Phrasal Intonation and the Acquisition of Syntax*

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§1 Introduction

It is frequently suggested that prosodic information may be used by children as a cue to syntactic phrase boundaries and constituent categories during language acquisition. As in the case of word segmentation, to assume that there are properties of the speech stream that with some statistical reliability make these units perceptually salient certainly seems a reasonable working hypothesis, whatever else one thinks might be involved. However, the fact that fluent intonational phrasing may on occasion be completely orthogonal to traditional syntactic constituency, as in the following example, has appeared to present a problem for this proposal:

(1)	(YOU	want)	(a BISCUIT!)
	L+H*	LH%	H* LL%

The example uses Pierrehumbert's notation for the intonation contour. In this utterance, the subject and the verb constitute one intonational phrase

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with a pitch accent on the former and a "continuation rise" on the latter, while the object constitutes a separate intonational phrase.[1] (Readers who are unfamiliar with this notation should think of this as the intonation that conveys a meaning paraphrasable as "What you want is a biscuit"). The utterance gives rise to the perceptual structure suggested by the brackets (which are not part of Pierrehumbert's notation). This structure is orthogonal to the traditional syntactic surface structure for this sentence. Similar examples have led Selkirk (1984) and others to postulate a level of "Intonational Structure", orthogonal to syntactic structure. While intonational constituents are not entirely independent of syntactic constituency, they allow considerably freer bracketing of the string, and at the level of meaning convey distinctions of discourse focus and propositional attitude, rather than function-argument structure. Such a system therefore seems to present an obstacle for the child who relies on "prosodic bootstrapping" to identify syntactic constituency, since such prosodic groupings seem to be quite common in adult speech to infants (see Jusczyk, this volume).

Combinatory Categorial Grammar (CCG) is a theory of syntax that was primarily developed to account for coordination and relative constructions without the use of movement, Wh-traces, or deletion. It has the property of allowing much freer constituent structure than traditional grammars, while still projecting semantic function-argument relations correctly. Under this novel view of syntactic constituency, the apparent disjuncture between syntactic and intonational constituency vanishes: these two "levels" of structure turn out to be simply the same.

This chapter begins with a brief review of the CCG account of intonation, before considering the implications for language acquisition. One implication is that the apparent complexity of the child's task in inferring syntactic boundaries from prosodic boundaries is somewhat simplified. According to this theory, whenever such a boundary is present, it can safely be assumed by the child to coincide with the boundary of a fully interpretable constituent.

Of course, this is not to suppose that that phrasal intonation is the only source of information that the child has available, or that such information

[1] Such intonational boundaries should be clearly distinguished from pauses engendered by prosodic disfluencies, such as hesitation pauses. Such interuptions are phonetically quite different from true intonational boundaries.

is sufficient for the child to acquire grammar. To identify constituent boundaries is not enough to identify the grammatical category of such constituents, or the rule by which they combine. It will also become clear that, at least at the level of the intonational phrase, the distinctive characteristics of the intonational tunes that appear on a given phrase specify something quite unrelated to syntactic category. The claim will be that a complete or nearly complete semantic or conceptual representation of the meaning behind the utterance, commensurate with the child's limited understanding of the world, but held in common with the adult, and including limited information about the attitudes and focus of attention of participants in the discourse, remains an indispensible source of information for the child at even the earliest stages of acquiring the constructions of the language.

§2 Grammar and Intonation

CCG is fully described in Steedman (1991), to which the interested reader is referred for fuller details. In such grammars, as in all Categorial Grammars, most of the work that in a phrase structure grammar is done by rules like (2 is done by lexical categories like (3):[2]

(2)
$$\begin{array}{lll} S & \rightarrow & NP \quad VP \\ VP & \rightarrow & TV \quad NP \\ TV & \rightarrow & \{like, eat, want, \ldots\} \end{array}$$

(3) want $:= (S\backslash NP)/NP$

Such categories say that transitive verbs like *want* are entities that combine with an NP to the right to yield a predicate $S\backslash NP$ – which is itself a category that combines with NPs to its left to yield sentences S.[3] Such a category defines the transitive verb as a *function*, and can also be viewed as defining the semantic type of the function in question. It is this semantics which further determines that the NP on the right takes the role of object, while that on the left takes the role of subject. That is to say that in CCG most of work in the grammar is done by the equivalent of subcategorisation frames.

[2]We pass over the details of number and person agreement, which are the same in both frameworks.

[3]Of course, such lexical items can have more than one category.

The combinations of such functions with arguments are effected by the following pair of "combinatory rules", which can be thought of as very general CFPS rule schemata:

(4) Functional Application:

$$
\begin{array}{llcll}
a. & X/Y \quad Y & \Rightarrow & X & (\texttt{>}) \\
b. & Y \quad X\backslash Y & \Rightarrow & X & (\texttt{<})
\end{array}
$$

We will leave implicit all details of semantics here, merely noting that the combinatory rules effect semantic combination as well as syntactic combination, and have the character of *function application*. It is convenient to write derivations in such grammars as in (5a), with suitably annotated underlines corresponding to applications of the combinatory rules, a notation which is simply equivalent to the traditional tree diagram in (5b):

```
(5) a.   You      want      a  biscuit      b.  You  want  a  biscuit
        ----- --------- ---- -------             |     |    |     |
         NP   (S\NP)/NP NP/N    N                NP    V   DET    N
                        --------->                \     \    \  /
                            NP                     \     \    NP
              ---------------->                     \     \  /
                  S\NP                               \    VP
         -------------<                               \  /
             S                                          S
```

CCG extends this strictly context-free categorial base in two respects. First, we can assume that all arguments, such as NPs, can freely *type-raise* to become functions over function categories. For example, subject NPs raise via the following rule:

(6) Subject Type Raising (>T):

$$NP \;\Rightarrow\; S/(S\backslash NP)$$

The following derivation of the same simple transitive sentence is therefore possible (the details of the derivation of the object are omitted):

(7)
```
  You         want    a biscuit
--------  ---------  ---------
   NP     (S\NP)/NP     NP
------->T
S/(S\NP)
          ----------------<
               S\NP
-------------------->
         S
```

Although we do not discuss it here, the semantics of the rules of type-raising guarantees that this derivation yields the same interpretation as the previous one.

The combinatory rules are further extended by the inclusion of rules of *functional composition*, in addition to the earlier rules of application. The following rule is an important example:

(8) FORWARD COMPOSITION (`>B`):
$X/Y \quad Y/Z \quad \Rightarrow_{\mathbf{B}} \quad X/Z$

This rule, which can be thought of as "cancelling" the term Y, as in fractional multiplication, allows a *second* non-standard syntactic derivation for the above sentence, as follows. (Once again, although the details are passed over here, the semantics of the composition guarantees that the interpretation for the S that results is identical to those obtained in the earlier derivations):

(9)
```
a.     You        want    a biscuit      b.   You  want a  biscuit
     --------  ---------  ---------            |    |   |     |
     S/(S\NP)  (S\NP)/NP     NP                NP   V  DET    N
     -------------------->B                     \  /     \  /
            S/NP                                 ??       NP
            ------------------<                    \      /
                   S                                \   /
                                                      S
```

The original reason for making this move was to provide the basis for a simple account of coordination and relativisation. Most obviously, we can account for the presence of similar non-constituent fragments in the following examples:

(10) a. You want, and I need, a biscuit.
b. The biscuit that you want.
c. The biscuit that I want and you need.

(The last two examples require the assumption that the relative pronoun has the category $(N\backslash N)/(S/NP)$ – that is, a category mapping fragments like *You want*$_{S/NP}$ onto noun modifiers, as its semantics would suggest.) Somewhat less obviously, the theory also covers unbounded extraction and various other non-constituent coordinations, such as the following (the interested reader is directed to Steedman 1991 for details):

(11) a. Harry seems to think that you want, and I certainly know that I need, a biscuit.
b. The biscuit that Harry seems to think that you want.
c. I gave you a biscuit and Harry a banana.

The last of these examples, which is of a type that presents considerable problems for other theories, provides very strong support for the claim that type raising and composition constitute the correct set of elementary syntactic combinatory operations.

We will pass over the further details here, together with all questions concerning the general class of rules from which the composition rule is drawn. The important point for present purposes is that the partition of the sentence in (9) into the object and a non-standard (but fully interpreted) constituent S/NP corresponding to the string *You want* makes this theory structurally and semantically suited to the demands of intonational phrasing.[4]

In other words, we can make CCG sensitive to the presence of intonational phrase boundaries, so that of the two preceding derivations (5) and (9 for the string *You want a biscuit*, only the latter will be allowed with the intonation shown in (1) – that is, the one meaning roughly "What you want is a biscuit", repeated here:

(12)	(YOU	want)	(a BISCUIT!)
	L+H*	LH%	H* LL%

By contrast, only the former derivation will be allowed with the following different intonation:

[4]The interpretation in question can be written $\lambda x[want'\ x\ you']$ using the standard notation of the λ-calculus (cf. Partee et al. 1990).

(13) (YOU) (want a BISCUIT!)
H*L L+H*LH%

(This is the intonation contour that conveys a meaning roughly paraphrasable as "It's you who wants a biscuit".) We will pass over the formal details of how this is done, again referring the interested reader to Steedman (1991), apart from the following further remarks.

First, it should be intuitively clear, even in advance of the formal details, that the intonational "bracketings" exemplified above, together with the particular tunes that are involved, are associated with a very clear discourse semantics. The "rise-fall-rise" tune that is written L+H*LH% appears to be associated with the "topic" or *theme* of the utterance – roughly, *what the speaker assumes the conversation to be about.* In the case of (12), the theme seems to be the one that would be established by the prior question "What do I want?". In (13), the theme is the one that would be established by the question "Who wants a biscuit"? Similarly, the part of both utterances that is marked by the "rise-fall" tune, written H*L or H*LL% marks the "comment" or *rheme* – that is, the part of the utterance which conveys *what the speaker has to say* about the theme.[5]

The second point to note is that both the above examples include regions of the sentence which have no tone marking in Pierrehumberts system, and which in these examples are realised with low pitch and no stress or accent. Again, the discourse semantics seems intuitively clear. Pitch accents mark the parts of the theme and rheme that are "interesting", usually by reason of *contrast* with alternative concepts in the discourse model. The parts with no pitch accent are non-contrastive *background* information, as the reader can tell by comparing the following alternative with (12):[6]

(14) (You WANT) (a BISCUIT!)
L+H* LH% H* LL%

It is important to note that the vast majority of utterances between adults consist mainly of such unmarked backgrounded content, with only a pitch

[5]The terms theme and rheme originate with Halliday (1970), although we have generalised his usage somewhat here.

[6]The contrast between contrast and background is comparable to Hallidays "new" and "given" information.

accent and boundary tone at the end to indicate the contrastive rheme, as in (15):

(15) You want a BISCUIT.
H* LL%

According to the theory that has been sketched above, such examples simply remain ambiguous between the two derivations permitted by the earlier more informative intonations. While we continue to pass over the formal details, this is obviously a desirable result, as soon as we think about the discourse semantics of such utterances. They are indeed ambiguous as to whether the topic is "You" or "What you want", as the reader can verify by observing that this utterance is an appropriate answer either to the question "what do I want?" or to the more open question "What about me?".

It should also be noted that in speech between adults, longer sentences with this sort of intonation, like 16, may be many ways ambiguous as to syntactic derivation:

(16) Harry seems to think you want a BISCUIT.
H* LL%

Again this is correct: the interpretations associated with the major constituents of such derivations distinguish between occasions on which the topic or theme of the discourse is "what Harry seems to think you want", "What Harry seems to think", "Harry" and so on, to all of which contexts it is appropriate.

Since such ambiguous intonation contours are actually more common in adult speech than the explicitly informative contours we were examining earlier, it should be clear that there is no claim here that intonation disambiguates syntactic derivation. The claim is merely that when intonational boundaries *are* present, they will coincide with syntactic boundaries. Since adult speech to children may well include a greater number of explicit boundaries, this seems to be encouraging news. However, there is reason to be cautious here. It is quite likely that the difference is one of degree rather than quality, and that children resemble adults in resolving ambiguities including this one by appeal to meaning and context.

There is every reason to have expected intonation to be congruent with syntax, because it makes for a simpler competence theory. But we should not be surprised to find that performance – including that of the child – has to cope with a great deal of ambiguity, since there is a great deal of ambiguity and nondeterminism in every other component of grammar. Nor is this particular type of ambiguity an artefact of CCG: the nondeterminism is a fact of English and every other language, and must be encountered by any theory that attempts to deal with the range of constructions covered by CCG. However, this observation prompts the further questions of what performance mechanism allows adult human sentence processors to cope with the nondeterminism of competence grammar in general, and whether it is reasonable to attribute a similar mechanism to the child.

§3 Performance

There is a growing consensus among psycholinguists that the principal resource that adult human parsers use to resolve grammatical nondeterminism calls on incremental interpretation of rival analyses, in order to "weed out" analyses that do not make sense in the context. (See Marslen Wilson et al, 1978, Crain and Steedman 1985, Tanenhaus 1988, Frazier 1989, Altmann and Steedman 1988, Clifton and Ferreira 1989, Steedman and Altmann 1989, Pritchett, 1992, Gibson 1991, Niv 1993a, Trueswell et al 1993.) While these authors differ on the details of how exactly this might work, one extremely plausible alternative is the "semantically filtering beam-search" theory. According to this proposal, as each word of the sentence is processed, a partially specified interpretation of the sentence is produced for each alternative syntactic analysis compatible with that word, in parallel. These interpretations are immediately evaluated with respect to both semantic and contextual plausibility, the less plausible analyses being assigned low priority or weeded out entirely. On occasion of course, the context may resolve the ambiguity in a way that is incompatible with the syntactic continuation of the sentence. On such occasions, a "garden path" or other processing difficulty may be experienced.[7]

[7]The question of whether any *other* resource (such as parsing "strategies" or the exploitation of low-level stochastic properties of the language) is needed to explain human parsing in the face of nondeterminism is an open research question.

It seems likely that adults deal with the syntactic and information-structural ambiguity noted for examples like (15) in a similar way. The occasions on which it is appropriate to utter the informative and unambiguous contour in (12) are those in which there could be some doubt as to whether the topic or theme is what the hearer wants, or what some other person wants. If no part of the theme is in contrast to anything else, then the theme should be backgrounded, and uttered with low pitch and no pitch accent, exactly as in (15).

What this means is that the ambiguity inherent in (15) arises only in *contexts which resolve the ambiguity* – that is, those contexts in which the theme is entirely given. It follows that this ambiguity is entirely comparable with the attachment ambiguities more commonly investigated by psycholinguists like those cited above, and can be resolved by the same semantically filtering beam-search.

§4 Acquiring Syntax from Spoken Language

Where does this leave the child language learner? It seems that what we have given with one hand, by showing that they can rely on intonation boundaries very directly when they are present, we have taken away with the other, by revealing even more ambiguity than was previously recognised in the surface structures that they must infer.

We shall of course not be surprised if we find that adults treat children as less securely in control of the discourse context than themselves, and use informative intonations like that in (12) more frequently when speaking to them. And in fact there is a considerable amount of evidence that this is the case (cf. Bernstein-Ratner, this volume). Should we therefore conclude that CCG lends support to the "prosodic bootstrapping" hypothesis, according to which the child acquires syntactic structure from its explicit reflection in the prosody? Considerable caution may again be in order, for two reasons.

The first is the obvious reason that structure is not enough to determine syntactic categories and syntactic rules. This is a problem for all structural bootstrapping proposals, whether the source of information is prosodic, as in the work of Lederer and Kelly (1992), syntactic, as in Gleitman (1990), or string-based and stochastic, as in the computational work of Brent (1991). The properties involved, which include prosodic characterisations of nouns versus verbs, and basic clause constituent order, are all language-specific. While many of these studies establish that the relevant entities are perceptually available, something more is needed if the child is to decide which of these entities are nouns, which are verbs, and what order they can occur in. These proposals therefore presuppose the existence of some additional information identifying the basic categories and subcategorisation frames for the language, as has been cogently pointed out by Braine (1992, p.82). Of course, in the terms of categorial grammar, the categories and subcategorisation frames of any given language simply *are* its grammar.

The second reason follows from the first. As soon as it is recognised that the very earliest stages in acquiring syntax require some language-independent source of information about grammatical categories and grammatical relations, the only plausible source that has ever been identified is the semantic interpretation that underlies the utterance.[8]

It is concievable that if a language included a sufficiently reliable prosodic marker of, say, nouns, then the learning of the members of this class could begin in advance of the learning of the syntactic significance of that class or of the semantics of each member, much as if they were morphologically disambiguated with similar reliability. While access to semantics for at least one member of the class would still be necessary to identify it as a noun, rather than some other category, all members of the class could promptly be categorised as nouns. Their interpretations could then be learned at leisure. While such a process would allow some of the work of acquisition to be done "off line", perhaps at a stage when the conceptual apparatus necessary to support a semantics were still under development, it is hard to see any great payoff, especially if category markers are unreliable. It is striking in this connection that irregularity in form-class markers seems to be the rule rather than the exception across languages, particularly among the most frequent and earliest-acquired items. In any case, it is clear that access to semantics is crucial even here.

However, once we realise that, sooner or later, the child needs access to semantic interpretations in order to acquire syntactic competence, it be-

[8]In the context of modern linguistics, the suggestion goes back at least to Chomsky (1965, pp.56-59) and Miller (1967). But of course it is a much older idea. See Grimshaw (1981) for a more recent example, and Pinker (1979) for a review of some proposed mechanisms, including the computational work of Anderson (1977).

comes even more plausible to think of the child's performance as being much like that of the adult language processor – that is, to think of both children and adults as processing utterances on the basis of an understanding of conceptual meaning and discourse context, both of which drastically limit the possible meanings for the utterance, and differing only in their degree of complexity and extent of world knowledge. Of course, conversation would be a dull business for all concerned if context were so completely informative as to render utterance completely redundant, and we cannot assume that the child invariably has a unique correct interpretation for every sentence that they encounter during learning. However, even for the child with no grammar at all, we do not need such a strong assumption, as the computational work of Siskind makes clear (cf. 1992, 1993). Siskind's learning program embodies the weaker assumption that the relevant conceptual structure is merely present with reasonably high probability among a fairly small set of candidate interpretations that are available to the program via its perceptual access to the situation, and provides an important existence proof for such a mechanism. It follows that Pinker's 1987 worry that, because "such inferences fall short of telepathy and hence are fallible", "incorrect conclusions [could] be made, and [further] learning based on them would spread the damage", may be too pessimistic.[9]

Of course, we should not assume that the conceptual structures in question are confined to those directly supported by instantaneous sense-data in any simple sense of the term. We have no reason to assume that the child lacks sufficient short-term memory and attention span to cope with reasonably immediate sequential relationships between utterances and the phenomena that they refer to. It would also probably be wise to assume that children have some grasp of the social context, including certain primitive concepts of attentional focus and intention on the part of the other participant(s) in the situation. This makes experimentation in this area very difficult indeed. However, it is significant that many of the discourse meanings that were associated above with intonational tunes are directly related to such attentional and intentional states. Work reported by Fernald, this volume, suggests that intonational tunes and their discourse meanings are among the properties of language that are leaned earliest by infants.

[9] I am grateful to Jim Morgan for drawing my attention to this passage.

To say this much is not to deny the relevance of the observation that prosodic cues to category and constituency are available, or to deny the reality of syntactic bootstrapping of the kind investigated by Gleitman (1990), who has shown that children may on occasion learn subcategorisation frames independent from semantics. On the contrary, some such process is probably crucial to human cognitive development for identifying concepts which are *not* prelinguistically salient. It seems highly likely that this is the primary mechanism underlying the explosive cognitive conceptual development that accompanies the onset of language in children, along the lines that Vygotsky 1962 has suggested.[10] It is this process that affords the human child relatively effortless and immediate access to many concepts which are not simply and directly evident in the situation, and which represent the hard-won intellectual discoveries and cognitive bequest of generations that have gone before.

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[10]See Steedman 1993, p.XXX.

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