcel'$ (>B)	

Since under this convention the syntactic category of *Marcel* when written in full is $S_\eta/(S_\eta\backslash NP_\eta)$, the composition unifies η and θ, projecting θ-marking to the entire result.

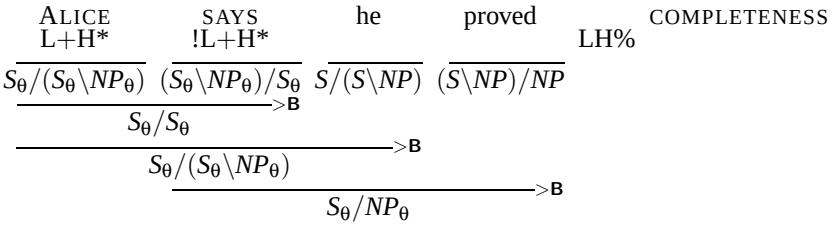
As in the earlier system in Steedman 1991a, iterated compositions of the same kind have the effect of allowing the theme and rheme markers associated with the pitch accents to spread

[24]See note 8 regarding the possible realization of null tone with "secondary" accent. In the terms of the earlier autosegmental-categorial approach, this category could be realized as a very general bidirectional functor $\eta|\eta$.

unboundedly across any sequence that forms a grammatical constituent according to the combinatory grammar. For example, if in answer to the same question *What did Marcel* PROVE? the reply is ALICE *says he proved* COMPLETENESS, then the tune will typically be spread over ALICE *says he proved* as in the (incomplete) derivation (63), in which the semantics has been suppressed.

(63)


Such unboundedly iterated composition may include further occurrences of the L+H* pitch accent, as in the following alternative answer to the same question, in which the level of the second L+H* pitch accent would be downstepped. That is, its entire pitch range is lowered with respect to its predecessor, a phenomenon for which the ToBI conventions (Silverman et al. 1992) offer a convenient notation, extending Pierrehumbert's system with the prefix "!" on downstepped pitch accents.

(64)


(The phonological category of the pitch accent is unaffected by downstep, and its specification in the string is, strictly speaking, redundant.)

All other possible combinations of L+H* accents and null tones are similarly allowed, differing only in which elements in the translation are marked for contrast.[25]

5.2.2 The Boundaries Unlike the pitch accent categories, which are associated with whatever grammatical entity the accent falls within, the boundaries are autonomous string elements, much like the punctuation marks that on occasion represent them in the orthography. It is combination at the syntactic level that makes them coarticulate with the words. They bear a phonologically augmented grammatical functor category that in effect makes the boundary the "specifier" of a phonological phrasal constituent of which the pitch accent is the head, much like the determiner in a nounphrase.

In order to formalize the boundaries in CCG, a distinction must be drawn that has until now been suppressed between what Pierrehumbert called "intermediate" phrases and the intonational

[25]Other pitch accents that bear the category θ, such as L*+H, may possibly alternate as well. Different ρ accents may alternate with each other, but they are not allowed to alternate with θ, at least under present assumptions.

phrase proper. Intermediate phrases, which are the domain of downstep, consist of one or more pitch accents, followed by either the L or H boundary, sometimes known as a "phrasal" tone. Tunes like L+H* LH% and H* LL% apply to intonational phrases, consisting of an intermediate phrase L+H* L or H* L, followed by a intonational phrase boundary tone H% or L%. In general, according to the Selkirk/Pierrehumbert theory, tunes that apply to intonational phrases consist of a sequence of one or more intermediate phrases followed by an L% or H% boundary tone.

The intermediate phrase boundaries, or phrasal tones, can both be assigned the following category, whose most important effect is to transfer the theme/rheme marking θ or ρ to the corresponding semantic functions θ′ and ρ′ via the variable η:

(65) L, H := $S\$_\iota \backslash S\$_\eta : \lambda f.\eta' f$

The syntactic category $S\$_\iota \backslash S\$_\eta$ maps θ- and ρ-marked categories onto identically ι-marked categories, where ι will no longer unify with η, θ, or ρ. This marks the category as a theme/rheme intermediate phrase and prevents further combination with anything except similarly complete prosodic phrases.[26]

The variable $S\$_\eta$ in the syntactic type ranges over a set $\{S\$_\eta\}$ of syntactic categories including those unifying with S_η and all η-marked functions into members of $\{S\$_\eta\}$; that is, $S\$_\eta$ matches S_θ, S_ρ/NP_ρ, and all verbs and type-raised arguments of verbs, but not nouns and the like.[27]

The category (65) therefore does the theoretical work of the *designated category parameter* in end-based theories of the syntax-prosody relation (see Selkirk 1990:180–181). The difference is that the domain of the prosodic phrase is totally identified with a syntactic domain. We therefore do not need to specify an independent end parameter in the sense of those theories.

The intonational phrase boundary tones L% and H% can be assigned the following modifier-like categories, which have the effect of mapping intermediate phrase boundaries (i.e., phrasal tones) into intonational phrase boundaries.

(66) L% := $(S\$_\phi \backslash S\$_\eta)\backslash(S\$_\iota \backslash S\$_\eta) : \lambda f.\lambda g.[S](fg)$
H% := $(S\$_\phi \backslash S\$_\eta)\backslash(S\$_\iota \backslash S\$_\eta) : \lambda f.\lambda g.[H](fg)$

φ is a value that again unifies or is compatible with only itself and ι, preventing further combination with anything except similarly complete prosodic phrases.[28]

These categories draw a further discourse semantic distinction already noted for the LL%

[26]The ι can be thought of as a placeholder for a bundle of feature values distinguishing the more specific meanings of the pitch accents distinguished earlier (just as θ and ρ are), some of whose components (such as the denial associated with L* accents) may be inherited by ι. This manipulation goes beyond mere term unification but I gloss over the details here.

[27]This is a version of the "dollar convention" of earlier papers.

[28]Like ι, φ can be thought of as a place-holder for bundles of feature values distinguishing the more specific meanings of the pitch accents. Because of the way the semantics has been specified, it is important that the boundary categories combine by the backward application rule alone. For this reason, the backward composition rules of *TSP* must be restricted so that they do not apply to functions from η-marked categories to φ- or ι-marked categories. Since backward composition rules do not figure in the present article, I will ignore this detail here.

and LH% boundaries in connection with examples (28a–b), marking the information unit of the intermediate phrase as speaker's or hearer's knowledge via the modal operators $[S]$ and $[H]$. These operators distinguish speaker's and hearer's knowledge using the notation developed in Stone 1998, but here they are no more than placeholders for a proper logical treatment of the conjectured discourse-semantic effects of the H% and L% boundary tones, which remains a topic for further research.

Although utterance-medial LL% boundaries do not figure in the examples discussed here, and may or may not be categorically distinct from intermediate phrase L boundaries, they are permitted under the present analysis. Their inclusion obviates the criticism of Steedman 1991a by Beckman (1996:63–64) on this point.[29]

As far as the logical form is concerned, $[H]$, $[S]$, θ', and ρ' are all identity functions that effectively vanish. However, until they apply, they block any further reduction of the interpretation to the canonical predicate-argument structure. When they do apply, their evaluation brings about updates to the model or database—in particular the identification of the theme and rheme alternative sets. These reductions can occur at any point in a derivation.

Example (67), which completes the derivation of the theme of (5) in the earlier example (62), demonstrates the effect of an intonational phrase boundary.

(67)

Marcel	PROVED L+H*	L	H%	COMPLETENESS H*	L	L%
$S/(S\backslash NP)$: $\lambda p.p\ marcel'$	$(S_\theta\backslash NP_\theta)/NP_\theta$: $\lambda x.\lambda y.{*}prove'xy$	$S\$_\iota\backslash S\$_\eta$: $\lambda f.\eta' f$	$(S\$_\phi\backslash S\$_\eta)\backslash(S\$_\iota\backslash S\$_\eta)$: $\lambda f.\lambda g.[H](fg)$			
	S_θ/NP_θ : $\lambda x.{*}prove'x\ marcel'$ (>B)		$S\$_\phi\backslash S\$_\eta$: $\lambda f.[H](\eta' f)$ (<)			
	S_ϕ/NP_ϕ : $[H](\theta'(\lambda x.{*}prove'x\ marcel'))$ (<)					

The second prosodic phrase in the example bears the H* LL% rheme tune, as in (5). Example (68) completes the derivation.

(68)

Marcel	PROVED L+H*	L	H%	COMPLETENESS H*	L	L%
	S_ϕ/NP_ϕ : $[H](\theta'(\lambda x.{*}prove'x\ marcel'))$			$S_\rho\backslash(S_\rho/NP_\rho)$: $\lambda p.p\ {*}completeness'$	$S\$_\iota\backslash S\$_\eta$: $\lambda f.\eta' f$	$(S\$_\phi\backslash S\$_\eta)\backslash(S\$_\iota\backslash S\$_\eta)$: $\lambda f.\lambda g.[S](fg)$
					$S\$_\phi\backslash S\$_\eta$: $\lambda f.[S](\eta' f)$ (<)	
				$S_\phi\backslash(S_\phi/NP_\phi) : [S](\rho'(\lambda p.p\ {*}completeness'))$ (<)		
	$S_\phi : [S](\rho'(\lambda p.p\ {*}completeness'))([H](\theta'(\lambda x.{*}prove'x\ marcel')))$ (<)					
	$S_\phi : {*}prove'{*}completeness'marcel'$					

This intonation contour and information structure are appropriate to the context established in (5) by the questioner's *wh*-question *Which result did Marcel PROVE?* uttered in a context of a theme alternative set including the following previously established theme:

[29]Utterance-final intermediate phrase boundaries such as L are also allowed under the present theory. However, utterance-final lengthening forces them to be pronounced indistinguishably from LL%.

(69) $\lambda x.predict' x\ marcel'$

The newly derived theme $\lambda x.*prove' x\ marcel'$ must contrast with this prior theme in the earlier sense.[30] If it does not, as in (29) and (30), the analysis will fail. Otherwise, the new theme can then be used to identify a rheme alternative set, such as (12). The rheme $\lambda p.p\ *completeness'$ can then be used to reduce this set to a single proposition $prove' completeness' marcel'$.[31]

Example (70) shows the derivation for the response in (4).

(70)

MARCEL		proved	COMPLETENESS		
H*	L		L+H*	L	H%
$S_\rho/(S_\rho\backslash NP_\rho)$	$S\$_\iota\backslash S\$_\eta$		$S_\theta\backslash NP_\theta$	$S\$_\iota\backslash S\$_\eta$	$(S\$_\phi\backslash S\$_\eta)\backslash(S\$_\iota\backslash S\$_\eta)$
$\lambda p.p\ *marcel'$	$:\lambda f.\eta' f$		$:\lambda x.prove'*completeness' x$	$:\lambda f.\eta' f$	$:\lambda f.[H]f$
$S_\iota/(S_\iota\backslash NP_\iota)$				$S\$_\phi\backslash S\$_\eta$	
$:\rho'(\lambda p.p\ *marcel')$				$:\lambda f.[H]\eta' f$	
			$S_\phi\backslash NP_\phi : [H](\theta'(\lambda x.prove'*completeness' x))$		
			$S_\phi : \rho'(\lambda p.p\ *marcel')([H](\theta'(\lambda x.prove'*completeness' x)))$		
			$S_\phi : prove'*completeness'*marcel'$		

This derivation deviates from the standard account, in that the intermediate phrase MARCEL is not considered part of the same intonational phrase as *proved* COMPLETENESS, as the Strict Layer Hypothesis (Selkirk 1984) would require. Although a more orthodox variant of the present system allowing intermediate phrases to combine in advance of the boundary tone could easily be devised, this does not seem to be what the compositional semantics of the tones requires, since the effect of the H% (however it should be formalized) appears to be confined to the predicate.[32]

As in the case of themes like (63) and (64), pitch accents, including multiple ones, can in general be distributed over the words of a rheme in a number of ways, depending on the possibilities for contrast afforded by the context.

Nevertheless, many impossible intonation contours correctly remain excluded by the grammar. In particular, all of the examples in (2), repeated here as (71), are ruled out for the same reason as the corresponding coordinations and extractions in (72), without the stipulation of an autonomous Sense Unit Condition.[33]

[30] In effect, the theme update function θ' first abstracts over the * constant in the new theme to construct a term corresponding to the theme alternative set. Higher order unification can be used for this task, via Huet's (1975) algorithm, in a manner discussed by Shieber et al. (1996). Prevost (1995) discusses a related procedural device.

[31] At this point too there may be mismatches. For example, if the rheme tune is H* LH% instead of H* LL%, as in (29) and (30), then the rheme will be marked as the hearer's $[H]$ rather than the speaker's $[S]$, causing infelicity in this context.

[32] As a consequence, the rheme subject receives no explicit $[S]$ or $[H]$ modality. I assume that such information units are evaluated as having $[S]$ modality by default.

[33] *Wh*-island constraints are notoriously soft, and some judges accept (72c). The point here is that they limit intonation *to the same extent* that they limit relativization and right node raising.

(71) a. *(Three MATHEMATICIANS) (in ten derive a LEMMA).
L+H* LH% H* LL%

b. *(Seymour prefers the NUTS) (and bolts APPROACH).
L+H*LH% H* LL%

c. *(They only asked whether I knew the woman who CHAIRED) (the ZONING board).
L+H* LH% H* LL%

(72) a. *Three mathematicians in ten derive a lemma and in a hundred can cook a boiled egg.

b. *the nuts that Seymour prefers and bolts approach

c. *Which boards did they ask whether you knew the woman who chaired?

5.2.3 Unmarked Themes As noted in connection with (6) and (7), the majority of themes in everyday utterances are null themes, unmarked by explicit boundary tones, so that the position of the theme-rheme boundary is usually ambiguous. It is therefore a virtue of the grammar as it stands that it allows multiple derivations, yielding several analyses in which the theme is unmarked, bearing the null tone category η, as in the following examples:[34]

(73) a. (I read a book about)$_{Theme}$ (COMPLETENESS)$_{Rheme}$

b. (I read)$_{Theme}$ (a book about COMPLETENESS)$_{Rheme}$

c. (I)$_{Theme}$ (read a book about COMPLETENESS)$_{Rheme}$

d. (I read a book about COMPLETENESS)$_{Rheme}$

We can therefore capture the earlier observation that these alternative analyses are identical in information-structural terms to those involving marked themes, differing only in the contrastive properties of the various alternative sets involved, as follows.

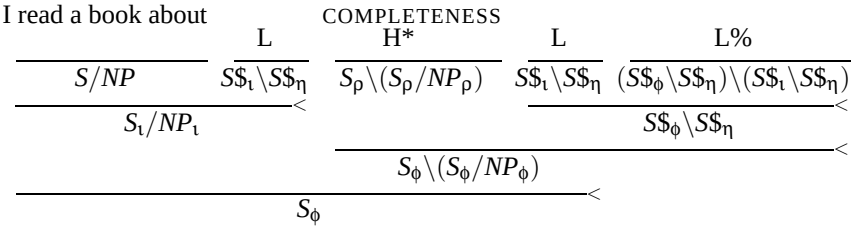
The category $S\$_\iota\backslash S\$_\eta$ of phrasal tones, as defined in (65), already allows them to combine with a null tone η-marked category. The result is a category whose semantics differs from that of a theme only in including η' in place of the theme update function θ'. We may assume that η' evaluates exactly like θ'. Because the interpretation of a constituent of this kind by definition contains no focused or *-marked elements, the corresponding theme alternative set will necessarily be a singleton containing only that theme. If we further assume that (intermediate phrase) L and H boundaries are indistinguishable from the null tone and may therefore be postulated anywhere there is no tone, then such invisible boundaries can act as an edge of an unmarked theme.

Such a tactic nondeterministically allows multiple derivations. It follows from this analysis that utterances with unmarked themes are typically ambiguous with respect to derivation and information structure, since there are several ways of splitting them up into a theme and a rheme. For example:[35]

[34] See note 8 concerning the realization of null tone and the possibility of secondary accents.

[35] As noted earlier in reference to Fougeron and Keating 1997, we should not exclude the possibility that this nondeterminism is in fact eliminated by subtle metrical effects distinguishing between L and the null tone, and in fact one such effect is discussed below. However, it is safest to assume the worst, and in practice it is likely that such boundaries will

(74) I read a book about COMPLETENESS



The representation of theme and rheme in the interpretation is exactly as in the earlier examples.[36] As in earlier papers, I assume that as far as the processor goes, the non-determinism induced by unmarked themes can be eliminated by taking advantage of the fact that they are exclusively used when the hearer can be assumed to already *know* the theme. (Straub (1997) gives experimental evidence for the systematic omission of explicit prosodic boundaries by speakers when alternative sources of disambiguating information, including contextual ones, are present.) Thus, a processor can determine whether a boundary should be postulated after a constituent bearing null tone by checking whether the discourse model supports or will accommodate the presupposition that the theme is the corresponding singleton set.

The same process of comparing the presuppositions of potential themes to the actual theme and rheme alternative sets made available by (or accommodatable within) the contextual model also offers a means for a processor to similarly disambiguate the results of perceptual confusions between H* and L+H*, L* and L*+H, and so on. For the same reason, the present theory is relatively independent of the precise inventory of tones.[37]

The ambiguity of unmarked theme boundaries is further constrained by the grammar itself. That is, the following do not appear to be possible information structures, because, like the related marked examples (71), they are not acceptable syntactic structures.

(75) a. *(Three mathematicians)$_{Theme}$ (in ten derive a LEMMA)$_{Rheme}$
b. *(Seymour prefers the nuts)$_{Theme}$ (and bolts APPROACH)$_{Rheme}$
c. *(They only asked whether I knew the woman who chaired)$_{Theme}$ (the ZONING board)$_{Rheme}$

Again, no stipulation of a Sense Unit Condition is necessary.

in general remain highly ambiguous.

[36]In Steedman 1991a, this process was compiled into a single step, in effect nondeterministically turning constituents marked η into ones marked φ, with appropriately modified interpretation. However, this missed a generalization concerning the relation of these unmarked themes to the corresponding marked variety.

Since such phonetically elided boundaries can be postulated anywhere null tone occurs, any given theme such as the one analyzed in (67) may have alternative analyses made up of a number of marked and unmarked fragments. These alternative derivations will be semantically equivalent, under the argument of section 3.4, and can be ignored for present purposes. However, there inclusion is essential in order to permit examples like the following:

(i) Marcel PROVED COMPLETENESS and CONJECTURED SOUNDNESS
L L+H* LH

Evidence for the analysis is provided by the fact that in this case the Rhythm Rule does not appear to apply to *Marcel*.

[37]For example, the theory would still rule out many impossible combinations of contexts and intonation contours if it were discovered that all finer distinctions within the H* and L* families were illusory, and that both H* and L* were entirely ambiguous between marking theme and rheme.

If undetectable boundaries can be postulated at the right-hand end of an unmarked theme, then they must also be allowed in other positions where there is no tone—for example at the right-hand end of an utterance-initial rheme followed by an unmarked theme, as in the following answer to the question *Who proved completeness?*:[38]

(76) (MARCEL) (proved completeness) .
H* L LL%

Again, this possibility introduces a non-determinism: again it only arises in contexts where the theme in question is entirely given, or background, and hence is recoverable by the hearer.

However, intonational-phrase-final null tone cannot invariably be assumed to be an unmarked theme. It may just be background information in the rheme. To take an example from Ladd (1980), provided that once one has drawn attention to the referent of the focused expression, the rest of the information is self-evident and hence in present terms background, the following all-rheme utterance will be appropriate:[39]

(77) Your TROUSERS are on fire!
H* LL%

6 Conclusion

According to the combinatory theory of grammar presented above, intonation structure and surface structure are simply different aspects of the same derivational structure. The Sense Unit Condition on intonational phrases follows immediately: the set of possible intonational phrases is identical to the set of possible CCG derivational constituents, whose compositional semantics guarantees them to be identical to the set of sense units. The contours in (2) that motivated the Sense Unit Condition are thereby excluded without stipulation.[40]

To identify surface structure and intonation structure this closely is to attribute a richer structural representation to the latter than has been assumed by Selkirk and others, since it includes constituent boundaries that do not necessarily have a phonetic realization. Postulating more surface-/intonation-structural boundaries than are marked by instrumentally attested prosodic

[38]The prosodic annotation of this example represents a minor departure from Pierrehumbert's theory, which does not permit boundaries without corresponding pitch accents, and which would regard the whole tune as a single H* LL% intonational phrase. The present analysis is quite close to one proposed in a different notation by Bing (1979). A similar analysis in terms of an "invisible" H intermediate phrase boundary seems to be required to explain the similarly nondeterministic boundary between theme and rheme in the "hat" or "bridge" topic-focus contour discussed for Dutch by Terken (1984), and for German by Büring (1995, 1997), Féry (1993), and Mayer (1995).

[39]In contrast to Germanic languages, Romance language generally do not allow this sort of noncontrastive nonfinal stress on the rheme (see Ladd 1996 and Zubizarreta 1998 for discussion).

[40]The only departure the predictions of the present theory make from those of Selkirk's (1984:290–296) specification of the constraint in terms of headedness concerns the possibility of making argument and complement clusters into intonational phrases. Although Selkirk's definition excludes examples like the following, they do in fact appear to be allowed:

(ii) Q: I know what you SOLD to Mary. But what did you GIVE to Mary?
A: (I GAVE) (the BOOK to Mary.)
L+H*LH% H* LL%

Such examples are predicted under the present theory and are discussed further in Steedman 1991a:288.

events has been criticized by Ladd (1996) and Croft (1995). However, all that this aspect of the theory tells us is that (quite unremarkably, given the profusion of ambiguity elsewhere in Universal Grammar) structural boundaries are no more explicitly marked by tones than they are by words.

Once that fact of life is appreciated, it becomes clear that many of the "end-based" effects of syntax upon phonology argued for by Selkirk (1986, 1990), Selkirk and Shen (1990), Hirst (1993), Truckenbrodt (1995, 1999), and Zubizarreta (1998), according to which in any given language, intonation-structural boundaries coincide with either left- or right- edges of specified types of syntactic constituents, but not both, can be seen as artifacts of the syntactic theories within which they have been framed. For instance, English appears to be a right end-parameter language because a traditional right-branching account of its surface structure does not afford phonologists enough right parentheses.[41]

The claim of the present theory is simply that those right parentheses are surface-syntactic boundaries, arising from left-branching structures like (57). It is unnecessary under this interpretation of surface structure to postulate an additional independent prosodic structure, as do Selkirk (1984), and Nespor and Vogel (1986) (see also Vogel and Kenesei 1990; Zec and Inkelas 1990). The freer notion of surface structure engendered by the present theory may also explain some of the examples that Bolinger (1989) used to argue for an entirely autonomous, lexically oriented account of accent assignment, and that Gussenhoven (1983) has used to argue for a similarly autonomous focus-based account. It may also allow us to eliminate some of the nonsyntactic string-based rules and "performance structures" that Cooper and Paccia-Cooper (1980), Gee and Grosjean (1983), and Croft (1995) have proposed to add to the syntax-driven model.

If intonation structure boundaries and surface syntactic boundaries coincide in this way, then there are a number of specifically prosodic effects in English and other languages that might be expected to be explicable in terms of the surface structures afforded by CCG in as direct a manner as English intonation contour, all of which would then be brought under the heading of "superficial" syntactic constraints on prosody called for by Pullum and Zwicky (1988). Some obvious candidates were mentioned at the start of the article, including the English Rhythm Rule (Selkirk 1981, 1984, Ladd 1986), whose domain (as we have seen in passing at a number of points above) can be defined in terms of the combined syntactic and prosodic phrases of CCG, as exhibited by its contrasting effects on the word *Marcel* in (4) and (5).

Whereas the role of derivation in CCG resembles that of surface structure in more standard theories, its status is somewhat different from that of the related concepts in GB and its antecedents such as the "annotated surface structures" used in Chomsky 1970 and Jackendoff 1972, as can be seen by viewing the architecture of the present theory of grammar in terms of the traditional "T" or "Y" diagram of figure 2. The figure includes an example of an object characteristic of each module for the answer in (5).

[41]The question of how readily CCG generalizes to the more parametrically diverse languages discussed by these authors, and in particular to languages that use morphological markers of information structure rather than intonational ones, goes beyond the scope of this article. However Hoffman (1995a,b), 1996, 1998), Komagata (1998), and Baldridge

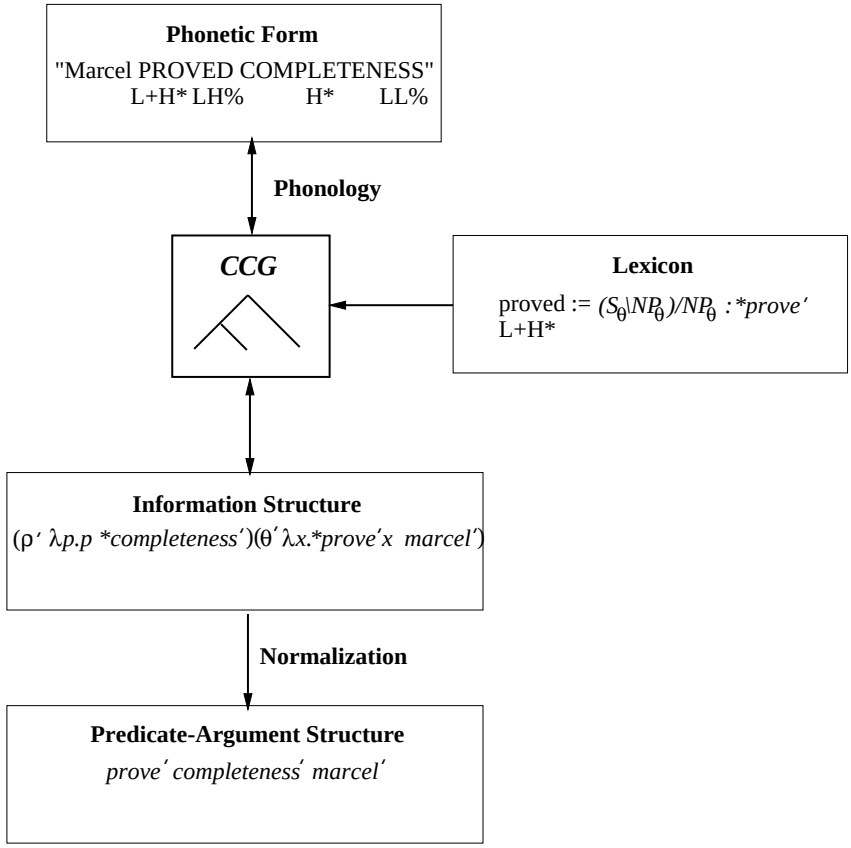


Figure 2
Architecture of a CCG theory of Prosody

The lexicon associates category-interpretation pairs with (the phonological specification of) each word of the language. Derived objects or surface-structural constituents also pair (the phonological specification of) strings with category-interpretation pairs, which are projected in parallel from (ordered multisets of) lexical entries, via derivations using combinatory rules. Both in the case of lexical items and in the case of derived constituents, the category is, strictly speaking, redundant, since it is entirely predictable from (a) the type of the interpretation, (b) X-bar theory, (c) a parametric description of the language defining position of heads, and so on. Each object in a derivation can therefore be thought of as directly pairing a phonological representation (which provides the input to "late" phonological rules relating to the metrical grid of Liberman and Prince (1977), Prince (1983), and Hayes (1995, such as the Rhythm Rule) with a single

(1998) offer CCG analyses for the grammar and information structure of Turkish, Japanese, and Tagalog.

representation related to the corresponding logical form (providing the input to systems like inference and reference). This theory can therefore, like other Montagovian categorial approaches, be viewed as in harmony with Chomsky's (1995) program, many of whose principles can then be seen in categorial terms as concerning the nature of logical form and the notion "possible lexicon," rather than syntax as such.

The interpretation that the derivation associates with a constituent of category S (or any other derived constituent) is a "structured meaning" that directly reflects such information-structural distinctions as those between theme and rheme, and focus and ground, and the units that affect the context via the process of update, including what have been described as "discontinuous" themes and rhemes, which we saw can be modeled using the Alternative Semantics of Rooth (1985, 1992) and others. (Speaker and hearer modalities are omitted from the figure, for simplicity.)

As in earlier versions of this theory, neither the derivational form of surface structure nor the information structure that it yields preserves traditional notions of dominance and command, including c-command. Relations of dominance and command are instead represented in the canonical predicate-argument structure that results from the trivial procedure of normalizing or "β-reducing" the alternative structured meanings yielded by the alternative derivations of a given proposition via functional application, as discussed in connection with examples (57) and (58), and as implicitly assumed in derivations throughout the article. It follows that c-command should be redefined as lf-command, since all grammatical relations that depend upon it, notably including binding and control, quantifier scope, and such related phenomena as crossover, must be treated as properties of interpretations or logical forms, rather than of surface structures, a suggestion consistent with the observations of Bach and Partee (1980) and Lasnik and Saito (1992).[42] Since normalization can be carried out at each step in a derivation (and would be automatic in certain unification-based alternatives to the λ calculus for representing interpretations, such as the one used in Steedman 1990), information structure is the only explicit level of representation in this theory of grammar, and is the defining level of logical form, as tentatively proposed in different terms by Zubizarreta (1998:165, n.31).

In contrast to information structure, derivation or surface structure does not constitute a level of representation as such. Although the combinatory derivations that map phonological strings onto such category-interpretation pairs (and vice versa) can be represented as trees, no rule or relation of grammar is ever predicated over such structures. Rules are strictly syntactically type-driven, and the trees are merely a history or record of how an algorithm might get from the string to the interpretation (or vice versa).

Such derivations or surface structures correspond to intonation structure in the extended sense of the term defined above, but also capture coordinate structure and the effects of relativization (Steedman 1996). In the present theory, therefore, surface structure subsumes some functions of S-Structure, and all those of Intonational Structure, together with some of the role

[42] Although in present terms, interpretations are represented as logical forms, nothing in the present account precludes a purely model-theoretic account of binding and control of the kind proposed by Bach, Dowty, Jacobson, and others.

of PF as these components are understood in GB, and as shown in figure 1. The remainder of the functions of S-Structure, as well as those of D-structure, revert to logical form. The latter—either in its unreduced information-structural form representing theme and rheme, or its normalized quantified predicate-argument structural form—is the only true structural level of representation. Phonetic form is in present terms no more than an abstract specification of the speech waveform, derived from a surface string of words and tones via purely phonological rules.

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