THE INTONATIONAL STRUCTURING OF DISCOURSE

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1. Introduction

The role of prosody in discourse has been generally acknowledged but little understood. Linguistic pragmatists have noted that types of information status (such as given/new, topic/comment, focus/presupposition) can be intonationally marked [1, 2, 3, 4], that reference resolution may depend critically on intonation [5, 6], that intonation can be used to disambiguate among potentially ambiguous utterances [7, 8], and that indirect speech acts may be signalled by intonational means [9, 10, 11]. Conversational analysis of naturally occurring data has found that speakers may signal topic shift, digression, and interruption, as well as turn-taking, intonationally [12, 13, 14]. And the fact that intonational contours contribute in some way to utterance interpretation is itself unquestionable [8]. To date, however, identification of the prosodic phenomena involved -- and the proper mapping between these phenomena and their semantico-pragmatic effects -- has been largely intuitive, and the intonational phenomena involved have not been precisely described.

Here, we describe how certain of the resources of the intonational system are employed in discourse. In particular, we discuss how speakers' choice of pitch range, accent, and tune contribute to the intentional and attentional structuring of discourse -- the way speakers communicate the relationships among their discourse goals and the relative salience of entities, attributes, and relationships mentioned in the discourse. Our findings emerge from an intensive study of a simple example of speech synthesis: the script of a computer-aided instruction system, TNT (Tutor 'n' Trainer) [16], which employs synthetic speech to tutor computer novices in the text editor vi. Using the Text to Speech system (TTS) [17], we have been able, by systematic variation of pitch range and by a principled choice of accent and tune, to highlight the structure of the tutorial text and thus to enhance its coherence. While most studies of how intonation is used in discourse have been based solely on examination of intonational contours found in a natural corpus, we have found that intonation synthesis provides a unique opportunity to manipulate the dimensions of variation orthogonally. Thus we can pinpoint factors crucial for a given effect and evaluate various patterns for a given utterance and context.

2. The Domain

TNT was designed to teach computer-naive subjects vi, a simple UNIX screen-oriented text editor. The tutorial portion provides a brief introduction to word processing, to general features of vi, and to the tutor's help facilities; the tutor then guides subjects through a series of learning tasks of graduated difficulty. While the overall task structure is implicit in the tutorial text, the subject can influence the course of the interaction via his/her manipulation of a set of 'helper' keys; these keys provide hints (HINT) and reminders (REMINd) as well as the option of starting a task over again (DO OVER) or suspending the tutorial temporarily (HOLD).

The fact that TNT is explicitly task-oriented, makes it a good test-bed for our purposes. An appropriate segmentation of the text, and a notion of the purpose of each segment and the hierarchical relationships among segments, can be independently determined from the text. First, the script contains little pronominal reference and very few so-called clue words -- words and phrases such as new, next, returning to, but, and on the other hand, which can identify discourse segment boundaries and relationships among segments, signal interruptions and digressions, and so on [19, 20]. Both of these phenomena (together with intonation) have been identified as important strategies for communicating discourse structure [15, 18, 19]. Their virtual absence from the text presents a convenient opportunity for testing the power of intonation to structure a discourse. Second, while we were not able to isolate points in the text where subjects had special difficulties, we did informally observe certain general problems with turn-taking in the tutor -- specifically, it was not always clear when the tutor's turn was over -- which we addressed in our synthesis of the text.

3. F0 Synthesis

To synthesize the fundamental frequency (f0) contours for the TNT script, we used the intonation synthesis program

1. Gross and Sidner [18] propose a tripartite view of discourse structure: a linguistic structure, which is the text/speech itself; an attentional structure, including information about the relative salience of objects, properties, relations, and intentions at a given point in the discourse; and an Intentional structure, which relates discourse segment purposes (those purposes whose recognition is essential to a segment achieving its intended effect) to one another.

2. That is, the tutorial is organized around a series of data processing tasks, which the subject is guided through. See [18] for discussion of the characteristics of task-oriented domain discourse.

3. The process by which speakers signal that they have (temporarily) finished speaking and by which hearers interpret such signals [21].
described in [22] in [23, 24]. It permits explicit control over the different dimensions of variation in the intonation system. The dimensions we will discuss here are phrasing, pitch range, accent location, and tune. We illustrate each in our synthesis of the introduction to TNT:

1. Hello.

2. Welcome to word processing.

3. That's using a computer to write letters and reports.

4. Word processing makes typing easy.

5. Make a typo?

6. No problem.

7. Just back up, type over the mistake, and it's gone.

8. And, it eliminates retyping.

9. Need a second draft?

10. No problem.

11. Just change the first, and you've got the second.

12. Today, the computer will teach you word processing.

13. The computer is new at this, so be a good student and give it a chance.

14. We can't answer questions, if you are confused.

15. We have to let the computer do all the teaching.

16. But if the computer is not working right, we will help you out.

3.1 Phrasing

The first dimension of variation, phrasing, may be indicated by a pause, by a lengthening of the phrase-final syllable, and by the occurrence of extra melodic elements on the end of the phrase. Variation in phrasing is illustrated in Figures 2 and 3. And is set off as a separate phrase. One consequence of this strategy is that And becomes more prominent in the second version. Phrasing variation will not be of central concern here. Because of the syntactic simplicity of TNT, there were only a few cases where the phrasing could be varied in interesting ways.

3.2 Pitch Range

When a speaker raises his/her voice, his/her overall pitch range -- the distance between the highest point in the f0 contour and the speaker's baseline (defined by the lowest point a speaker realizes over all utterances) -- is expanded. Thus, the highest points in the contour become higher and other aspects are proportionately affected. Figure 4 shows an f0 contour for line 1 in the script above in the default pitch range used by TTS.

Figure 1. The TNT Introduction

In Figure 1 and in all figures below, 'T' indicates the top of the pitch range in Hz, 'F' indicates amount of compression of the pitch range at the end of declarative phrases, 'H' and 'L' indicate high and low tones, '*' indicates a tone's alignment with a stressed syllable, and '%' indicates a phrase boundary tone. We discuss these phenomena and our notational system in more detail below.

Figure 2. One Phrase

Figure 3. Two Phrases

Figure 4. TTS Default Pitch Range

Figure 5 shows the contour actually used in synthesizing the TNT script.
In the notational system employed here, $T$ represents the topline, of a phrase — the maximal value for the f0 contour in the phrase. $F$ expresses the amount of final lowering in terms of the ratio of the lowered pitch range to the starting pitch range. The default value assumed below for $T$ is 115 Hz and for $F$ is 0.87.

### 3.3 Accent

**Pitch accents**, which fall on the stressed syllable of lexical items, mark those items as intonationally prominent. In line 16, for example, *right* has no pitch accent. If *right* were to be especially emphasized, it would have an accent. (In our notation, the absence of a specified accent indicates that a word is not accented; where we wish to highlight this point, we will employ '-' to mark a deaccented word.) The contrasting outcomes are shown in Figures 8 and 9.

In the first case, the last f0 peak occurs on *work* and there is a fall to a low pitch on *right*, then a rise at the end of the phrase. In the second case, the entire peak-fall-rise configuration occurs on the word *right*.

There are six types of pitch accent in English [23], two simple tones -- high and low — and four complex ones. The most frequently used accent, the simple high tone, comes out as a peak on the accented syllable (as, on *right* in Figure 9) and will be represented below as $H^*$. The $H^*$ indicates a high tone, and the $*$ that the tone is aligned with a stressed syllable. In some cases, we have used a $L^*$ accent, which occurs much lower in the pitch range than $H^*$ and is phonetically realized as a local f0 minimum. The accent on *make* in Figure 13 below is a $L^*$. The other English accents have two tones. Figure 10 shows a version of the sentence in Figures 2 and 3 with a $L^*+H^*$ accent substituted for both $H^*$ accents in the second phrase.
Note that there are still peaks on the stressed syllables, but now a striking valley occurs just before each peak.

In our synthesis of the TNT script, we have made extensive use of the type of accent transcribed in [23] as H*+L. This accent, like other bitonal accents, triggers a rule which compresses the pitch range on following material in the phrase, a phenomenon known as downstep or catathesls. For example, a simple contrast between H* H* and H*+L H*+L is illustrated in Figures 11 and 12 in two versions of the tutorial command to hit the 'remind' helper key -- *Hit remind.

We have made particular use of downstepped contours such as this -- i.e., sequences of H*+L tones -- which we will term H*+L sequence in the discussion below. (See Section 4.3.) The way a speaker is structuring a text helps to determine where pitch accents will fall, as a speaker indicates how referents of accented or deaccented items are related to other items in the utterance or in some larger context.

In addition to pitch accents, each intonational phrase has a phrase accent and a boundary tone. These two extra tones may be either L or H. The boundary tone (indicated by 'o') falls exactly at the phrase boundary, while the phrase accent (indicated by an unadorned H or L) spreads over the material between the last pitch accent and the boundary tone. Each intonational phrase contains one or more pitch accents, a phrase accent, and a boundary tone.

### 3.4 Tune

A phrase's tune or melody is defined by its particular sequence of pitch accents, phrase accent, and boundary tone. Thus, H* L L% represents a tune with a H* pitch accent, a L phrase accent, and a L% boundary tone. This is an ordinary declarative pattern with a final fall. A interrogative contour is represented by L* H H%. The contrast between these two melodies is illustrated in Figures 13 and 14. Figure 13 shows the actual f0 contour for line 5 of the TNT introduction, produced as a question.

Figure 14 shows a declarative pattern for the same sentence.

With the declarative intonation characteristic of imperatives, 5 would probably convey that the hearer was being ordered to produce a typo. Roughly speaking, the tune appears to convey information about speaker attitudes and intentions (as, the speech act the speaker intends to perform) and about the relationship between utterances in a discourse.
4. Intonational and Discourse Phenomena

The major questions underlying our research are: First, what is the relationship between particular intonational phenomena and particular discourse phenomena? For example, what discourse phenomena are associated with changes in pitch range? With the accenting or deaccenting of particular lexical items? With choice of tune? More generally, we also characterize the contributions of these intonational phenomena in terms of the theory of discourse structure developed in [15], by relating intonational contributions to aspects of intentional and attentional discourse structure. Second, how do intonational features such as these interact with one another? Does an expansion of pitch range affect the interpretation of a rise-fall-rise contour [25], for example, and if so how? Third, when several discourse features predict conflicting intonational strategies, how is a decision made? When the information represented by a single referring expression, for example, is both 'given' and 'contrastive' -- and thus both deaccentable and accentable -- how is the choice to be made?

4.1 Pitch Range Manipulation

Students of discourse commonly observe that discourses often exhibit a hierarchical structure -- into major topics, their subtopics, sub-subtopics, and so on. In task-oriented domains, it has been claimed that this structure reflects the hierarchical structure of a task and its subtasks [18]. So, for example, the TNT introduction above might be segmented as follows (where utterances are labeled by line number).5

Table 1. Segmenting the TNT Introduction

|   |   |   |
|---|---|---|
|   |   |   |
| 1 | 2 |   |
| 3 |   |   |
| 4 |   |   |
| 5 | 6 |   |
| 7 | 8 |   |
| 9 | 10| 11|
| 12| 13| 14|
| 15| 16|

This bracketing schema defines a discourse segment as any node together with all the nodes it dominates; for example, lines 1-11 form a segment, as do lines 14-16, and so on. An alternative depiction of the hierarchy above would be [[[0],[1/2],[3/4]], [5, 6, 7], [9, 10, 11]] [12, 13] [14, 15, 16].6 Evidence for such hierarchical segmentation in general is found in instances of pronominal reference to referents linearly distant in the discourse; in such cases, a notion of hierarchical proximity appears plausible.

Previous research [12, 14] has observed that 'topic jump' can be signalled by raised pitch, as well as increased amplitude and markers of self-editing, hesitation, and discontinuity -- and that pauses and changes in rate characterize segment boundaries. In our work with the TNT script, we found that a hierarchical segmentation of discourse can be marked by systematic variation in pitch range, which can signal movement between levels in the segment hierarchy. In addition, by varying the amount of final raising or lowering at the end of phrases, we can indicate the degree of conceptual continuity between one phrase and the next. We have developed algorithms for assigning pitch range and final raising/lowering in terms of the discourse segmentation.

To illustrate the algorithms, we relate the TNT introduction presented in Figure 1 to its segmentation in Table 1. When the introduction is synthesized using the TTS default pitch range of 75-115 Hz, the topline for each utterance will remain around 115 Hz. However, the hierarchical relationship schematized above among the various segments may be signalled more clearly if the pitch range is varied. In our version of the script, each segment boundary is marked by a variation in pitch range which correlates with the segment's position in the overall discourse. So, major boundaries are denoted by the largest increases, with smaller increases marking subsegment boundaries, and so on. The segment beginning at 1, for example, is marked by raising the topline to 150 Hz; that beginning at 4, by raising the topline to 138 Hz; and that beginning at 15, by raising the topline to 125 Hz.7 Human speakers do seem to employ a wider spectrum of pitch range variation than we have been able to use in synthesis, however.

We would claim that the appropriateness of changes in pitch range is a function of the segmentation hierarchy -- and is not inherent in the utterance in isolation. Our algorithm for pitch range assignment can in fact enforce one segmentation of a given discourse over another and, in so doing, can disambiguate among potentially ambiguous reference resolutions. For example, if in line 7 of Figure 1 coindexes mistake, while if in line 8 coindexes word processing. A simple linear approach to reference resolution (such as [29]) would have the second coindexed with the previous noun-phrase (up), mistake, but a hierarchical approach to discourse structure holds out the possibility that a referent in a segment dominating the current segment may also provide a referent [18], as, in fact, is the case here. While a little thought will make the appropriate referent clear, it is clearer when line 8 is produced with a larger pitch range to signal the beginning of a new subsegment of the segment headed by 4. By so doing, we lessen the possibility that a referent for this it will be sought in lines 5-7. The most likely candidate, found in 4, is now both intonationally and conceptually 8's superordinate discourse segment.

While an increase in the pitch range indicates segment boundaries, a decrease in the final lowering effects can indicate the absence of such boundaries, and thus indicate that a given utterance and one which follows it are part of the same segment. So, manipulation of final lowering can also serve to indicate discourse structure, by identifying the internal structure of segments. For example, at one point in the TNT script, the following utterance constitutes an entire discourse segment, so it has the default final lowering (F=0.87); in consequence, the L0 tone at the end of had will be only 87% as high as it would have been if final lowering had not applied.

F.87 Type had. N* N* N* L L *

Compare this with:

F.93 Type had. N* N* L L *

Here, the same utterance is synthesized with less final lowering -- the L0 tone at the end of had, in particular, will attain 93% of its target height. In this segment, the first line does not end the segment. We further propose that the degree of final lowering may correlate with the utterance's position in the discourse hierarchy. Specifically, we suggest that minimal final lowering may indicate a "push" onto the segment stack and greater degrees of final lowering.
may be associated with ‘pops’ of this stack. In our synthesis of the TNT text, we have varied degree of final lowering for such ‘pops’ based on the level of the segment which this utterance completes (or, equivalently, the level of the segment the next utterance begins). So, to determine the amount of final lowering to assign when synthesizing line 7 in the TNT introduction, we first determine whether it completes a segment (representing a pop) or not (representing a push). If the former, we may note either that it completes the segment begun at line 5 (with a topline of 136 Hz), or that the subsequent segment is begun (by line 8) with a topline of 136 Hz. We assign final lowering of 0.80 when synthesizing line 7 based on either observation; this rather large amount (close to the synthesizer’s default maximum of 0.87) conveys a relatively important change of subtopic within the larger discourse segment by indicating rather more disjunction than we would want, for example, between lines 9 and 10.

We are currently testing the associations between pitch range/ final lowering variation and discourse structure proposed above in several ways: by pitch-tracking a large corpus of natural speech, by recording and analyzing subjects reading structured texts, and by asking subjects to perform tasks such as reference resolution from texts synthesized with varying pitch ranges.

4.2 Accent Placement

Accent placement, too, can convey information about the structure of a discourse. Traditionally, it has been noted that stress, or accent, can convey information about the focus of an utterance, about given or new information in the discourse, about parallelism, or about contrastiveness. In more general terms, one might say that accent placement appears to be associated with Grosz and Sidner’s [15] attentional structure — the salience of discourse entities, properties, relations, and intentions at any point in the discourse. We have particularly noted that the decision to accent or deaccent some item is sensitive to the position of that item in the discourse structure — that is, just as salience is always determined relative to some particular context, accent placement must be determined with respect to the segment in which the accentable item appears. We take the position that it is the signaling of salience relative to the discourse segment that produces the secondary effects of given-new distinction, topic-hood or contrastiveness, and the favoring of one reference resolution over another.

One of the more common observations about the role of accent placement and the structuring of discourse is that accent can mark some item in the discourse as in focus — i.e., as ‘what is being talked about’ [28, 29] — particularly when syntactic or thematic information might predict otherwise. For example, in the following instructions, erase is accented in line 2 to indicate that the action of ‘erasing’ is the focus of the current task.

1. Type hello.  
   He H* L L~
2. Next, let’s erase hello.  
   He H* H* - L L~
3. Hit backspace.  
   He H* - L L~

For similar reasons, we accent hello in line 1 and deaccent it in line 2.

While focus considerations clearly influence accent placement, determining accent placement solely on the basis of utterance-level focus (as proposed in Gussenhoven [29] and Cum-
tutorial system itself. Since pronouns -- as ‘given’ information -- are commonly deaccented, we accent this one to indicate that an ‘unusual’ referent should be sought.10 So, both accent placement and manipulation of pitch range can be used to reorder the list of potential referents for a given referring expression.

Finally, contrastiveness or parallelism may also be communicated via accent. For example, second is accent in 3, although it is certainly given in this segment (via mention of second draft in 1):

1. Need a second draft?
   \( L^* H \ H \ L \ H^* \ H \)
2. No problem.
   \( H^* H^* H^* L \ L \)
3. Just change the first, and you’ve got the second.
   \( H^* \ H^* L \ H^* H^* H^* L \ L \)

Note that, while second may be ‘given’ at the discourse segment level, the decision to accent it is based on contrast within a smaller context, 3. Furthermore, if this function of accent is ignored, contrastiveness may be inferred incorrectly. If we accent see in the last line of the tutorial introduction WE will help you out, for example, the student would be entitled to infer that others will not be helpful.

We are currently developing algorithms for determining accent placement, based upon the interaction of focus, given/new, parallelism, contrastiveness, and pronominal reference within segment and phrase.

4.3 Choice of Tune

It is now widely accepted that the overall melody a speaker employs in an utterance can communicate some semantic or pragmatic information. However, since there are few particular tune types for which we can specify with any confidence just what the meaning might be, it is difficult to generalize about what type of information tunes in general can convey. From those tunes whose ‘meaning’ seems fairly well understood -- namely, declarative, yes-no question [23], surprise/redundancy [10], contradiction contour [33] rise-fall-rise [25], and continuation rise [34, 35] contours -- we propose that tunes convey two sorts of information about discourse.

First, we believe that contours can convey propositional attitudes11 the speaker wishes to associate with the propositional content of an utterance. For example, the speaker may wish to convey that s/he knows x, or that s/he believes x, or that s/he is uncertain about x, or that s/he is ignorant of x. In the case of \( H^*+L \) sequences, it appears that a speaker may convey his/her (propositional) attitudes about a hearer’s (propositional) attitudes toward an utterances. This tune seems to indicate the speaker’s belief that the speech act s/he is performing is superfluous. For example, a speaker may employ it to convey that the propositional content of his/her utterance is already known or would be obvious to the hearer (who, of course, may or may not be attending to it). Note that the speaker may or may not believe that this information is known, in order to wish to convey this meaning. Particularly in pedagogical texts, this contour seems appropriate to introduce straightforward material, as in the following instruction to hit the remind key:

Remind, tells you again what to do if you forget.

\( H^* L \ H \ H \ H^* H^* H \ H^* L \ L \)

Hit remind.

\( H^* L H^* L \ L \ L \)

However, an \( H^*+L \) sequence is not appropriate in the following similar exchange:

10. The standard example of accentuation influencing pronominal reference resolution in this way is ‘john hit Bill and then HE hit HIM’ [32].
11. Propositional attitudes include knowing, believing, intending, uncertainty, and ignorance.

In general, such contours do not seem felicitous when the utterance conveys information which the speaker believes will be unexpected for the hearer. Here tune choice may reflect attentional as well as intentional aspects of the discourse structure. Like the deaccenting of references to given items, \( H^*+L \) sequence contours seem to convey ‘givenness’ at a more general level.

Second, we believe that tune can convey the speaker’s commitment to some semantico-pragmatic structural relationship holding between the propositional content of utterances (as, that one ‘completes’ another or is subordinate to another). Many such relations have been proposed in textual analysis [35, 37, 15]. In the phonological literature, continuation rise has been commonly associated with some sense of ‘continuation’ or ‘more to come’ [34]. We have found, however, that this contour can be characterized more precisely as conveying a subordination relationship between the phrase uttered with continuation rise and other utterances in the discourse segment. For example, if the second phrase of line 1 is uttered with continuation rise, then this utterance appears to be subordinated to 2.

1. We can’t answer questions. If you are confused.
   \( H^* H^* H^* L \ H \ H \ L \ H^* \)
2. We have to let the computer do all the teaching.
   \( H^* H^* H^* L \ H \ H \)
3. But if the computer is not working right, we will help you out.
   \( H^* H^* H^* L \ H \ H \ H^* \)

That is, 2 ‘completes’ 1. Without continuation rise on 1, all three utterances will appear to have equal status in the segment. Furthermore, continuation rise is not felicitous in all contexts in which the simple sense that ‘there is more to come’ clearly should be appropriate; for example, continuation rise over 3 – at the end of the tutorial introduction – seems quite odd, even though more will clearly follow.

In synthesizing the TNT script, we have employed only a small subset of possible English tunes. Analysis of the ‘meaning’ of additional tunes is part of our future research. More generally, we must examine how structural relationships conveyed by tunes such as \( H^*+L \) sequence are associated with those conveyed by pitch range.

We have described certain mappings between intonational features and discourse phenomena, associating pitch range variation with the identification of discourse segments and with their internal coherence; accent with types of information status such as topic (focus) and the given/new distinction, with reference resolution and with contrastiveness; and tune choice with the relationships among propositions in the discourse as well as with some propositional attitude the speaker wishes to associate with those propositions. It appears that pitch range and accent placement are most closely associated with a discourse’s attentional structure, while tune choice is more closely associated with its intentional structure. However, clearly this picture is too simple. Several intonational features may be used together to create some discourse effect; moreover, in some cases two distinct intonational phenomena seem to produce discourse effects that seem intuitively to be closely related. And sometimes several discourse phenomena may indicate conflicting intonational strategies. These problems are the subject of our future research.

5. Discussion

The central thesis of this work is that there are many ways in which intonation helps to structure discourse. By understanding the mapping between intonational phenomena and discourse phenomena, we can enhance both our ability to interpret what
We have described three major intonational phenomena -- pitch range, accent, and tune -- and some of the information they allow speakers to communicate about discourse, demonstrating some links between discourse and intonational phenomena which have not been noted in the literature and refining some notions which have. We also identify major issues which future research on the relationship between discourse and intonation must address, including a more precise mapping between discourse and intonational phenomena, the interaction of intonational phenomena to produce particular discourse effects, and the way conflict between intonational strategies signaled by various aspects of the discourse may be resolved.

We are currently testing and refining our hypotheses by 1) pitch tracking recorded natural discourse to determine pitch range manipulation, and 2) conducting pilot empirical studies of how principled manipulation of pitch range can affect reference resolution. We are also examining in some detail the relationship between prononominalization and deaccenting, pursuant to the development of better accenting algorithms for synthetic speech. Our ultimate goals are practical as well as theoretical. Once we have determined how particular intonational phenomena are related to particular discourse phenomena, the next step is to determine how these findings can be applied to natural-language generation. In particular, how much intonational structuring of generated text can be done automatically? What sorts of information must be represented to support the assignment of rhetorically effective intonation?

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