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Abstract

This paper proposes a theory relating syntax, semantics, and intonational prosody, and covering a wide range of English intonational tunes and their semantic interpretation in terms of focus and information structure. The theory is based on a version of combinatory categorial grammar which directly pairs phonological and logical forms without intermediary representational levels.

Keywords

Intonation, Syntax, Information Structures, Focus, Categorical Grammar

Comments

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**Information Structure and
the Syntax-Phonology Interface**

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Information Structure and the Syntax-Phonology Interface*

Mark Steedman

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The paper proposes a theory relating syntax, semantics, and intonational prosody, and covering a wide range of English intonational tunes and their semantic interpretation in terms of focus and information structure. The theory is based on a version of combinatory categorial grammar which directly pairs phonological and logical forms without intermediary representational levels.

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1 Introduction.

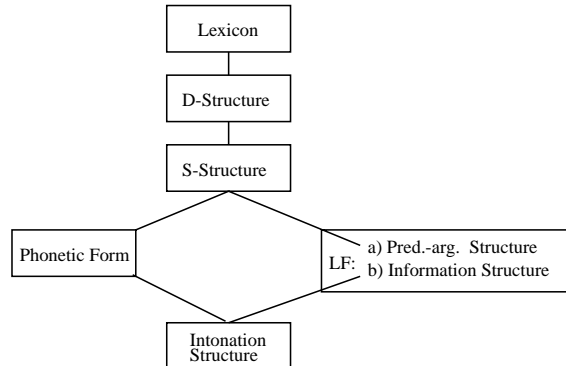
Phrasal intonation in English is frequently orthogonal to traditional notions of surface syntactic structure. For example, the subject and transitive verb may form an intonational phrase, at odds with the traditional subject-predicate structure, in a simple transitive sentence such as the following:

- (1) Anna married Manny.

This fact presents a problem for any theory of grammar.

Selkirk's 1984 proposal to incorporate phrasal phonology in a then-standard GB framework gives rise to a theoretical architecture that can be summarized in the 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 Intonation

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**Figure 1**

Architecture of a GB Prosody

Structure is to define those aspects of LF that relate to discourse information structure— that is to relations such as theme (or topic), rheme (or comment), and focus (or contrast).

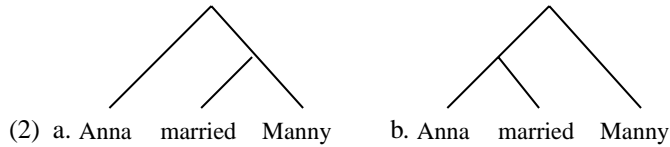
It would be in keeping with other recent developments in generative grammar to reduce the number of modules in the theory, either by eliminating some of them entirely, as Chomsky 1995 has proposed, or (equivalently) by unifying one with another. The present paper shows how the levels of S-structure, and Intonation 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 that 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 structural and predicate-argument structural aspects of a logical form.

2 The Claim

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

¹PF plays a rather different role in GB theory 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 which is more in keeping with its actual role.

²Wood 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, Moortgat 1988 and Morrill 1994 explicitly relate Lambek-style categorial grammars to prosody.



More complex sentences like *Harry says that Anna married Manny* 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 are either 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 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 which Chomsky (1957, Ch. 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 recent 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 1996b and below).

In earlier work, I have tried to show that the intonational structure of English, essentially as described by Pierrehumbert 1980, Selkirk 1984, and others, is directly subsumed by surface syntactic structure, as it is viewed in CCG (Steedman 1991a). The interpretations which the grammar assigns compositionally to these non-standard surface derivations directly correspond to information structure in Selkirk's sense of the term. The present paper presents a new version of this theory, covering a wider inventory of prosodic tunes and information categories, building on work by Scott Prevost (Prevost and Steedman 1994, Prevost 1995), and by Kirkeby-Garstad and Polgardi 1992, 1994.

The claim is that surface structure and information structure entirely coincide, the latter being simply the interpretation of the former. Intonation in turn coincides with surface structure (and hence information structure) to the extent that all intonational boundaries coincide with syntactic boundaries, a position which is to some extent implicit in more recent work by Selkirk (cf. 1990, p.195).

Of course, the reverse does not follow. Not all surface syntactic boundaries are explicitly marked by intonational boundaries. Pierrehumbert, at least, 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 prosody. 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 syntactic structure has to be inferred from the sequence of words.³

3 Intonation and 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, Pierrehumbert and Beckman 1989, and Pierrehumbert and Hirschberg 1990, is particularly helpful in defining intonational tunes entirely in terms of two components, the *pitch accent(s)* and the *boundary*. The first of these tones are realised as maxima or minima in the pitch contour, and coincide with the perceived major stress or stresses of the prosodic phrase, while the second marks the righthand boundary of the phrase. These two components are essentially invariant, and all other parts of the pitch contour can be determined by interpolation. The advantage for present purposes is to capture formally the fact that the same tune can be spread over longer or shorter strings, in order to mark the corresponding constituents for the particular distinction of discourse information-type and/or propositional attitude that the melody denotes. Pierrehumbert and Hirschberg 1990 provide a helpful introduction to this notation.

Consider the prosody of the sentence *Mary likes musicals* in the following pair of discourse settings, adapted from Jackendoff 1972, pp. 260 and the earlier papers. To aid the exposition, words bearing nuclear pitch accents are printed in capitals, and prosodic phrase boundaries are explicitly marked in the sentences, using brackets. (These devices are not part of the formal notation.)

(3) Q: Well, what about MUSICALS? Who likes THEM?

A: (MARY) (likes MUSICALS).
 H* L L+H* LH%

(4) Q: Well, what about MARY? What does SHE like?

A: (MARY likes) (MUSICALS).
 L+H* LH% H* LL%

In these contexts, the main stressed syllables on both *Mary* and *musicals* may receive a pitch accent, but a different one. In the answer A of the former example, 3, there is a prosodic phrase on *Mary* made up of the sharply rising pitch accent which 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 less rapidly rising pitch-accent called L+H* on *musicals*, preceded by null tone (and therefore interpolated low pitch) on the word *likes*, and immediately followed by a rising "continuation" boundary, written LH%. (See Pierrehumbert and Hirschberg's 1990, ex. 33 discussion of a similar example.)⁴ In the answer A of the second example 4 above, the

³More specifically, the reason that English intonational tunes can be viewed as a regular language has to do with the fact that English is in the terms of Selkirk 1986, 1990, a "right end parameter" language, which marks the right hand end of structural units but not the left hand end. That is to say that the structures underlying intonational tunes are at least context-free, and there is only "weak equivalence" to a regular language over the tones.

⁴For the moment, the distinction between the intonational phrase proper, and what Pierrehumbert and her colleagues

two tunes are reversed: this time the tune with pitch accent L+H* and boundary LH% is spread across a prosodic phrase *Mary likes*, while the other tune with pitch accent H* and boundary LL% is carried by the prosodic phrase *musicals*.⁵

The intuition that there is some systematic distinction in meaning between these tunes seems to be very compelling, though it has in the past proved hard to formalize. The tunes have variously been associated with social attitude (O'Connor and Arnold 1961; Merin 1983), illocutionary acts (Lieberman and Sag 1974, Sag and Lieberman 1975, Lieberman 1975), propositional attitudes (Ward and Hirschberg 1985), maintenance of mutual belief (Pierrehumbert and Hirschberg 1990), and information structure (Halliday 1967, Jackendoff 1972, Ladd 1980, Gussenhoven 1983, Selkirk 1984, Rochemont 1986, Steedman 1991a, 1991b).

The present paper concentrates on certain aspects of intonation that are primarily to do with information structure, in the sense of that term proposed by Vallduvi 1990, and Steedman 1991a, although these proposals differ in detail—see Vallduvi and Engdahl 1996 for a survey. These theories follow Halliday 1967, 1970 in assuming that there are two independent dimensions to information structure that are relevant to intonation. The first corresponds to the traditional contrast between the theme or topic of an utterance, and the rheme or comment that the utterance makes about the theme. In English, we will see that this dimension of information structure determines the overall shape of the intonational tune or tunes imposed upon an utterance. The second dimension is one of focus. In English, this dimension is reflected in the position of pitch accents. 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 (see Pierrehumbert and Hirschberg 1990, p.288-289). This section of the paper considers these two dimensions and their place in a grammar for the full range of tunes identified by Pierrehumbert.

3.1 *Theme and Rheme*

The L+H* LH% tune seems (at least in the contexts discussed so far) to bear a close relation to the traditional notion of topic, which in order to avoid confusion with a number of other uses of that term I will refer as the *theme* of an utterance.⁶ This choice of term is merely chosen to be mnemonic of the fact that when this tune is present, it seems to mark some or all of that part of the sentence corresponding in some sense to what the speaker believes to be the matter of mutual interest that the utterance bears upon. I do not assume any prior definition of the term, which will be defined more formally below in terms of both the “structured meanings” approach of Cresswell 1973 and others and the “alternatives semantics” of Rooth 1985 and others.

The H*L and H*LL% tunes, in contrast, seem to be used to mark some or all of that part of the sentence expressing information that the speaker believes to be what the hearer needs to know about the theme or matter of mutual interest. This notion corresponds to that of comment

call the “intermediate” phrase is ignored. These categories differ in respect of boundary tone-sequences.

⁵The reason for notating the latter boundary as LL%, rather than L is again to do with the distinction between intonational and intermediate phrases.

⁶Cf. Steedman 1991a, p.275, and 1991b, p.28. The terms theme and rheme are taken from Halliday 1967, 1970, although I follow Lyons 1977 and Bolinger 1989 in dropping Halliday's requirement that the theme be utterance-initial. In fact we leave open the possibility that an utterance might involve more than one theme.

or *rheme* of an utterance. Again no prior definition of the term is assumed, and a formal definition is provided below.

Jackendoff 1972 seems to have been the first to suggest that themes in utterances like 4 should be characterized semantically via functional *abstraction*, using the notation of the λ -calculus, as in the following example:⁷

$$(5) \lambda x. \text{like}'x \text{mary}'$$

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 Mary's liking them. When the above concept is supplied with an argument in the form of the rheme, *musicals'*, it therefore *reduces* to give a proposition, with the same predicate-argument relations as the canonical sentence:

$$(6) \text{like}'\text{musicals}'\text{mary}'$$

As in the related “structured meanings” approach to the notion of presupposition of Cresswell 1973 and others, it is the presence in the context of the abstract proposition in 5 that makes the intonation contour in 4 felicitous.⁸ In the case of this example, it is clear that this abstract proposition is explicitly introduced into the context by the *wh*-question Q. In fact we will see later that it gets there by virtue of itself constituting the rheme of that question. That is not to say that the question uniquely *determines* this response, nor that its explicit mention is necessary for interpreting the response. (We will see 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: exchanging the answers to the questions in examples 3 and 4 yields complete incoherence.

The λ -abstraction operator is closely related to the existential quantifier \exists . It is therefore also natural to associate the notion of theme with a set of propositions among those supported by the conversational context which could possibly instantiate the corresponding existentially quantified proposition. In the case of the exchange in 4, the existential in question is the following, in which \diamond indicates possibility:

$$(7) \exists x. \diamond \text{like}'x \text{mary}'$$

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

$$(8) \left\{ \begin{array}{l} \diamond \text{like}'\text{jazz}'\text{mary}' \\ \diamond \text{like}'\text{opera}'\text{mary}' \\ \diamond \text{like}'\text{musicals}'\text{mary}' \end{array} \right\}$$

(I am simplifying by assuming that these propositions are represented as predicate-argument structures, rather than something more extensional, because the way such a set is obtained need

⁷Juxtaposition of terms AB indicates the application of a function A to an argument B , and application “associates to the left” —that is, the formula $\text{like}'x \text{mary}'$ is equivalent to $(\text{like}'x)\text{mary}'$. Primes indicate constants, denoting semantic interpretations whose detailed nature is of no direct concern here.

⁸Such abstractions are also related to Sperber and Wilson 1982 and Prince 1986 have called the “open proposition” of an utterance.

3.2 Focus and Background

The position of the pitch accent(s) in the phrase has to do with a further dimension of information structure *within both theme and rheme*, corresponding to a distinction between *the informative or contrastive part(s)* of either information unit, and the rest. (In the case of the unmarked themes just discussed, the absence of a pitch accent means that the theme does not contrast with any earlier one.) Halliday 1967, who was probably the first to identify the orthogonal nature of these two dimensions, called it “new” information, in contrast to “given” information, (cf. Brown 1983). 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, as is the case for the examples to hand. 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.⁹

The following example serves to illustrate the full range of possibilities for the distribution of focus and background within the theme and the rheme.

(12) Q: I know that Mary envies the man who wrote the musical.

But who does she LIKE?

A:	(Mary	LIKES)	(the woman who	DIRECTED	the musical)
	L + H* LH%			H*	LL%
	Background	Focus	Background	Focus	Background
	Theme		Rheme		

Here the theme is something that I will call *Mary likes*, as an informal shorthand referring to the translation of that part of the utterance as the abstract proposition $\lambda x.likes'x mary'$. Only the word *likes* is emphasized, because the previous theme was also about Mary. The alternatives set is therefore a set of propositions about Mary liking various people. The rheme is *the woman who directed the musical*, where only the word *directed* is contrasted.

It is important to note that it is *all and only* the material marked by the pitch accent(s) that is contrasted. This applies when there is more than one pitch accent, as can be verified by observing the effect of adding a further pitch accent on the word *musical*. Anything not so marked, including the material between the pitch accent(s) and the boundary, is background. Examples like this suggest that the focusing property of pitch accents applies at the level of *words* and their interpretations, not at the level of larger constituents, unlike the theme/rheme

⁹It is important to know that the term “focus” 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, and Vallduvi 1990, who in different ways confine the use of the term focus to the rheme. Still other authors, notably Selkirk 1984, Rooth 1985, 1992, Jacobs 1991, and Krifka 1992, invoke “two levels” of focus, using the term to cover both comment/rheme *and* phonological focus. In the present paper, the term focus is only used in the narrow phonological sense.

distinction.

However, there is an asymmetry between the “prenuclear” background material *the woman who . . .* that precedes the pitch accent on *directed*, and that which succeeds it (*the musical*). The fact that there is no pitch accent on the latter seems to demand that all individuals in the context have the property of having something to do with this particular musical. It would actually be wrong in this context to have a pitch accent. However, the lack of accent on the former does not seem similarly to demand that all the individuals that we are restricting over are women, and in fact in the example they are not. The implication is that in this context, the property of directing the musical is sufficient to distinguish the individual uniquely—the fact that this individual is *also* unique by virtue of being a woman need not be marked.¹⁰

In the light of these observations we can extend the account of the semantics of theme and rheme sketched earlier, as follows.

The significance of the presence or absence of pitch accents within a theme like *MARY likes* in the initial example 4 seems to lie in the existence or accommodatability of a prior theme identical to the new one except for the replacement in its translation of elements corresponding to accented items like *MARY* by variables compatible with other items. (If the theme is unmarked, lacking any pitch accents, as in certain common cases discussed below, then the pre-existing or accommodatable theme must be identical to the new one.) We might therefore mark the presence of pitch accents in the translation itself, distinguishing the corresponding constant *mary'* with an asterisk

$$(13) \lambda x. \textit{like}'x *mary'$$

(Of course, the idea that the only semantic contribution of the various pitch accents is a single undifferentiated marking of focus or contrast is an oversimplification, to which we will return in section 3.3.) Unless a compatible prior theme—that is, one which will unify with the above expression when **mary'* is replaced by a variable—can be retrieved or accommodated, the utterance is simply infelicitous, and the analysis will fail at this point.

In the absence of such infelicity, the old theme is then removed from the context and the new theme is added, in a process that I will refer to as “update.”¹¹ The effect of the update is much like that of Jacobs’ (1991) and Krifka’s (1992, p.4) *ASSERT* operation over structured meanings. The new theme can also be used as before to generate the related alternatives set 8.

3.3 *The Generalization to Other Intonational Tunes*

The claim that the L+H* LH% tune marks the theme is implicit in the accounts of Jackendoff 1972, Ladd 1980, and others, but it remains controversial. Pierrehumbert and Hirschberg propose a compositional semantics for intonational tunes that is based on scalar dimensions of propositional attitude such as certainty concerning relevance and degree of commitment to belief revision (Pierrehumbert and Hirschberg 1990, p.294-297). According to their account, the L+H*

¹⁰The difference between pre- and post- nuclear material is underlined by the fact that it is also possible to have an H* pitch accent on *woman* in this example—unlike *musical*.

¹¹See Veltman 1983, Heim 1983, Landman 1986, Groenendijk and Stokhof 1990 and Steedman 1997 for discussion of various “dynamic” logics which can be used to formalize the notion of updates and side-effects.

pitch accent is used “to convey that the accented item – and not some alternative related item – should be mutually believed” (p.296).

As an example, they discuss the following dialogue, adapted from Jackendoff 1972, p.258-265, and also discussed by Ladd 1980, 157-159 and Steedman 1991a, which is isomorphic to example 3 above:

(14) Q: What about the beans? Who ate THEM?

A: FRED ate the BEANS.
 H* L L+H*LH%

In support of their claim that the L+H* pitch accent evokes a set of alternatives besides the accented item, they correctly observe that the utterance implicates the possibility that other people may have eaten other things. However, this particular alternatives set has already been introduced into the context by the question, and in the absence of such a question (or some other utterance establishing a context that supports or can accommodate this theme), the intonation contour is inappropriate. The example therefore does not exclude the possibility that the L+H* LH% tune evokes this set of alternatives by marking a part of the theme in the sense defined here.

The following minimal pair of dialogues will be helpful in deciding between these claims, since it appears at first glance to raise problems for both:

(15) Q: Does Mary love opera?

A: Mary likes MUSICALS.
 H* LL%

(16) Q: Does Mary love opera?

A: Mary 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 concerns a proposition that is not among those alternatives.

In the first example, the entire 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 liking musicals entails hating opera, then this response implicates denial. If on the other hand liking musicals entails loving opera, then affirmation is implicated. Either way, the speaker’s intonation only commits them to the claim that their utterance is a rheme—that is, that it restricts the set of alternatives established by the question to just one—rather than to a particular change in belief.

The second example is of a kind discussed by Jackendoff 1972, p.264-5, Liberman and Sag 1974, and Ladd 1980, p.146-8, and might appear at first glance to be almost equivalent. 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 restrict the set of alternatives sufficiently.

However, it is also possible to believe that the entire answer A in example 16 is in fact a theme, and that what the respondent has actually done is to offer a new theme or set of alternatives, replacing the one established by the question, without stating a rheme at all. On this view, the lack of commitment to whether the utterance restricts the alternatives 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 of the inference that might be drawn. But that would not be a matter of literal or conventional meaning of the utterance itself.

This is essentially the analysis proposed by Ladd 1980, p152-6 who relates all uses of “fall-rise” contours including this one to the function of evoking a set of alternatives established by the preceding context—a notion which I have identified with the notion of theme, and which I have interpreted above in terms of the alternatives semantics of Karttunen and Peters 1979 and Rooth 1985. It is also consistent with the related analysis of intonational tunes by Büring 1995, p.51.

In the case of the answer A in 16 the new theme is simply the following:

(17) $\diamond(\textit{like}'\textit{musicals}'\textit{mary}')$

The corresponding alternatives set is therefore a singleton:

(18) $\{ \diamond(\textit{like}'\textit{musicals}'\textit{mary}') \}$

Since this set contains only one member, it also entails an answer to the question—but that is a matter of implicature rather than what has actually been said.

Example 16 is closely related to an example discussed by Ward and Hirschberg 1985, who notate it with an L*+H pitch accent (which Ladd subsumes under fall-rise, and does not distinguish from L+H* LH%).

(19) A: Harry’s such a klutz.

B: He’s a good BADMINTON player.
 L*+H LH%

(See Pierrehumbert and Hirschberg 1990, p.295, ex. 26, Prince 1986).

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, it is also unclear that *degree* of clumsiness is at issue in this example, rather than the all-or-none property of clumsiness. Ward and Hirschberg’s example 19 is also consistent with an implicature along the same lines as 16, in which B’s response acts as a theme establishing a set of alternatives such as the following, the single member of which entails denial.

(20) $\{ \diamond(\textit{good}'\textit{player}'\textit{harry}') \}$

Under this analysis, any implicature of uncertainty about the relevance of the information would result from the fact that for reasons of indirection, the speaker has left the rheme unsaid, rather than from literal or conventional meaning.

be merely to mark question illocution. Nor does it mark “ceding the turn” to the other speaker, since examples like the following (again adapted from Pierrehumbert and Hirschberg, section 7) can be uttered with LH% boundaries at the end of every sentence except the last:

- (25) Attach the jumper cables to the car that’s running.LH% Attach them to the car you want to start.LH% Try the ignition.LH% If you’re lucky...LH% You’ve started your car.LL%

All of the uses that we have encountered here, including the use in questions and in monologue, are consistent with Pierrehumbert and Hirschberg’s claim (pp.304-8) that LH% (and all other boundaries ending in H including HH%) mark discourse units as *to be interpreted with respect to a succeeding phrase* (from either speaker—cf. Brown 1983), whereas LL% (and all boundaries ending in L including HL%) do not.

This observation seems to generalize across the remaining pitch accent tones in Pierrehumbert’s system. For example, in the following, adapted from Hobbs 1990, pp.313-323 (cf. Merin and Bartels 1997), L* appears to function rather similarly to H* in marking a rheme, and seems to involve the same effect of LH%:

- (26) It’s not a FREUDIAN account. It’s a COGNITIVE one.
L* LH% H* LL%

In particular, L* seems to restrict the alternatives set in a similar way to H*, from which it seems to differ mainly in terms of whether the restriction is to do with denial or affirmation. This property suggests that in English questions like 27 (from Pierrehumbert and Hirschberg’s ex. 16), L* seems to carry the same presupposition of a negative that in Latin is marked by the particle *num*. (In 28, H* carries no such presupposition.)

- (27) Do PRUNES have FEET?
L* L* LH%
- (28) Do PRUNES have FEET?
H* H* LH%

More precisely, H* rhemes seem to restrict the alternatives to the one that the speaker supposes that the hearer wants, while the L* variety seem restrict to something that they may not want. While this distinction may signal affirmation vs. denial, it is also used indirectly, in polite offers of alternatives, as can be seen from the increased diffidence of the second of the following offers:

- (29) There’s ORANGE juice, and APPLE juice.
H* LH% H* LL%
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. We have already discussed the theme-accent L+H* and L*+H in terms of the degree of denial conveyed. The two remaining rheme accents H*+L and H+L* behave much like Lady Bracknell’s version of H* and L*:

- (30) JEREMY!
H*+L LH%
- (31) Do PRUNES have FEET?
H+L* H+L* LH%

3.4 The Relation of Grammar and Information Structure

What is the relation of such intonational structures to syntax and semantics, and how is information structure computed by a language understander? Many of the intonational constituents that we have just been examining—such as the string *Mary likes*—do not correspond to traditional syntactic constituents.¹²

Such “non-constituent” intonational units are very widespread, and can coincide with all of the intonational tunes considered above—for example, as a rheme in the following example (adapted from Ladd 1980 – see below), when uttered in the context of a question like *I know that Harry keeps up with the newspapers, but has he read Ulysses?*:

- (32) Harry doesn’t READ BOOKS!
H*L L+H* LH%

Here the theme seems to be *books*, marked because the concept stands in contrast to *newspapers*. The rheme seems to be *Harry doesn’t read*, with the usual final H*L tune on *read*. The theme can also be unmarked, even in this context, as in Ladd’s original example:¹³

- (33) Harry doesn’t READ books.
H* LL%

The earlier paper argued that fragments like *Mary likes* and *Harry doesn’t read* were not only prosodic constituents but syntactic constituents. The argument is briefly summarized next.

4 Combinatory Grammars.

I will assume some familiarity with Combinatory Categorical Grammar of the kind presented in Steedman 1987, 1991a, 1996b. As in other varieties of Categorical Grammar, elements like verbs are associated with a syntactic category which identifies them as *functions*, and specifies the type and directionality of their arguments and the type of their result. We here use the “result leftmost” notation in which a rightward-combining functor over a domain β into a range α are written α/β , while the corresponding leftward-combining functor is written $\alpha\backslash\beta$.¹⁴ α and β may themselves be function categories. For example, a transitive verb is a function from (object) NPs into predicates—that is, into functions from (subject) NPs into S:

- (34) likes := $(S\backslash NP)/NP$

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

¹²Jacobs 1991 and Krifka 1992, section 4.8 have pointed out the complications that ensue for the semantics of focus.

¹³There is a question about how to notate the tune of this example that I will defer for the moment.

¹⁴There is an alternative “result on top” notation due to Lambek 1958, in which the latter category is written $\beta\alpha$.

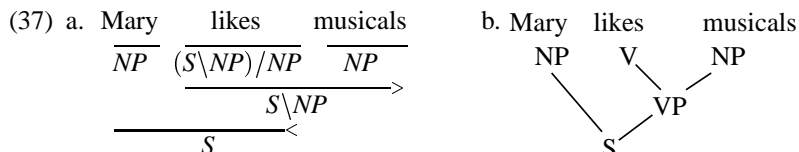
(35) *Forward Application*: ($>$)

$$X/Y \quad Y \Rightarrow X$$

(36) *Backward Application*: ($<$)

$$Y \quad X \backslash Y \Rightarrow X$$

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



The lexical categories can be augmented as in Bach 1983 with a feature system to capture phenomena like agreement, here represented informally by subscripts, and with an explicit identification of their semantic interpretation, here associated with the category via a colon operator.

(38) $\text{likes} := (S \backslash \text{NP}_{3s}) / \text{NP} : \text{like}'$

(The third person singular feature bundle written $3s$ is “underspecified” for gender and can combine with a more specific feature bundle such as $3sm$ by a standard unification mechanism that I will pass over here – cf. Shieber 1986.)

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

(39) *Forward Application*: ($>$)

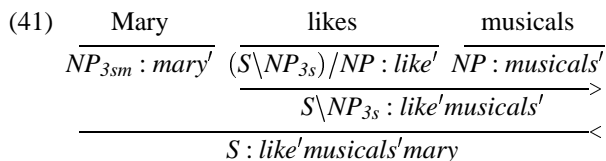
$$X/Y : f \quad Y : a \Rightarrow X : fa$$

The semantic interpretation of this and all other combinatory rules is completely determined by their syntactic form under the following principle:¹⁵

(40) *The Principle of Combinatory Transparency*: The semantic interpretation of the category resulting from a combinatory rule is completely determined by the definition of categories as functions mapping between two sets of logical forms.

That is to say 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.

Derivations can then be written as follows:



¹⁵This principle is stated differently in Steedman 1996b but is in fact identical.

The derivation yields an S with a compositional interpretation, equivalent as usual under the convention of left associativity to *(like'musicals')mary'*.

Coordination of constituents of like type to yield a single constituent of the same type is permitted by the following rule schema, whose semantics I will pass over here.

$$(42) \textit{Coordination: } (<\&>) \\ X \textit{ conj } X \Rightarrow X$$

One of the original motivations behind CCG was to account for coordination of contiguous strings that do not constitute traditional constituents, as in the following example:

$$(43) \textit{I requested and would prefer opera.}$$

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

$$(44) \textit{Forward Composition: } (>\mathbf{B}) \\ X/Y \ Y/Z \Rightarrow X/Z$$

Since *would* is $(S \setminus NP)/VP$ and *prefer* is VP/NP the rule yields the transitive verb category $(S \setminus NP)/NP$ for *would prefer* in 43.

The Principle of Combinatory Transparency means that the semantic effect of this rule is as follows, yielding an interpretation $\lambda x. \lambda y. \textit{would}'(\textit{prefer}'x)y$ for the same fragment:

$$(45) \textit{Forward Composition: } (>\mathbf{B}) \\ X/Y : f \ Y/Z : g \Rightarrow X/Z : \lambda x. f(gx)$$

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:

$$(46) \textit{Mary likes, and I dislike, musicals.}$$

$$(47) \textit{Forward Type-raising: } (>\mathbf{T}) \\ X : a \Rightarrow T/(T \setminus X) : \lambda f. f a$$

$$(48) \textit{Backward Type-raising: } (<\mathbf{T}) \\ X : a \Rightarrow T \setminus (T/X) : \lambda f. f a$$

T is a variable ranging over categories such as S , $S \setminus NP$ etc. Such rules must be restricted to application to a fixed set of categories—essentially to the types that verbs take as arguments. (This restriction is in keeping with a general resemblance between type-raising and the traditional notion of *case* – cf. Steedman 1985, 564; 1990, 221.) They have an “order-preserving” property. For example, 47 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 Combinatory Transparency 40.

Since categories like NP can be raised over a number of different functor categories, such as predicate, transitive verb, ditransitive verb etc, and since the resulting raised categories

$S \setminus (S/NP)$, $(S \setminus NP) \setminus ((S \setminus NP)/PP)$, etc. of NPs, PPs, etc. are quite hard to read, it will sometimes be convenient to abbreviate the raised categories as schemata written NP^\uparrow , PP^\uparrow , etc.

Since complement-taking verbs like *think*, VP/S , can in turn compose with fragments like *Mary likes*, S/NP , we correctly predict the fact that right-node raising is unbounded, as in a, below, and also provide the basis for an analysis of the similarly unbounded character of leftward extraction, as in b (see the earlier papers and Steedman 1996b for details, including ECP effects and various extraction asymmetries, and a variety of coordination phenomena):

- (49) a. [I dislike] $_{S/NP}$ and [you think Mary likes] $_{S/NP}$ musicals.
 b. The musicals which [you think Mary likes] $_{S/NP}$.

5 Grammar and Intonation.

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 Mary likes* to be surface constituents of type S/NP , then they must also be possible constituents of non-coordinate sentences like *Mary likes musicals*, which must permit the following derivation 50, as well as the traditional derivation 41, repeated as 51 below:

- (50)
$$\frac{\frac{\frac{\text{Mary}}{NP : mary'} \quad \frac{\text{likes}}{(S \setminus NP)/NP : like'} \quad \frac{\text{musicals}}{NP^\uparrow : musicals'}}{S/(S \setminus NP) : \lambda f.f \text{ mary}' \quad \text{>T}}}{S/NP : \lambda x.like'x \text{ mary}' \quad \text{>B}} \quad \text{>B}$$
- (51)
$$\frac{\frac{\frac{\text{Mary}}{NP : mary'} \quad \frac{\text{likes}}{(S \setminus NP)/NP : like'} \quad \frac{\text{musicals}}{NP^\uparrow : musicals'}}{S/(S \setminus NP) : \lambda f.f \text{ mary}' \quad \text{>T}}}{S \setminus NP : \lambda y.like' \text{ musicals}'y \quad \text{>}} \quad \text{>}$$

Crucially, once we simplify or “normalize” the interpretations by β -reducing λ -abstracts with arguments, as I have tacitly done throughout the derivations, both yield an identical appropriate proposition, which can be represented by the following predicate-argument structure:¹⁶

- (52) *like' musicals' mary'*

The Principle of Combinatory Transparency guarantees that all such non-standard derivations yield identical interpretations, over which such c-command-dependent relations as the Binding

¹⁶It 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 which in GB are covered by the Binding Theory can be most straightforwardly defined within the present theory – cf. Chierchia 1985, 1988, 1989. However, Szabolcsi 1989, Jacobson 1990, Hepple 1990, and Dowty 1982, 1992, discuss a number of ways of doing 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.

Conditions can be defined as in any other grammar framework. In more complex sentences than the above, there will be many such equivalent derivations for each distinct interpretation.

The interest of such derivations for present purposes will be obvious. The claim is simply that the non-standard surface structures that are induced by the combinatory grammar to explain coordination in English subsume the intonational structures that needed in order to explain the possible intonation contours for sentences of English discussed earlier. Intonational boundaries, when present as in spoken utterances like 3 and 4, determine *which* of the possible combinatory derivations such as 50 and 51 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 information, 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 markers are present, they will disambiguate in this way.

5.1 *Combinatory Prosody*

I shall follow the earlier papers in assuming that all grammatical categories include not only a syntactic type and a semantic interpretation, but also a phonological type. In all other details the present analysis departs from the earlier one. In particular, where the earlier analysis 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 present grammar uses a much simplified set of phonological types, and uses this information to directly limit the syntactic derivation (and hence information structure).

5.1.1 The Pitch Accents: I have already noted that the focus-marking property of pitch accents seems to belong at the level of the word, while the theme/rheme-marking property seems to belong at the level of phrasal constituents. Pierrehumbert’s six pitch accents can be assigned the following categories, which identify them (under the argument of section 3) as markers of theme (θ) and rheme (ρ), respectively:¹⁷

$$(53) \quad \begin{array}{ll} L+H^*, L^*+H & := \theta \\ H^*, L^*, H^*+L, H+L^* & := \rho \end{array}$$

These categories simplify considerably in omitting some further specification of distinctions within the classes θ and ρ of theme accents and rheme accents. The symbols θ and ρ should be regarded as abbreviations for more specific bundles of features-values distinguishing the individual pitch accents on dimensions such as denial and the factors identified by Pierrehumbert and Hirschberg.

I will further assume that pitch accents mark (some element of) the interpretation of the words that they occur on, using the asterisk notation introduced earlier. While eventually we will certainly want to do this by rule, for present purposes I will regard this as happening at the

¹⁷These categories differ from those in earlier papers.

level of lexical entries like the following category for the verb *likes* bearing an H* pitch accent, before they are input to syntax:¹⁸

$$(54) \quad \underset{\text{H}^*}{\text{likes}} \quad := \quad \underset{\rho}{(S \setminus NP) / NP : *like'}$$

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 the string, bears the category ϵ , which is an anonymous variable, unique to this particular occurrence of the null tone, that ranges over the theme and rheme markers θ and ρ and nothing else (although I have suppressed explicit typing of variables in the notation).¹⁹

$$(55) \quad := \quad \epsilon$$

We will further assume that all the grammatical combinatory rules 39, 45, 47 etc. include a similar phonological variable for each input and output, as in the following version of 39 in which χ is a variable unique to this rule:

$$(56) \quad \text{Forward Application: } (>) \\ X/Y : f \quad Y : a \quad \Rightarrow \quad X : fa \\ \chi \quad \quad \chi \quad \quad \quad \chi$$

Similarly, we get the following composition and type-raising rules

$$(57) \quad \text{Forward Composition: } (>\mathbf{B}) \\ X/Y : f \quad Y/Z : g \quad \Rightarrow \quad X/Z : \lambda x.f(gx) \\ \chi \quad \quad \chi \quad \quad \quad \chi$$

$$(58) \quad \text{Forward Type-raising: } (>\mathbf{T}) \\ X : a \quad \Rightarrow \quad T / (T \setminus X) : \lambda f.f a \\ \chi \quad \quad \quad \chi$$

Under the standard unification-based interpretation of these rules and in particular of the variable χ , these rules allow intonational tunes to be spread over arbitrarily large constituents.

For example, in analysing the first two words of the sentence *Mary likes the Mondrian*, the following partial derivation is allowed:

$$(59) \quad \begin{array}{ccc} \text{MARY} & \text{likes} & \text{the MONDRIAN} \\ \text{L} + \text{H}^* & & \text{LH}\% \end{array} \\ \hline \frac{S / (S \setminus NP) : \lambda p.p *mary' \quad \underset{\theta}{(S \setminus NP) / NP : \lambda x.\lambda y.likes'xy}}{\underset{\theta}{S / NP : \lambda x.likes'x *mary'}} \rightarrow \mathbf{B}$$

Since the phonological value of the null tone on *likes* is a unique anonymous variable ϵ , it can unify with χ in the second term in the composition rule 57. Since the result is still a variable, the

¹⁸In this I follow Bird 1991 and Prevost 1995.

¹⁹In the terms of the earlier autosegmental-categorial approach, this category could be realized as a very general bidirectional functor $\epsilon|e$

θ on *Mary* can also unify with the same variable χ on the first term of the rule, to yield θ . Since the same variable χ appears on the result, the entire phrase *Mary likes* is marked θ .

Iterated compositions of the same kind have the effect of allowing the theme and rheme markers associated with the pitch-accents to spread unboundedly across any sequence that forms a grammatical constituent according to the combinatory grammar. For example, if in answer to the same question *What does MARY like?* the reply is *HARRY says she likes the MONDRIAN*, then the tune will typically be spread over *Harry says she likes* as in the (incomplete) derivation 60 below, in which the semantics has been suppressed.

$$\begin{array}{ccccccc}
 (60) & \text{HARRY} & \text{says} & \text{she} & \text{likes} & \text{the MONDRIAN} & \\
 & \underline{\text{L+H}^*} & & & & & \text{LH\%} \\
 & \frac{S/(S\backslash NP)}{\theta} & \frac{(S\backslash NP)/S}{\varepsilon} & \frac{S/(S\backslash NP)}{\varepsilon} & \frac{(S\backslash NP)/NP}{\varepsilon} & & \\
 & \frac{S/S}{\theta} & & & & & \\
 & \frac{S/(S\backslash NP)}{\theta} & & & & & \\
 & \frac{S/NP}{\theta} & & & & & \\
 \end{array}$$

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:

$$\begin{array}{ccccccc}
 (61) & \text{HARRY} & \text{SAYS} & \text{she} & \text{likes} & \text{the MONDRIAN} & \\
 & \underline{\text{L+H}^*} & \underline{\text{!L+H}^*} & & & & \text{LH\%} \\
 & \frac{S/(S\backslash NP)}{\theta} & \frac{(S\backslash NP)/S}{\theta} & \frac{S/(S\backslash NP)}{\varepsilon} & \frac{(S\backslash NP)/NP}{\varepsilon} & & \\
 & \frac{S/S}{\theta} & & & & & \\
 & \frac{S/(S\backslash NP)}{\theta} & & & & & \\
 & \frac{S/NP}{\theta} & & & & & \\
 \end{array}$$

As in Pierrehumbert's original system, the phonological category of the pitch accent is unaffected by downstep, and its specification in the example is strictly 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.²⁰

²⁰Other 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.

5.1.2 *The Boundaries:* The phonological categories of the boundaries can be written as follows.²¹

$$(62) \quad L, H, LL\%, LH\%, HH\%, HL\% \quad := \quad S\$ \backslash S\$: \lambda f. \text{update} \epsilon f \\ \phi \backslash \epsilon$$

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 include a grammatical category (written on top, as usual) and a phonological category (written below).²²

The phonological category $\phi \backslash \epsilon$ has the form of a function from the pitch accent categories θ and ρ over which the variable ϵ ranges into ϕ the type of phonological phrases of all kinds. As in the case of the pitch-accents, I am simplifying in omitting some further specification in the semantics of the “looking forward” and “looking back” effect of the boundaries, discussed by Pierrehumbert and Hirschberg and above. The result ϕ represents a bundle of feature-values distinguishing these meanings, like those represented by the arguments θ and ρ , some of whose components (such as the denial associated with L^* accents) may be inherited by ϕ .

This category cannot combine by the standard combinatory rules 56, 57 and 58. Instead we need a special Boundary Application rule, as follows:

$$(63) \quad \textit{Boundary Application:} (<\%) \\ Y : a \quad X \backslash Y : f \quad \Rightarrow \quad X : fa \\ \epsilon \quad \phi \backslash \epsilon \quad \phi$$

This rule is annotated as $<\%$ in derivations because it is grammatically a backward rule of application, restricted to categories bearing the boundary category. The phonological variable ϵ in this rule schematizes over the two pitch accent categories, and over the null tone itself, and nothing else. In particular, ϵ does not unify with ϕ or $\phi \backslash \epsilon$.

The boundary tones must also mark the informational units at the level of semantics, so that the combination of a boundary tone with a constituent including a pitch accent defines the major informational elements such as the theme and the rheme. The upper grammatical element in the categories given in example 62 above consists of a syntactic type and an interpretation, as usual. The variable $S\$$ in the syntactic type ranges over a set $\{S\}$ of syntactic categories including S and all functions into members of $\{S\}$ —that is, it includes S , S/NP , and all verbs and type-raised arguments of verbs, but not nouns and the like.²³ The boundary categories apply the function $\text{update} \theta$ (if the phonological category on the argument is θ) or $\text{update} \rho$ (if it is ρ) to the interpretation of that argument, marking it for the corresponding discourse function. It follows that, according to this category, the responsibility for identifying a phonological phrase

²¹These categories differ from earlier proposals.

²²This category follows Prevost and Steedman 1994, and implies that boundaries are phonological “heads,” and constitutes a modification to previous versions of the present theory that brings it more closely into line with the proposals in Pierrehumbert and Hirschberg 1990. The idea that boundaries are in categorial terms heads or functors was also proposed by Kirkeby-Garstad and Polgardi 1992, 1994.

²³This is the “dollar convention” of earlier papers.

as theme or rheme lies entirely with the pitch accent.

As far as the predicate-argument structure that the derivation yields is concerned, $\text{update}\theta$ and $\text{update}\rho$ are identity functions that effectively vanish. However, until they apply, they block any further reduction of the interpretation to the canonical predicate-argument structure. We further assume that, when they do apply, their evaluation brings about an update to the model, in the sense defined earlier. The update has the effect of withdrawing one or more existing themes or rhemes, and asserting a new one, in the manner described in section 3.

The following example, which completes the derivation of the theme of the earlier sentence *MARY likes the MONDRIAN*, demonstrates the effect of the first type of boundary tone:

$$(64) \quad \begin{array}{c} \text{MARY} \quad \text{likes} \quad \text{the MONDRIAN} \\ \text{L+H*} \quad \quad \quad \text{LH\%} \quad \quad \quad \text{H*} \quad \text{LL\%} \\ \hline \text{S/(S\NP)} \quad \text{(S\NP)/NP} \quad \text{SS\SS} \\ : \lambda p.p *mary' : \lambda x.\lambda y.likes'xy : \lambda f.\text{update}\epsilon f \\ \theta \quad \quad \quad \epsilon \quad \quad \quad \phi \setminus \epsilon \\ \hline \text{S/NP : } \lambda x.likes'x *mary' \text{ } \xrightarrow{\text{B}} \\ \theta \\ \hline \text{S/NP : } \text{update}\theta(\lambda x.likes'x *mary') \text{ } \xleftarrow{\text{\%}} \\ \phi \end{array}$$

The second prosodic phrase in the example bears the H*LL% rheme tune, parallel to 4 above. Example 65 below completes the derivation.

$$(65) \quad \begin{array}{c} \text{MARY} \quad \text{likes} \quad \text{the} \quad \text{MONDRIAN} \\ \text{L+H*} \quad \quad \quad \text{LH\%} \quad \quad \quad \text{H*} \quad \quad \quad \text{LL\%} \\ \hline \text{S/(S\NP)} \quad \text{(S\NP)/NP} \quad \text{SS\SS} \quad \text{NP/N} \quad \text{N} \quad \text{SS\SS} \\ : \lambda p.p *mary' : \lambda x.\lambda y.likes'xy : \lambda f.\text{update}\epsilon f : \lambda x.the'x : *mondrian : \lambda f.\text{update}\epsilon f \\ \theta \quad \quad \quad \epsilon \quad \quad \quad \phi \setminus \epsilon \quad \quad \quad \epsilon \quad \quad \quad \rho \quad \quad \quad \phi \setminus \epsilon \\ \hline \text{S/NP : } \lambda x.likes'x *mary' \text{ } \xrightarrow{\text{B}} \quad \quad \quad \text{NP : } the' *mondrian' \text{ } \xrightarrow{\text{>}} \\ \theta \quad \quad \quad \rho \\ \hline \text{S/NP : } \text{update}\theta(\lambda x.likes'x *mary') \text{ } \xleftarrow{\text{\%}} \quad \quad \quad \text{NP}^\dagger : \lambda p.p(the' *mondrian') \text{ } \xleftarrow{\text{\%}} \\ \phi \quad \quad \quad \rho \\ \hline \text{S : } (\text{update}\theta(\lambda x.likes'x *mary'))(\text{update}\rho(\lambda p.p(the' *mondrian'))) \text{ } \xleftarrow{\text{\%}} \\ \phi \quad \quad \quad \phi \\ \hline \text{S : } likes'(the' *mondrian') *mary' \text{ } \xleftarrow{\text{\%}} \\ \phi \end{array}$$

The rules permit no other division into a theme and a rheme for this intonation contour.²⁴

It is important to notice that it is only once the functions $\text{update}\theta$ and $\text{update}\rho$ have applied that the final semantic reduction or normalization can take place, to yield the canonical predicate argument structure. The reduction of $\text{update}\theta$ and $\text{update}\rho$ can occur at any point in a

²⁴The present treatment of boundary tones, as exhibited in this derivation, allows a pitch accent and a boundary tone to affect the same word in the string. This detail was left implicit in earlier work, as Kirkeby-Gastad and Polgardi 1992 pointed out in a critique of the earlier papers. The element *the* in the interpretation in the derivation is merely a place holder for a proper treatment of determiners.

derivation.

The division of the utterance into an open proposition constituting the theme and an argument constituting the rheme is appropriate to a context parallel to that established in 4, say by a *Wh*-question *Which painting does MARY like?*, uttered in a context of a prior discussion of somebody else's preferences and a prior theme such as the following:

(66) $\theta(\lambda x.like'x\ alice')$

The newly-derived theme $\theta(\lambda x.like'x\ *mary')$ contrasts with this prior theme in the earlier sense.²⁵ The new theme can then be used to identify the alternatives set, which might be the following:

(67) $\left\{ \begin{array}{l} \diamond like'(the'mondrian')mary' \\ \diamond like'(the'breughel')mary' \\ \quad \quad \quad etc. \end{array} \right\}$

The rheme $\rho(\lambda p.p(the'*mondrian'))$ can then be used to reduce this set to a single proposition *like'(the'mondrian')mary'*.

As in the case of themes like 61, pitch accents, including multiple ones, can in general be included in theme or rheme in a number of ways. For example, for a rheme *the green corduroy*, we get the following possibilities:

(68) Q. Does Mary like the green corduroy or the green velvet?

A. (MARY likes) (the green CORDUROY)
L+H* LH% H* LL%

(69) Q. Does Mary like the green corduroy or the red corduroy?

A. (MARY likes) (the GREEN corduroy)
L+H* LH% H* LL%

It also applies when both words are marked for rheme accent with H* pitch accents, in a context in which both elements of the noun-group *green corduroy* are contrasted or informative, as in the following answer to the question *Does Mary like the green corduroy or the red velvet?*²⁶

²⁵In effect, the *update* action first abstracts over the *constant in the new theme. Higher order unification can be used for this task, via Huet's 1975 algorithm, in a manner discussed by Shieber et al. 1995, (to appear). Prevost 1995 discusses a related procedural device.

²⁶As before, downstep is redundantly indicated by prefix "!" and does not affect the category of the pitch accent.

(70) MARY likes		the	GREEN	CORDUROY	
$L+H^*$	$LH\%$		H^*	$!H^*$	$LL\%$
S/NP		NP/N	N/N	N	$SS\SS$
$update\theta(\lambda x.like'x *mary')$		$: the'$	$: *green'$	$: *corduroy'$	$: \lambda f.update\epsilon f$
ϕ		ϵ	ρ	ρ	$\phi \setminus \epsilon$
		$\xrightarrow{>B}$			
		NP/N			
		$: \lambda x.the'(*green'x)$			
		ρ			
		$\xrightarrow{>}$			
		$NP : (the'(*green' * corduroy'))$			
		ρ			
		$\xleftarrow{<T}$			
		$S \setminus (S/NP)$			
		$: \lambda f.f(the'(*green' * corduroy'))$			
		ρ			
		$\xleftarrow{<\%}$			
		$S \setminus (S/NP)$			
		$: update\epsilon\rho(\lambda f.f(the'(*green' * corduroy')))$			
		ϕ			
		$\xleftarrow{<}$			
		$S : (update\theta(\lambda x.like'x *mary'))(update\epsilon\rho(\lambda f.f(the'(*green' * corduroy'))))$			
		ϕ			
		$S : like'(the'(*green' * corduroy'))*mary'$			
		ϕ			

Although there is a second derivation for the rheme in 70, in which *green* combines with *corduroy* before combining the article *the* applies, the interpretation is unaffected. Indeed, examples 68 and 69 also allow both derivations. The only differences among the interpretations arise from different locations of the pitch accents and in the elements of the interpretation that are marked for contrast as a result. These observations reinforce the earlier suggestion that the discourse significance of the pitch accents operates at the level of *words* and their interpretations, rather than at higher levels of derivation, unlike that of boundary tones.

Many impossible intonation contours correctly remain excluded by the grammar. For example, both of the following are disallowed because the intonation structure is not compatible with any syntactic analysis, for exactly the same reasons that forbid nouns from extracting.

- (71) a. *(MARY likes the green) (CORDUROY).
 $L+H^*$ $LH\%$ H^* $LL\%$
- b. *(My OLDER) (sister likes the green CORDUROY).
 $L+H^*$ $LH\%$ H^* $LL\%$

5.2 Unmarked Themes

We noted earlier in connection with examples 10 and 11 that the majority of themes in everyday utterances are unmarked by either pitch accent or explicit boundary, so that the position of the theme-rheme boundary is usually ambiguous. It is therefore a virtue in the grammar as it stands that it allows multiple derivations, yielding several analyses in which the theme is unmarked, bearing the null-tone category ϵ , while the various possible rhemes are distinguished as such, as in the following example:

- (72) a. (I read a book about)_{Theme}(PAINTINGS)_{Rheme}
 b. (I read)_{Theme}(a book about PAINTINGS)_{Rheme}
 c. (I)_{Theme}(read a book about PAINTINGS)_{Rheme}
 d. (I read a book about PAINTINGS)_{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 alternatives sets involved, as follows.

The phonological category $\phi \setminus \varepsilon$ of the L boundary, as defined at 62, already allows it to combine with a null tone category ε . The result is a category whose semantics differs from that of a theme only in including a variable ε in place of the theme marker θ . If we further assume that an L boundary is phonetically indistinguishable from the null tone, and may therefore be postulated anywhere there is no tone, then such an “invisible” L boundary can apply to a preceding category marked with null tone.

A rule of the following form can then apply to make the result of such combinations semantically identical to a theme marked by an explicit theme pitch-accent:²⁷

$$(73) \quad S\$: \text{update} \varepsilon f \quad \Rightarrow \quad S\$: \text{update} \theta f$$

Such a tactic nondeterministically allows multiple derivations. It follows from this analysis that utterances with unmarked themes are typically ambiguous as to derivation and information structure, since there are several ways of splitting them up into a theme and a rheme, and there may be several ways of further dividing each of these into given and new. For example:²⁸

$$(74) \quad \begin{array}{c} \text{I read a book about} \quad \text{L} \quad \text{PAINTINGS} \quad \text{LL\%} \\ \hline \begin{array}{ccc} S/NP & S\$ \setminus S\$ & S \setminus (S/NP) \\ \varepsilon & \phi \setminus \varepsilon & \phi \end{array} \\ \hline \phi < \\ \hline S \\ \phi < \end{array}$$

The representation of theme and rheme in the interpretation is exactly as in the earlier examples.²⁹ Note that while the boundary L can apply to only part of the null theme—say just to *a book about*—but the remainder will then fail to combine because of the type restriction on ε , so that the derivation will block.

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. Thus the appropriateness of applying the rule to a given category can be directly decided by reference to the discourse

²⁷It seems likely that the rule itself could be made implicit in the update process.

²⁸We do not exclude the possibility that this nondeterminism is in fact eliminated by subtle phonetic distinctions between L and the null tone. However, it is safest to assume the worst.

²⁹In earlier papers, this process was compiled into a single step, in effect nondeterministically turning constituents marked ε 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, a point to which we return in connection with example 78, below.

model, to decide whether it supports the presupposition that the corresponding referent is theme, background, or whatever.

This ambiguity is further constrained by the grammar itself. That is, the following do not appear to be possible information structures, because, like the related examples 71, they are not acceptable syntactic structures.³⁰

- (75) a. *(Mary likes the green)_{Theme}(CORDUROY)_{Rheme}
 b. *(My older)_{Theme}(sister likes the green CORDUROY)_{Rheme}

If “invisible” boundaries can be postulated at the righthand end of an unmarked theme, then they must also be allowed in other positions where there is no tone—for example at the righthand end of an utterance-initial rheme followed by an unmarked theme, as in the following answer to the question *Who likes Mondrian?*:³¹

- (76) (MARY) (likes Mondrian) .
 H* L LL%

Again this rule introduces a non-determinism: again this nondeterminism only arises in contexts where the theme in question is entirely given, or background, and hence is recoverable by the hearer. (Notice that such themes must when evaluated by definition yield an alternatives set of propositions that is identical to the background set. We will return to this point below).

Intonational phrase-final null tone should not, however, invariably be assumed to be an unmarked theme. It may just be background information in the Rheme. To take an old example from Schmerling 1976, one may announce the death of Nixon in the absence of any prior discourse whatsoever by saying the following:

- (77) NIXON died .
 H* LL%

The second word is then part of the rheme, which of course is allowed by the grammar, and the utterance is felicitous just in case dying is a background possibility for the individual in question. (If not, as Schmerling points out, one has to say something like *NIXON DIED*.)

The other apparently phonetically indistinguishable analysis for this sentence, with a medial L and an unmarked theme, is the following, and is appropriate to a situation where the question is *Who died?*, as Ladd points out (1980, p. 53).

- (78) NIXON died .
 H* L LL%

A related partition into rheme followed by unmarked theme appears to arise in Ladd’s own example 33, repeated here in the revised notation, uttered in the context of a question *Has Harry read “Ulysses”?*:

³⁰Relativization and coordination reveal that the sentences are in violation of island constraints. The present paper remains agnostic on the source of island constraints. The point here is that they limit intonation as well as the rest of the system.

³¹The prosodic annotation of this example represents a minor departure from Pierrehumbert, whose theory does not permit boundaries without corresponding pitch accents, and who 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.

- (79) Harry doesn't READ books .
 H* L LL%

Although the phonological analysis proposed here is different from Ladd's own, he supports a view of the information structure according to which the utterance is "about books" (1980, p.52)—by which he seems to mean that *books* is in present terms theme. That in turn is merely to say that the alternatives set consists only of propositions about books.

6 Conclusion

The way is now clear to a unification of intonational structure and surface structure, since it is evident that they are simply different aspects of the *same* derivational structure. Such a notion of intonation structure is richer than the one assumed by Selkirk and others, since it includes constituent boundaries that do not necessarily have a phonetic realization. However, this conclusion seems unsurprising. All we are saying is that syntactic boundaries are no more and no less directly specified by tones than they are by words.

If information structure boundaries and surface syntactic boundaries coincide in this way, then there are a number of other prosodic effects which should depend upon the surface structures afforded by CCG in as direct a manner as English intonation contour. The obvious candidates are vowel-harmonic effects such as American English flapping (Nespor and Vogel 1986), the Rhythm Rule (Gussenhoven 1983, Selkirk 1984), and Italian *raddoppiamento syntattico* (Napoli and Nespor 1979, Kaisse 1985, Nespor and Vogel 1986, Vogel 1994). The latter authors in particular discuss information-structural effects of focus that seem to be directly capturable in this way.

More speculatively, it seems likely that many of the "end-based" effects of syntax upon phonology argued for by Selkirk 1986, 1990 and Selkirk and Shen 1990, according to which intonation-structural boundaries coincide with either left- or right- edges of syntactic constituents, but not necessarily both, are artifacts of the syntactic theories within which they have been framed. That is to say that English appears to be a "left edge" language because a traditional right-branching account of its surface structure just doesn't offer phonologists enough right brackets to work with. The claim of the present theory is simply that those right brackets are there, in surface syntax, in left-branching structures like 50. It is unnecessary under this interpretation of surface structure to postulate an additional independent prosodic structure, as do Selkirk, and Nespor and Vogel (cf. Vogel and Kenesei 1990, and Zec and Inkelas 1990). We should instead adopt a more liberal notion of syntactic structure, one which is directly compatible with the boundaries that the phonologists observe.³²

The status of Surface Structure in this theory is somewhat different from the status of the related concepts in GB and earlier theories such as the "annotated surface structures" of Chomsky 1970 and Jackendoff 1972. To understand this point it will be helpful to consider the architecture

³²The freer notion of surface structure engendered by the present theory may also explain some of the examples which Bolinger 1989 has used to argue for an entirely autonomous, lexically-oriented account of accent assignment, and which Gussenhoven 1983 has used to argue for a similarly autonomous focus-based account. It may also allow us to eliminate some of the non-syntactic string-based rules and "performance structures" that Cooper and Cooper 1980 and Grosjean and Gee 1983 have proposed to add to the syntax-driven model.

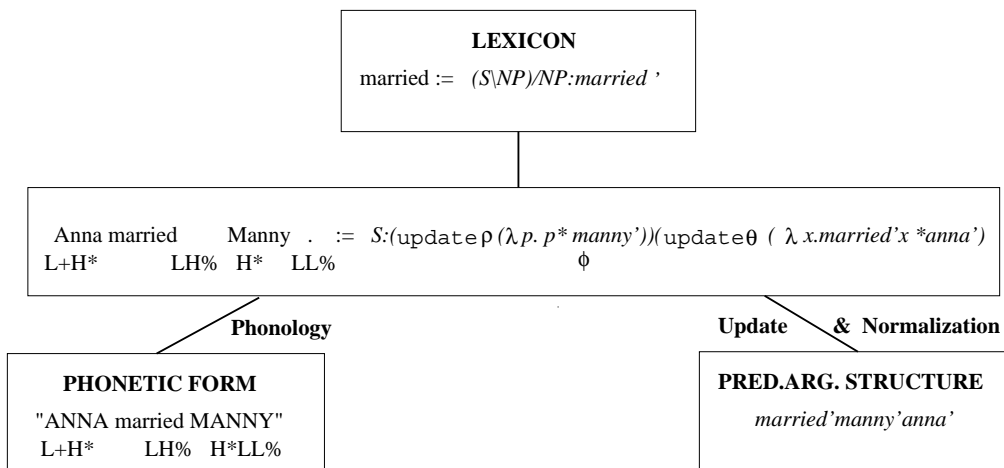


Figure 2
The Present Architecture

of the present theory of grammar in terms of the traditional “T” or “Y” diagram, as in Figure 2, which includes an example of an object of the kind represented in each module for one possible intonation contour for the sentence 1 with which the paper began:

- (80) ANNA married MANNY .
L+H* LH% H*LL%

The lexicon associates category-interpretation pairs with (the phonological specification of) each word of the language. Derived objects or 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 that of derived objects, the category is, strictly speaking, redundant, since it is presumably entirely predictable from a) the type of the interpretation, b) X-bar theory, and c) a parametric description of the language as to position of heads, etc. The category-interpretation pairs therefore count as a single level of representation. Each object in a derivation can therefore be thought of as pairing a phonological representation π (which provides the input to rules relating to the metrical grid) with a single representation related to the corresponding logical form λ (providing the input to systems like inference and reference). This theory can therefore, like other Montagovian categorial approaches, be viewed as “minimalist” in the sense of Chomsky’s 1995 program, many of whose principles can then be seen in categorial terms as concerning the specification of the lexicon.

The analogy is strengthened by the fact that surface structure does not figure as a level of representation at all in the theory. While I have described the combinatory derivations that map phonological strings onto such category-interpretation pairs (and vice versa) in terms of structures implicit in derivations, no rule or relation has been predicated over such structures, which

are merely a history or record of how an algorithm might get from the string to the interpretation (or vice versa). While in order to show that the theory is sound and complete it is convenient to write such derivations down and talk about them as surface structures, they do not constitute a level of representation in the theory. No rule ever needs to know how a category that it applies to was derived.

Combinatory derivations correspond to intonation structure in the extended sense of the term defined above, as well as capturing coordinate structure and the effects of relativization (Steedman 1996b). Surface Structure or derivation in the present sense therefore subsumes some functions of S-structure, and all those of Intonation Structure, together with some of the role of PF as it is understood in GB. Phonetic Form in present terms really is no more than an abstract specification of speech segments.

The interpretation which the derivation associates with a constituent of category S (or any other derived constituent) also directly reflects such information structural distinctions as those between theme and rheme, and focus and ground, and the units which affect the context via the process of update.³³

Surface structures of this derivational kind do not preserve 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 information structures yielded by the alternative derivations of a given proposition as discussed in connection with examples 50 and 51, and as implicitly assumed in derivations throughout the paper. It follows that all grammatical relations that depend upon *c*-command, notably including binding and control and such related phenomena as crossover, must be treated as properties of interpretations—in present terms, predicate-argument structures—rather than surface structures, a suggestion which is consistent with the observations of Bach and Partee 1980 and Lasnik and Saito 1992.³⁴ Since normalization can be carried out at each step in a derivation (and would be automatically in certain unification-based alternatives to the λ calculus for representing interpretations—e.g. the one used in Steedman 1990), predicate-argument structure is the only explicit level of representation in this theory of grammar—that is, the only level over which grammatical rules and relations are predicated. Predicate argument structures are automatically determined by combinatory derivation under the Principle of Combinatory Transparency.

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³³As we noted earlier, there is a close resemblance here between information structures and the “structured meanings” of Cresswell 1973, von Stechow 1989, and Chierchia 1989, as well as with the alternatives semantics of Karttunen and Peters 1979 and Rooth 1985, 1992.

³⁴Although 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.

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