Comparing Intonation

Eva Gårding

A comparison of intonation in different prosodic systems, analysed with the same method and described in the same manner, supports the opinion that such systems share some basic features. These common features are present in the underlying structures as well as their surface manifestations.

The goal of my paper is to substantiate this point. I shall draw from analyses of two tone languages, Hausa with two tones and Standard Chinese with four, and three accent languages, Swedish with two accents, English with one movable accent and French with one fixed accent (or none, depending on the analysis). (1)

Intonation without further specification is defined as the sum total of the main factors that shape the F0 curve, i.e. lexical and phrasal accents or tones, accentual or tonal expressions of information weight, speech act and boundaries.

In the first part, the intonation parameters used for analysis and description will be presented in schematic form together with their communicative functions. The second part gives real-life examples of these parameters and their correlations to lexical, syntactic and semantic properties. The third part describes a scheme which has been used to generate pitch for comparable sentences in some of the exemplified languages.

Intonational similarities and differences can be described in terms of this model.* Most of the material used in the following summary has been described in more detail elsewhere (see references).

1. Intonation parameters in schematic form

Figure 1 summarizes the main concepts of the model. The drawings, which are meant to have a logarithmic frequency scale, illustrate idealized cases consisting of at least two evenly accented words. There are several reasons for using such uncommon patterns. Focus has been avoided since it causes the F0 curve to deviate from its general direction, not just over the focused part but also over the neighbouring syllables. One-accent phrases have not been included since in such phrases the general direction is not so easy to catch. Phrases with sonorant segments have not been chosen to eliminate articulatory disturbances. An intonation curve of this idealized type has local maxima and minima, i.e. turning points. These turning points are part of a larger pattern, the grid, which is most easily seen if the main maxima are connected by a topline and the main minima by a baseline. When the turning points have been connected, as in the drawings, the grid appears as a sequence of units which are clearly rising, falling or level.

Each unit has a normal, expanded or compressed width, even to the extent of being best represented by one line only. The part of the grid where the direction or width is changed, or where the grid takes a jump, is called a pivot. An intonation unit is

---

* This last section was the main part of my contribution to the Working group on intonation at The XIIIth International Congress of Linguistics, Tokyo 1982, and has been published elsewhere (Gårding 1983c).

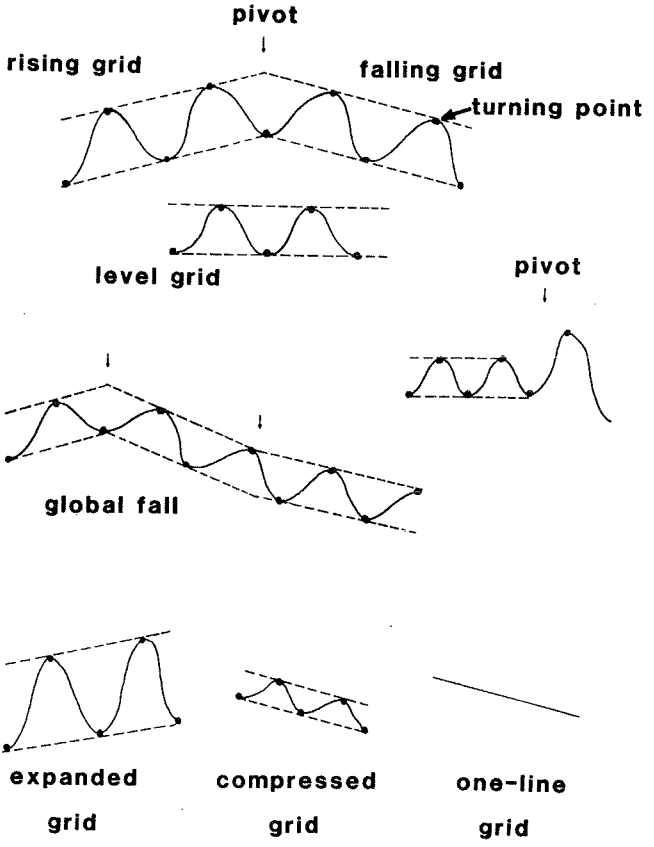


Figure 1. Concepts of the model, illustrated by schematic F0 curves connecting turning points over sonorant segments. Grids are marked by broken lines, pivots by arrows.

Intonation parameters	Function	
	Semantic	Syntactic
turning points	words, morphemes	d:o
pivots	constituents (theme/rheme)	d:o (subject/predicate)
grid: direction	speech act type	sentence type
grid. width, position	information weight (focus)	clause type

Table 1. Communicative function of the intonation parameters.

a piece of an utterance with an unbroken grid. The drawings reflect a superposition principle: lexical intonation is superimposed on a slowly varying phrase or sentence intonation, expressed by the grid. (2)

The concepts illustrated in Figure 1 are associated with the lexicon, syntax and semantics of the utterance, as summarized in Table 1. The local turning points signal words and morphemes. The pivots serve as semantic and syntactic boundaries. The general direction of the grid over the utterance, often in combination with the direction of the last intonation unit, is associated with speech act type and sentence type. These types may be declarative, interrogative and imperative to use the classical terms.

The width and position of the grid for an intonation unit signal its information weight relative to other intonation units. In this way the width and position of the grid may express coordination and subordination of various parts of an utterance. Of course, the prosodic structure, signalled by the intonation parameters, need not coincide with the semantic or syntactic structure of an utterance. It is possible to make a syntactic statement into a prosodic question and syntactic subordination may be completely eliminated by prosodic focus. In fact, there are many examples of prosody overruling syntax, particularly in spontaneous speech where intonation seems to be more closely related to semantics than to syntax. As a consequence, what is theme and rheme from the speaker's point of view can in general be identified unambiguously in such speech. Some examples will be shown in the next section.

2. Intonation parameters in real life

Turning points

An intonation curve can be efficiently described by the position in time and frequency of its end points and turning

points. In fact, being reasonably smooth, the curve can be obtained by smooth interpolation between these points over the voiced segments. The turning points are in general connected with accents and tones. The timing relations between segments and turning points are relatively constant in different prosodic contexts and crucial for the identification of words and morphemes in tone languages as well as accent languages. These relations are also important for the identification of boundaries.

In Hausa, a language with two tones, analysed as high and low, the turning points occur at the end of the syllable and are independent of sentence intonation (Fig.2). Note the wider grid of the question and its slightly different direction. In Standard Chinese, which has four tones, the highs and the lows are timed in relation to the syllables which in the majority of cases are also morphemes. Figure 3 shows a sentence consisting of a sequence of alternating falling and rising tones, uttered in different sentence intonations and focus patterns. Note that the timing of the turning points in relation to the segments is nearly constant throughout the prosodic contexts.

The two accents of Swedish have been described in different ways. Schematically both accents have triangular shapes, and in all dialects Accent 2 comes later than Accent 1. Their positions relative to the syllable vary with dialect. In some dialects the accent pair comes early relative to the accented syllable, in others late (Fig.4. Bruce and Gårding 1978).

Seen from the accented syllable only, Accent 1 can be high and Accent 2 low in one group of dialects. In another group of dialects the situation is reversed (e.g. Malmberg 1967). Neither way of analysing the accents seems linguistically interesting. The most attractive analysis is probably one that describes the accents by their highs and lows in the accented syllable and the adjacent ones (Elert 1970, Bruce 1983, Gårding 1981, Rischel 1963, Öhman 1966). This is necessary for a

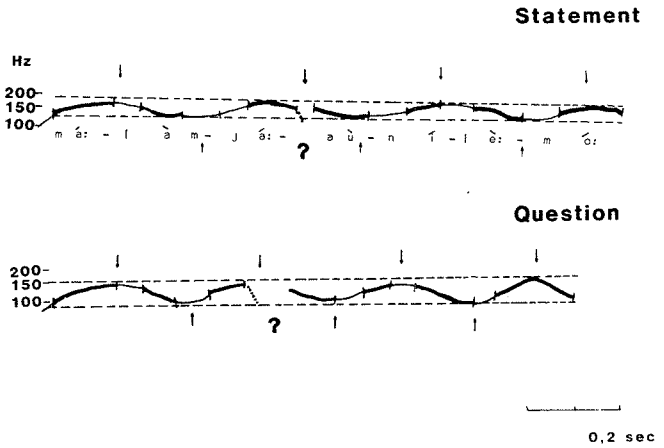


Figure 2. Turning point fixation in Hausa. Máalàm yáa aùní leèmóo. Teacher distributes oranges. The high /¯/ and low /ˇ/ tones occur at the end of the syllable marked by hyphen in the transcription. Thick lines denote vocalic segments. Arrows point to the turning points. Data from Lindau-Webb 1983.

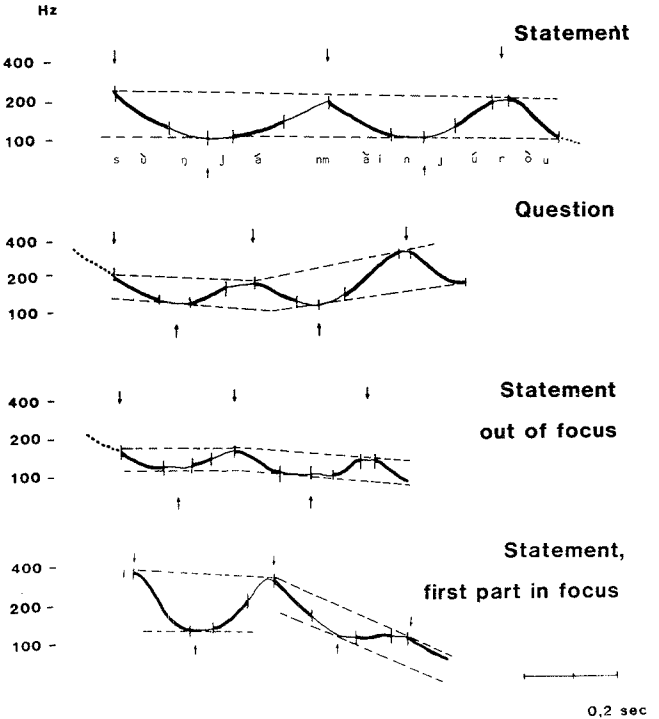


Figure 3. Turning point fixation in Standard Chinese. Sòng Yán mài niúròu. Song Yan buys calf's meat. Thick lines denote vocalic segments. Arrows point to the turning points. From Gårding et al. 1983.

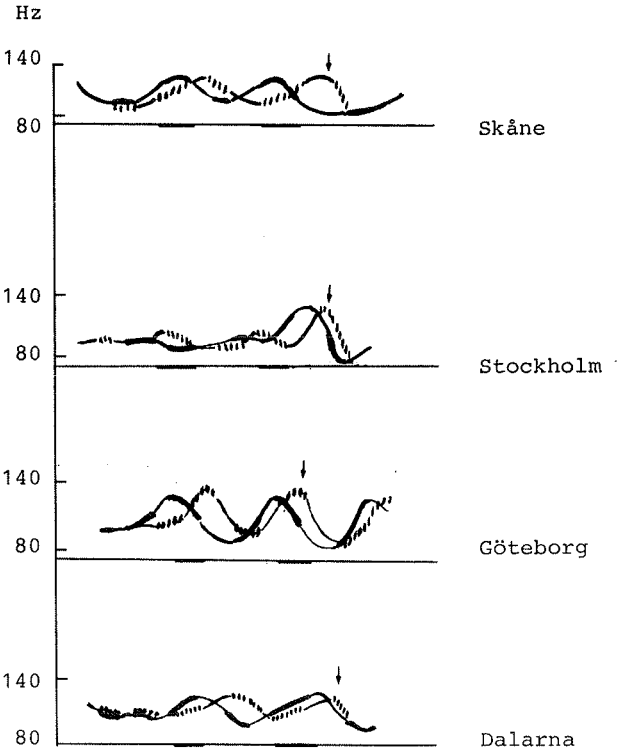


Figure 4. Comparable sentences with Accent 1 and Accent 2 in some Swedish dialects. Note the triangular shape of the accents and that Accent 2 follows Accent 1 in all cases. Note also that the accent pair is earlier in e.g. Skåne than in Dalarna relative to the accented syllable. In the accented syllables, marked by horizontal lines, Accent 1 is high and Accent 2 low in one dialect, e.g. Skåne. The situation is reversed in other dialects. Further discussion in the text.
From Bruce & Gårding 1978.

satisfactory analysis of dialectal variation and brings out the original function of the accents as markers of the word structure.

In Germanic languages outside of Scandinavia the turning points of accents are more or less fixed within the syllable but may alternate between high and low depending on the speech act intonation and the position in the phrase. Figure 5 shows how a focal high in a falling statement intonation corresponds to a low in a question (Bannert 1983, Gårding 1983c).

The grid

The sketchy definition of a grid given earlier needs some additional comments. When this notion is applied in the actual analysis of FO curves, the analyst has to bear in mind that the curve is the sum total of various elements in speech, segmental as well as suprasegmental. We cannot expect toplines and baselines, drawn automatically by connecting local maxima and minima to be a true representation of what is perceived as phrase or sentence intonation. Coarticulation effects, accentual patterns, boundary phenomena and pivots have to be recognized. There is at present no general algorithm for the construction or recognition of a grid.

Nevertheless, when the pivots have been identified, there is in most cases a natural grid, at least over intonation units that are not too short. This grid should reflect speech act, phrasing and accentuation. Connecting the maxima and minima of natural speech does not ordinarily give the idealized shapes of Figure 1 but more often wedge-shaped ones depending on the accent pattern. Figure 6 illustrates the difference between an automatically drawn grid and a grid that reflects the linguistic prosodic elements present in the intonation curve.

The intonation curve, the same in both cases, is derived from the Swedish sentence 'Hon gick inte o(ch) la sej', She did not go to bed, in an interrogative intonation. With an

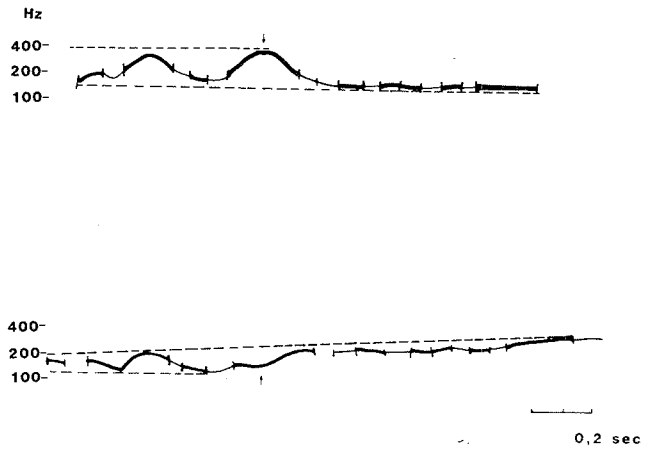


Figure 5a. Turning point fixation in English. I heard the BULLS bellow in the lane above and Did you hear the BULLS bellow in the lane bellow. The arrows point to the high and low focal turning points of bulls in the two cases.

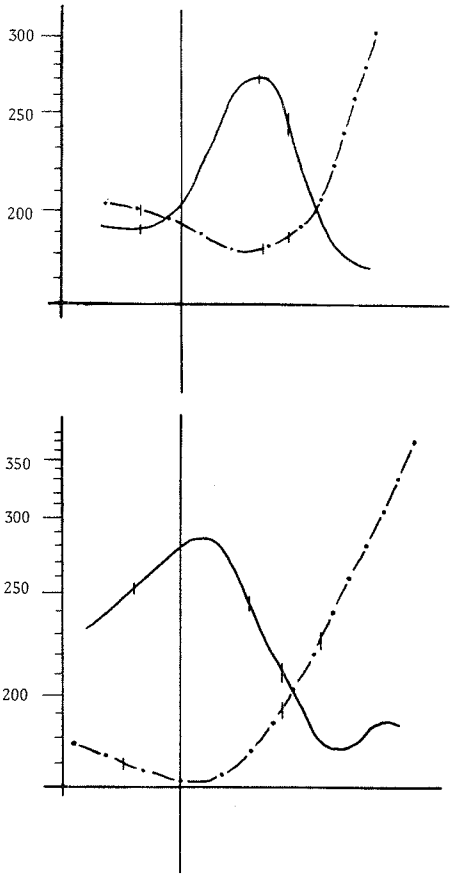


Figure 5b. Turning point fixation in German. Der Mahner. Two speakers of northern German. Solid line for statement and broken line for question. Vertical line indicates the beginning of the accented vowel. Bannert 1982.

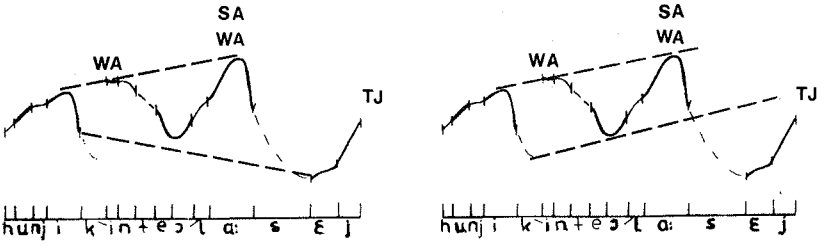


Figure 6. An automatically drawn grid left and a grid where the terminal juncture (pivot) has been recognized to the right. WA=word accent, SA=sentence accent, TJ=terminal juncture

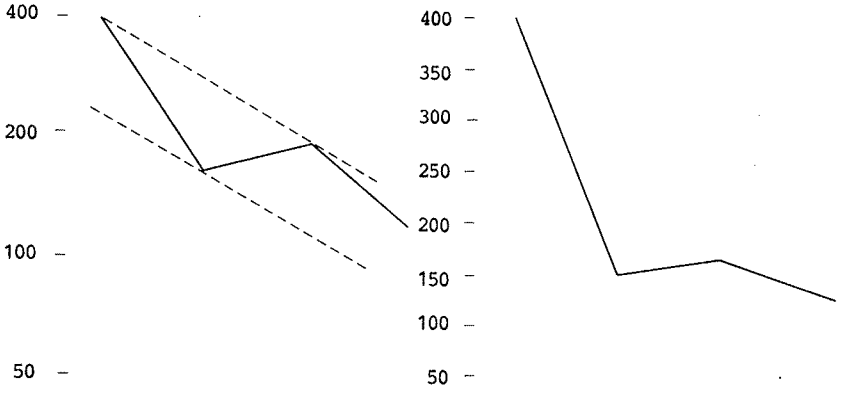


Figure 7. Fourth example of Figure 3 in logarithmic scale to the left and in linear scale to the right. The logarithmic scale lends support to the grid construction.

automatically drawn grid, as in the curve to the left, the baseline would be realized as falling and the topline as rising. This construction does not give a very clear picture of the prosodic events and their contributions to the curve.

If we presuppose the existence of a grid reflecting sentence intonation, as in the curve to the right, we get a rising grid enclosing the accents as a global expression of interrogative intonation and at the end a pivot. This pivot is manifested by the wide F0 range in connection with sentence accent (SA), and the terminal juncture (TJ), a rise from the bottom of the voice, is a local marker of the interrogative speech act.

As in the example above, the grid should as much as possible consist of approximately parallel lines on a logarithmic scale, broken at the pivots. In this way it brings out the direction of intonation while the width of the grid reflects the information weight of the corresponding phrase.(An accentual pattern with alternating strong and weak accents will have to be discussed separately.) To sum up, a single line is not sufficient to express all the information that can be provided by the grid.

For the grid to fit large pitch ranges, it is essential that the scale be logarithmic. (A logarithmic scale has also been used and motivated by Fujisaki, 1969.) Compare the fourth example of Figure 3 with the same phrase drawn to a linear frequency scale (Fig. 7).

With the linear scale the upper part of the curve is blown up out of proportion with the lower part and does not convey the auditory impression of a gradual fall.

As already mentioned the direction of an intonation unit is closely associated with the sentence type and speech act type and with its position in the sentence. The use of a falling grid to express a declarative speech act and a rising or level

one to express interrogation are common features for perhaps the great majority of the languages of the world (Bolinger 1977). An important part of the manifestation of speech acts seems to be carried by the last intonation unit. This means that speech acts can have a global and/or local expression. Figure 3 shows a level grid for a statement with a local drop to creaky voice at the end, a rising grid from the subject (theme) in the question and a falling grid from the subject (focused rheme?) in the last utterance. In the Hausa example (Fig.2) the change of direction is smaller, but here the width and the tempo increase in the question.

Focus is in general expressed as an expansion of the grid in connection with the part in focus, and this expansion is often combined with a compression of the part which follows after focus. Examples are shown in Figure 3 and Figure 8. In Hausa the focused word is always initial and a prosodic signal is not necessary. In languages without distinctive accents or tones, the unfocused part is compressed into a one-line grid. Figure 8 shows how the accentual up-and-down movements are almost completely flattened out in French and Greek after focus but not in an accent language such as Swedish, nor in a tone language such as Chinese (Fig.3) A support for a tonal grid encompassing the lexical tonal prosody is given by the strongly compressed accent and tone configurations after focus. Here the lexical points have retained their positions not only in relation to the segments but also to the grid. For a strongly falling grid this may have the effect that a rising tone may have constant pitch (Gårding 1983).

Pivots

There are many kinds of pivots depending on the nature of the two adjoining intonation units and the possible large-scale movements involved at the juncture. Apart from the ones shown in Figure 1, some additional examples are given in Figure 9. It is clearly possible to assign different weights to pivots where greater weight is associated with more important syntactic and

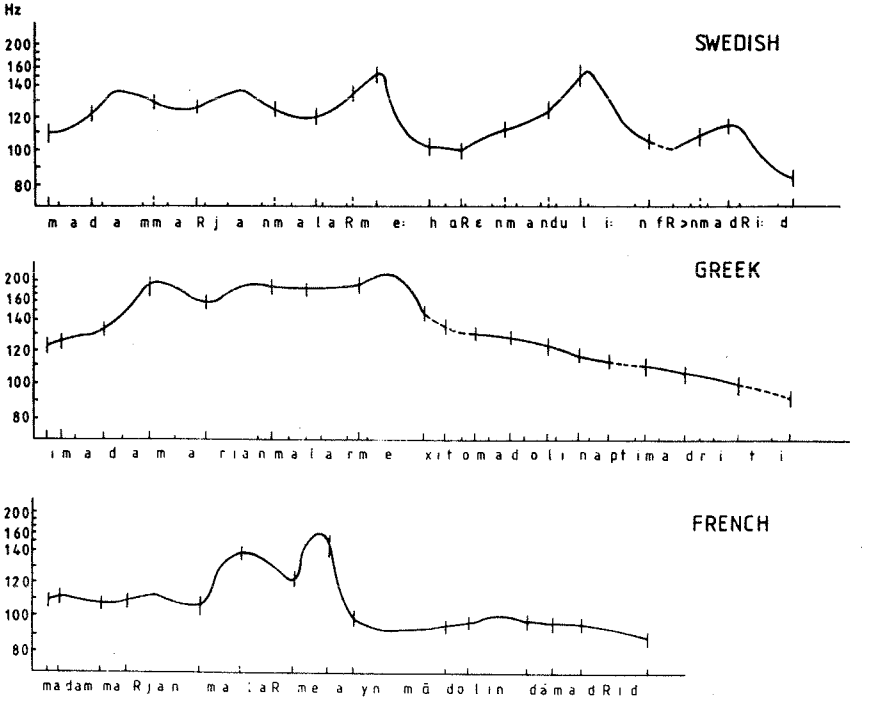


Figure 8. Language-specific ways of manifesting focus. Madame Marianne Mallarmé a une mandoline de Madrid in French and in comparable sentences in Swedish and Greek.

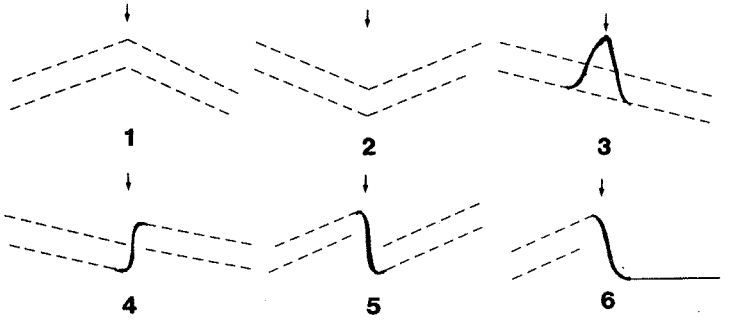


Figure 9. Different kinds of pivots. The direction of the grid changes (1,2). A pivot which does not change the direction of the grid (3). Pivots with resettings of the grid (4,5,6). Flattening of the grid after pivot (6).

semantic-pragmatic boundaries. A change of position as in 4 seems to mark a stronger break in coherence than a change of direction as in 1 or 2.

A strong degree of coherence between two sentences of a text may be shown by a unidirectional falling grid as in Figure 10 with a junctural pivot to mark the sentence boundary. A lesser degree of coherence is produced by a new, upshifted grid as in the same figure. Similarly two rising interrogations are connected by a downshifted grid (Fig.10). Figure 11 shows fundamental frequency curves of "Marie a une mandoline de Panama" and the corresponding sentence in Swedish, both pronounced as the first sentence of a short story. The intonation has certain traces of the syntactic structure of the sentence. In connection with the main syntactic boundary, there is a light pivot with a change in the direction of the grid in both languages.

The introduction of focus in the sentence, as in examples 2A

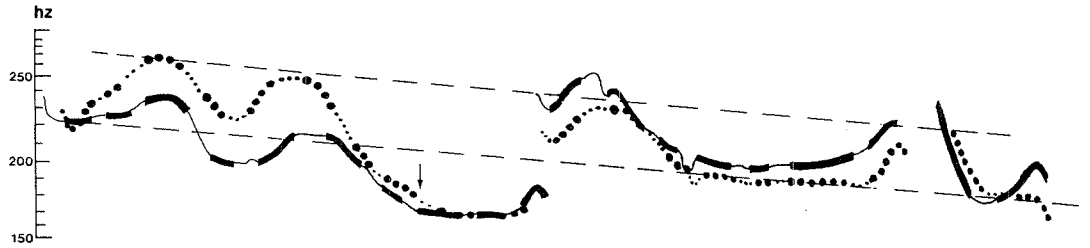
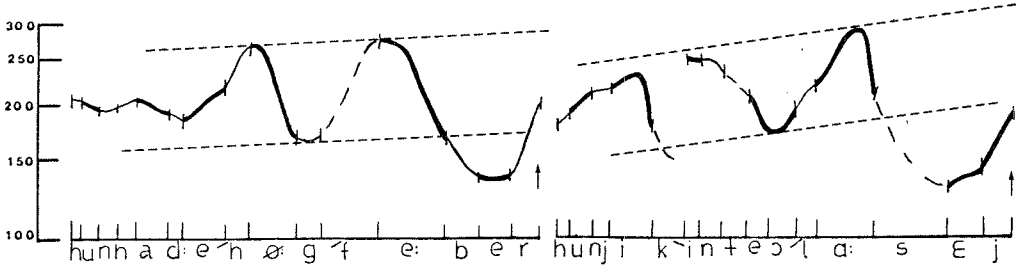


Figure 10. Coherence of phrases.

(a) Man anammar lundamodellerna 'They accept the Lund models', Lundamodellerna är lockande 'The Lund models are appealing'. The dotted lines shows declarative intonation stretching over two sentences with a common grid indicated by broken lines. The pause between the two sentences has been omitted. The solid line shows corresponding sentences each with a declarative intonation of its own and an upshift of the grid (not marked in the figure). This gives the impression of a fresh start and more emphasis to the second sentence. The arrow points to the terminal juncture fall, similar in both situations. From Bruce 1982 apart from the grid lines.



(b) Hon hade hög feber? 'She had a high temperature?', Hon gick inte och la sig? 'She did not go to bed?' Interrogative intonation in two connected sentences with a downshift of the grid. The speaker avoids going beyond her natural range. The arrow points to the terminal juncture rise. From Gårding 1982.

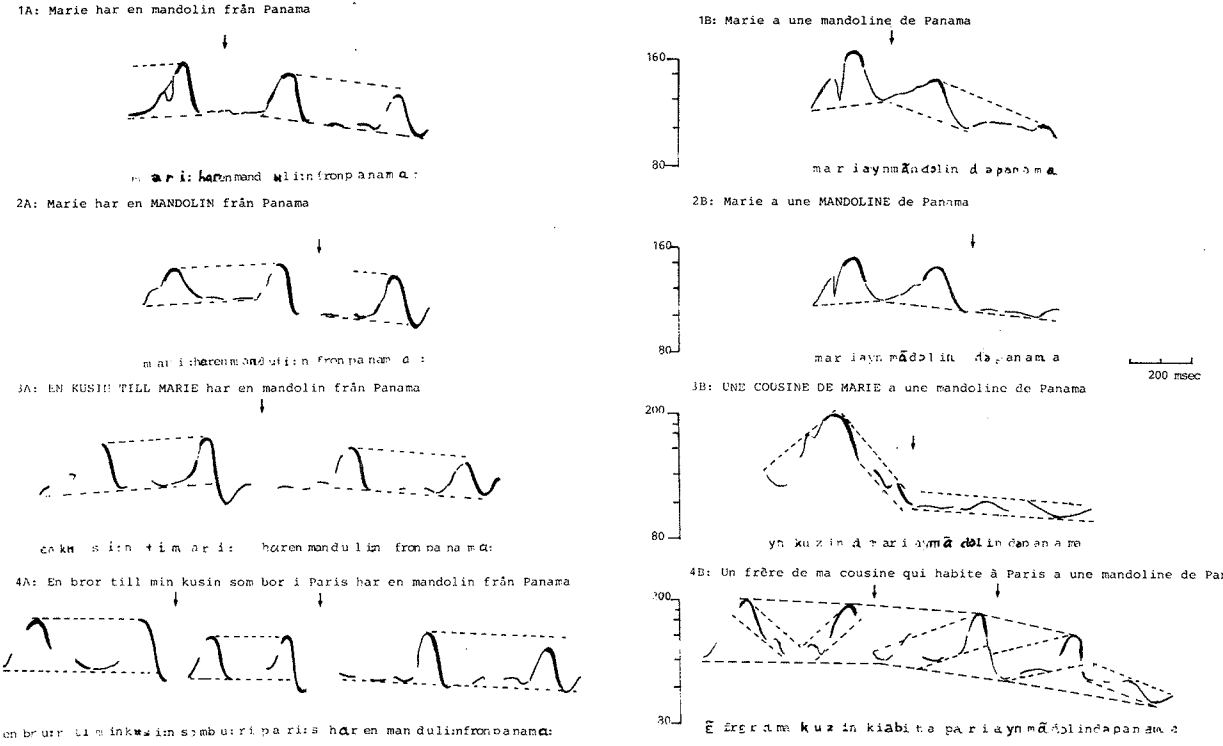


Figure 11. Some functions of intonation in French and Swedish.
From Gårding 1983

and 2B, produces a strong pivot after the focused word, splitting the sentence into a thematic part and a rhematic part. In the Swedish dialect exemplified here, the strong pivot is manifested as a large-range downward movement preceding the directional change of the grid. In the French example the grid is compressed after focus. In both languages the position of focus is free and the focal pivot divides the sentence into parts which are not given by the syntax but by the theme-rheme division chosen by the speaker.

The last pair of examples from French and Swedish show similarities and differences in the use of pivots and grids. In the Swedish example, the non-restrictive relative clause is set off by a compressed grid and the unity of the main clause is signalled by a continuation of the gradually declining topline of the first intonation unit. The intonation units here are well correlated with syntax but they have at the same time a more general semantic function, that of subordinating information parenthetical to the main message. In the corresponding French example the grid is broken more frequently by pivots. In this way the information units are shorter and have steeper slopes. In fact, intonation units in French can be said to play the role of accents in Swedish, namely to signal content words with appended functional items. In the French sentence the relative clause is set off by jump-down pivots. To show the global direction of the sentence intonation, the highs and lows of the intonation units have been connected. This global grid is falling as in Swedish, and both languages have an extra local fall on the last semantic unit, Panama.

3. Comparison in terms of a generative model for intonation

The analytic scheme demonstrated in the preceding sections has been worked out in connection with a generative model for prosody which has been the object of several articles since the mid seventies (see Gårding 1981, 1983a and references there).

Its object is to generate prosody in different languages in a uniform way. Here I shall only give a brief sketch.

The most important feature of the model is that it factors out utterance prosody from lexical prosody by a grid construction. The input to the model is a sentence with phonological markings. In the first stage correct syllable durations are generated from the input markings. In the second stage the phonological markings are subject to intermediate phonological rules which concern context rules at the symbol level. Exemples of such rules are the deletion of accent marks after focus in some languages and Chinese sandhi rules. In the following stage the accents or tones are converted into highs and lows or combinations of these features. Finally pitch is generated. Characteristic of the pitch generating scheme is that the sentence and phrase intonation are generated first from the speech act markings and boundaries in the form of a grid. The lexical highs and lows are then given their proper positions relative to the syllables and their frequency values relative to the grid. The next step modifies these positions by accentual rules and context rules. Finally the curve is obtained by smooth interpolation over the voiced segments through the points generated earlier. Figure 12 shows the model and the principles of the pitch generating scheme.

The generative model is useful for characterizing prosodic systems and comparing them. A summary of the intermediate phonological rules, the intermediate pitch representations and the rules of the pitch algorithm constitutes the main features of the intonational profile of a language or dialect. By adding an account of the function and distribution of the prosodic features needed in the input, we obtain something that could be called a prosodic grammar (Gårding 1983a). The uniform way in which such grammars can be obtained makes prosodic comparisons, also point by point, meaningful. To carry out this program for a sizable corpus of languages is of course a very large undertaking, but even with our small set of prosodically

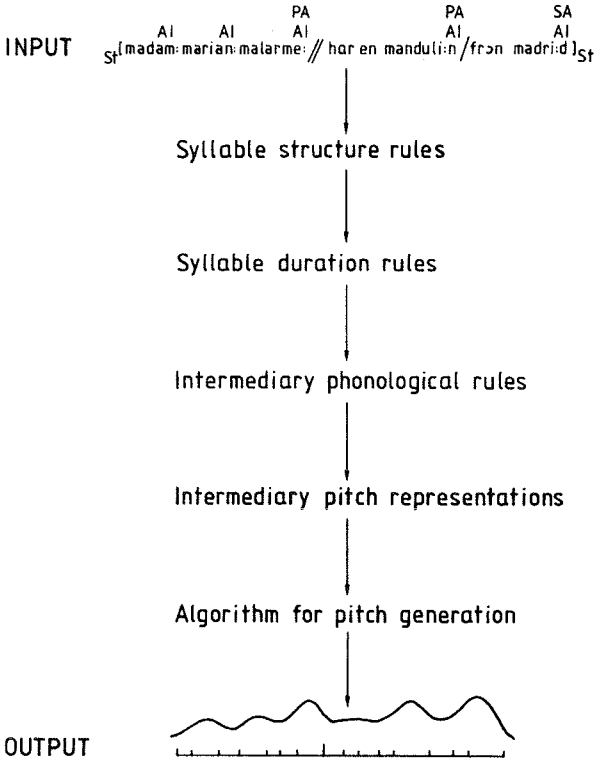


Figure 12a. Model for prosody and principles of the pitch algorithm.

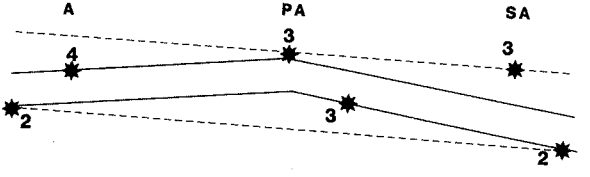


Figure 12b. Priciples of the pitch algorithm. Typical grid with insertion of Highs and Lows.
PA=phrase accent, SA=sentence accent, A=word accent

different systems and limited analyses, it is possible to venture some conclusions.

Grids and pivots

The notions of grid and pivot are applicable in a natural way to the languages analysed so far. Speech acts as manifested by grids seem to exhibit the following general features. They can have a global and/or local expression. In polyphrasal utterances it is the last phrase that carries the main part of the speech-act information. The intonation of the preceding phrase(s), at least in preplanned speech, is adjusted to fit the last phase of the sentence in an optimal way. A rising speech-act contour is preceded by a falling or level one and vice versa.

A falling final intonation unit expresses terminality in a general sense and is strongly connected with the declarative speech act. A rising or level intonation unit expresses non-terminality and connects with an interrogative speech act. The same is true of falling and rising (level) global patterns. This is a general tendency in the languages of the world (Bolinger 1978).

Focus is expressed as an expansion of the grid in connection with the part in focus and this is often combined with a compression of the part which is outside focus. At this point there is a difference between languages with lexical tones and accents and those without lexical prosody. Lexical tones and accents seem to prevent too much compression of the grid.

Accents and tones

The manifestation of accents and tones are local features of an intonation curve where highs or lows or a combination of highs and lows are fixed in time to specific parts of the carrying segments. This turning-point fixation seems to be a general feature. On the other hand, morpheme-bound tones and word-bound accents bring about some essential differences of phonological

as well as phonetical nature. Take for instance Chinese and Swedish. Pitch goes up and down more often in Chinese than in Swedish, evidently because of the greater functional load of the Chinese tones. The pitch range is wider in Chinese, and this is at least partly due to the fact that a rising or high tone in focus expands the range upwards towards the ceiling of the voice whereas falling and low tones go in the other direction (Gårding et al. 1983, Gårding 1984). In Swedish, focusing is achieved by the same principle, only here the effect will be dialect dependent. In a dialect with rising accents, focus raises the highs, while in a dialect with falling accents, the lows will lowered.

Prescriptions for the location of tones and accents in relation to the syllables show some important differences in tone and accent languages, even if the phonological representation is the same. The turning point of a Swedish accent, it may be high or low, tends to be located in the middle of the vocalic segment which is closely associated with the intensity maximum. This position is slightly shifted in focal or emphatic context (Gårding 1983c). This does not seem to be the case in Chinese. Here the turning point is connected with the syllable-initial consonant. We are reminded of the classical discussion of tones and accents as having different physiological mechanisms.

Superposition

The principle of regarding intonation as the sum of a phrase intonation component and a lexical component is suitable for all the languages that have been analysed here. It finds its expression in the grid as a frame for the accentual and tonal pitch movements. More precisely, the accents or tones are superimposed on a slowly varying intonation.

Conclusion

To conclude this paper let me try to express an overall view of

the manifestation of intonation which has emerged from the comparison of some different prosodic systems. Intonation curves in general can be said to have a threefold structure, each part encompassing the next, namely

(1) a global pattern of linear elements, related to sentences and speech acts
(2) a short-term linear structure, related to phrases and
(3) a local wave structure, related to lexical accents and tones.

Notes

1) Intonational similarities and differences between languages have also been studied by Jacqueline Vaissière, see e.g. Vaissière 1983, with overlapping results.

2) Superposition is implied in the metaphors used by Bolinger for accents as 'ripples on waves' (1964) and similary by Chao for tones (1968). Superposition was used explicitly in a quantitative model of intonation by Öhman (1967), Fujisaki (1969) and in my own qualitative model (1970 and subsequent papers), Mc Allister (1971), Thorsen (1978) and several others. The superposition principle has been considered contrary to the tonal sequence principle advocated by Pierrehumbert (1981). See Thorsen (1983).

REFERENCES

Bannert, R. 1982. Temporal and tonal control in German. Working Papers 22, Department of Linguistics, Lund University: 1-26

Bolinger, D. 1964. Intonation as a universal. Proceeding of the International Congress of Linguistics 1962, ed. Lunt. The

Hague: Mouton

Bolinger, D. 1977. Intonation across languages. In Universals of human language, ed. Greenberg, Vol.2: Phonology. Stanford University Press: 471-524

Bruce, G. 1977. Swedish word accent in sentence perspective. Travaux de l'Institut de Linguistique de Lund XII. Lund: Gleerups

Bruce, G. 1982. Experiments with the Swedish intonation model. In Preprints of Working group on intonation, eds. Fujisaki and Gårding, Tokyo: 35-45 and Working Papers 22, Department of Linguistics: 51-116

Bruce, G. and Gårding, E. 1978. A prosodic typology for Swedish dialects. In Nordic Prosody, eds. Gårding, Bruce & Bannert, Travaux de l'Institut de Linguistique de Lund XIII: 219-228

Chao, Y.R. 1968. A grammar of spoken Chinese. Berkely and Los Angeles

Elert, C.-C. 1970. Ljud och ord i svenskan. Stockholm: Almquist & Wiksell

Fujisaki, H. and Nagashima, S. 1969. A moel for synthesis of pitch contours of connected speech. Annual Report Eng. Res. Inst., University of Tokyo, vol. 28: 53-60

Gårding, E. 1970. Word tones and larynx muscles. Working Papers 3, Phonetics Laboratory Lund University: 20-46

Gårding, E. 1981. Contrastive prosody: A model and its application. Special lecture to the AILA congress 1981. Proceedings II, eds. Sigurd & Svartvik, Studia Linguistica 35, 1-2, 81, Gleerups: 146-166

Gårding, E. 1982. A comparative study of intonation. In Preprints of Working group on intonation, eds. Fujisaki & Gårding, Tokyo: 85-94

Gårding, E. 1982. Prosodic expression and pragmatic categories. Working Papers 22, Department of Linguistics, Lund University: 117-136. Also in Textstrategier i tal och skrift. Almqvist & Wiksell International, 1982

Gårding, E. 1983a. A generative model of intonation. In Prosody: Models and measurements, eds. Cutler & Ladd, Springer: 11-25

Gårding, E. 1983b. Intonation units and pivots, syntax and semantics. In Abstracts of the tenth international congress of phonetic sciences, eds. Cohen & v.d. Broecke, Foris: 99-103

Gårding, E. 1983c. Superposition as an invariant feature of intonation. Contribution to the MIT conference of Invariance and variability of speech signals. In press

Gårding, E. 1984. Chinese and Swedish in a generative model of intonation. In Nordic Prosody III, ed. Elert, University of Umeå

Gårding, E. and Lindblad, P. 1973. Constancy and variation in Swedish word accent patterns. Working Papers 7, Phonetics Laboratory Lund University: 36-110

Gårding, E., Botinis, A. and Touati, P. 1982. A comparative study of Swedish, Greek and French intonation. Working Papers 22, Department of Linguistics, Lund University: 137-153

Gårding, E., Zhang, J. and Svantesson J-O. 1983. A generative model for tone and intonation in Standard Chinese. Working

Papers 25, Department of Linguistics, Lund University: 53-65

Lindau Webb, M. 1983. Tone and intonation in Hausa. Paper presented to the tenth international congress of phonetic sciences.

Malmberg, B. 1959. Bemerkung zum Schwedischen Wortaccent. Zeitschrift fur Phonetik und allgemenie Sprachwissenschaft 12, 193-207

Mc Allister, R. 1971. Predicting physical aspects of English stress. Speech Transmission Laboratory, QPSR, Royal Institut of Technology, Stockholm: 20-29

Öhman, S. 1966. Generativa regler för det svenska verbets fonologi och prosodi. Förhandlingar vid sammankomst för att dryfta frågor rörande svenskans beskrivning III: 71-87

Öhman, S. 1967. Word and sentence intonation: A quantitative model. QPSR, Speech Transmission Laboratory Royal Institute of Technology, Stockholm, No 2/3: 20-54

Pierrehumbert, J. 1980. The phonology and phonetics of English intonation. MIT doctoral dissertation

Rischel, J. 1963. Morphemic tone and word tone in Eastern Norwegian. Phonetica 10: 154-164

Thorsen, N. 1978. An acoustical analysis of Danish intonation. Journal of Phonetics 6: 151-175

Thorsen, N. 1983. Two issues in the prosody of standard Danish. In Prosody: Models and measurements, eds. Cutler & Ladd, Springer: 27-38

Vaissière, J. 1983. Language-independent prosodic features. In Prosody: Models and measurements, eds. Cutler & Ladd, Springer: 53-66