



Language-independent prosodic features

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7 PRINCIPES DE COMPARAISON PROSODIQUE ENTRE LES LANGUES

7.1 LANGUAGE-INDEPENDANT PROSODIC FEATURES (ARTICLE)

5.1 Introduction

The purpose of this contribution is to investigate the similarities in form and function of prosody among diverse languages. All speakers, regardless of their specific language, are equipped with the same production and perception apparatus, and consequently have the same capabilities and must face the same physiological constraints. Such similarities should be reflected in the acoustic production of any speaker. The first specific aim of this contribution is to review a number of striking acoustic similarities in the suprasegmental aspects of neutral sentences in different languages, together with possible physiological explanations for them.

Since the global function of speech (i.e. communication) is language independent, the type of information conveyed by the speech signal should not vary greatly among languages. The second purpose here is thus to compare the linguistic functions assigned in several languages to similar suprasegmental phenomena, such as lengthening, fundamental frequency rises and falls, and intensity peaks.

Although the use of suprasegmental variation for paralinguistic functions (such as the expression of emotion) is also of prime importance in everyday conversation, the scope of this contribution is restricted to the strictly linguistic functions of prosody.

5.2 Language-Independent Similarities

5.2.1 Pauses

Acoustic analysis of speech production shows that speakers insert a large number of pauses while talking. Studies have indicated that the ratio of articulated sequences to total speaking time does not differ significantly from one language to another: at least, Grosjean and Deschamps [1975] have found no difference for such a ratio between native speakers of English and of French in radio interviews (about 83% for both languages).

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The first language-independent primary function assigned to pauses is that of grouping. Speakers tend to draw breath at the end of large conceptual units such as sentences and clauses. Pauses between sentences tend to be longer than pauses within sentences (Goldman-Eisler [1972] for English; Grosjean and Deschamps [1973] and Duez [1982] for French). The use of pauses as a major boundary marker between and within sentences seems to be similar across those languages for which there are available data. Black et al. [1966] found no significant differences in the use or location of pauses by speakers of English, Hindi, Japanese and Spanish. However, the length of pauses and their distribution per number of syllables may differ slightly from one language to another: Grosjean and Deschamps [1975] found that native speakers of French tend to pause less often but for a longer time than native speakers of English.

There also exists another type of pause, generally not located at grammatical junctures, the so-called hesitation pause. The duration and frequency of both types of pauses seem to depend on a larger number of factors, such as speech rate, speech mode, age and experience of the speaker, emotional state, and the pursuit of stylistic effects. At fast speech rates, pauses within sentences tend to be suppressed [Grosjean and Collins, 1979]; pauses are more frequent in descriptions than in interviews [Grosjean and Deschamps, 1973]; in political speeches, pause distribution tends to be more in agreement with grammatical structure than it is in interviews [Duez, 1982]. German and English adolescents make more ungrammatical pauses than adults while reading [O'Connell and Kowal, 1972]. Advanced students make longer and more judicious pauses in reading than inexperienced students [Clemmer et al., 1979]. In the sixth repetition of a spontaneous description, subjects made only half as many pauses as in the first repetition [Goldman-Eisler, 1968], and made fewer and shorter pauses when reading unusual stories as compared to ordinary ones [O'Connell et al., 1969]. Variations in semantic context can produce changes in the number of unfilled pauses in a situation in which syntactic and other variations are minimized, for both German and English speakers [O'Connell and Kowal, 1972]. Pauses also depend on the emotional state of the speaker [Fairbanks and Hoaglin, 1941], and are often used before words with low transition probability [Cowan and Bloch, 1948; Maclay and Osgood, 1959]. All such factors seem to be largely independent of language.

Speech is produced by modulating the airflow from the lungs. As a consequence, it is necessary for all speakers to insert a certain number of respiratory pauses while speaking. Respiratory pauses, which represent only a part of all pauses, can be considered physiological necessities. The constraints due to the production apparatus explain the basic similarities in pausing between languages. The probability of occurrence of a pause during continuous speech seems to depend on the amount of residual air in the lungs [Fujisaki and Sudo, 1971]. It has been shown by Grosjean and Deschamps [1975] that breathing during speech exerts an influence at similar time intervals indepen-

dently of the language spoken (here English and French). The most striking similarity between languages is that breathing (respiratory pausing) occurs at grammatical junctures. At fast rates, the physiological need to breathe is the sole determinant of pausing [Grosjean and Collins, 1979]. Fodor et al. [1974] have suggested that breathing is dependent on syntax: speakers will only breathe when allowed to do so, as it were, by the constituent structure of the utterance.

5.2.2 Fundamental Frequency Features

Figure 5.1 summarizes the general properties of F_0 curves in simple sentences pronounced in a single breath-group (that is, without pauses), as observed in a number of languages. We will review in turn the declination tendency of the F_0 curve, the resetting of the baseline, the control of F_0 range, and F_0 rising versus F_0 falling movements.

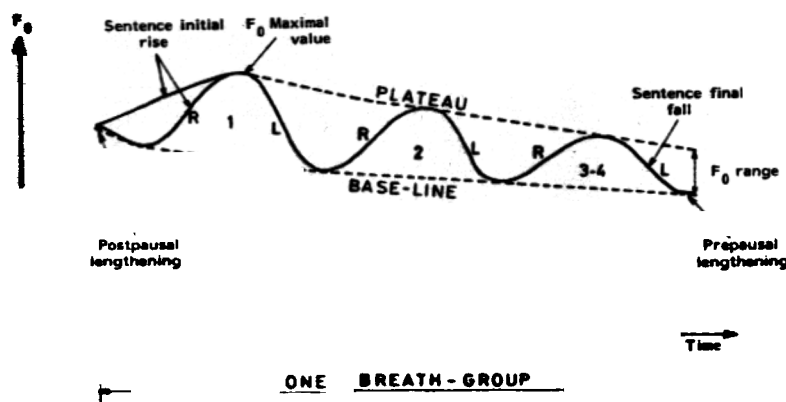


Fig. 5.1. General properties of F_0 contours observed in unmarked sentences in a number of languages. The common tendencies are the following: (i) a tendency for F_0 values to fluctuate between two abstract lines: the *plateau* and the *baseline*, which delimit the speaker's F_0 range; (ii) a tendency for the F_0 range to diminish as a function of time; (iii) a tendency to start sentences with a large *sentence-initial rise* in F_0 , located on one of the first syllables, or *spread* over the first few syllables; (iv) a tendency to repeat a succession of F_0 rises (R) and lowerings (L): a pair of opposing movements indicates a prosodic word (see text); (v) a tendency for the *maximal value* of F_0 to be located on the first prosodic word of the sentence; (vi) a tendency to lengthen the duration of the last syllable at the end of the breath-group (*prepausal lengthening*), and of the first phoneme at the beginning of the sentence (*postpausal lengthening*)

a) The Declination Tendency

In relatively long stretches of continuous speech, there is a global tendency for the F_0 curve to decline with time, despite successive local rises and falls

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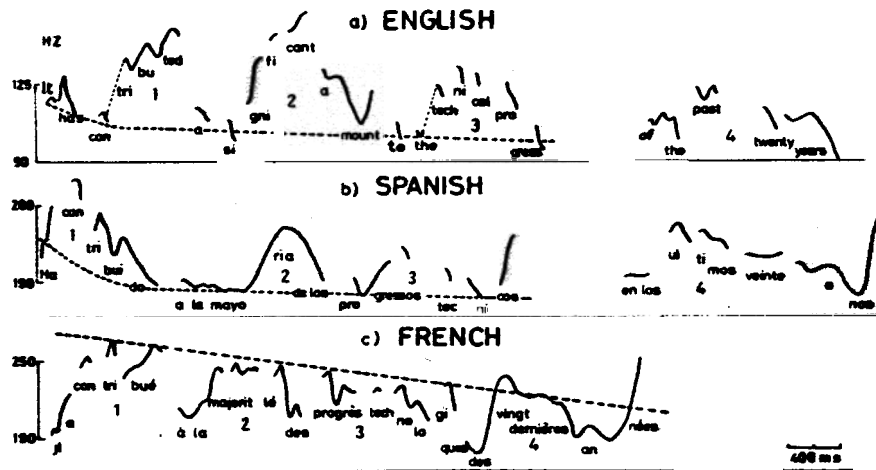


Fig. 5.2a-c. F_0 contours for the same clause translated into three languages and pronounced by native speakers: (a) "It has contributed a significant amount to the technical progress of the past twenty years, ..."; (b) "Ha contribuido a la mayoría de los progresos técnicos en los últimos veinte años, ..."; (c) "Il a contribué à la majorité des progrès technologiques des vingt dernières années, ...". The pauses and the rise-fall pairs in F_0 combine to divide the three clauses into four prosodic words (numbered 1 to 4)

(for Dutch, Cohen and 't Hart [1967]; for English, Maeda [1976]; for Italian, Magno-Caldognetto et al. [1978]; for Japanese, Fujisaki et al. [1979]; for tone languages, Hombert [1974]). Figure 5.2, which shows the F_0 contours of the same utterance translated into three different languages and spoken by a native speaker of each language, illustrates this tendency.

Several physiological explanations have been proposed. The F_0 declination could be mainly due to the decline in transglottal pressure (proposed by Lieberman [1967] and partially refuted by Hixon et al. [1971], to a trachea pull [Maeda, 1976, p. 220 ff.], or to a laziness principle (the rise supposedly being harder to produce than the falls [Ohala and Ewan, 1973]). The different explanations primarily invoke the production apparatus and are compatible with one another. The declination tendency has also been proposed to be a by-product of the perceptual system [Pierrehumbert, 1979]. The rate of declination has been found to vary with a number of factors, but no cross-linguistic differences have yet been proved.

Declination is a general tendency easily detected from a visual inspection of relatively long stretches of F_0 curve, but calculation of the exact rate of declination is a difficult task. For some speakers, the tendency seems to be adequately described by a constant rate of declination ("the declination line"), while for others, there is a tendency for F_0 to decrease more rapidly in the first part of the sentence, and then to decrease less rapidly or even stay flat (exponential declination). The slope of declination is not entirely phy-

siologically determined, but is partially controlled by the speaker. It has been shown that the speaker often adjusts the rate of declination with the length of the sentence, at least in isolated sentences: the shorter the sentence, the more rapid the declination. When the sentences are part of a text, the correlation between rate of declination and length of utterance is less obvious; in spontaneous speech, many sentences do not even display such a tendency. Furthermore, the declination tendency has been shown to be often suppressed in interrogative sentences (both in spontaneous speech and in read sentences).

It may be suggested that the rate of declination contributes (together with other features) to the perception of a sentence spoken in the declarative mode as an acoustic whole; its presence versus its absence contributes to the contrast between declarative and interrogative sentences (for French, Contini and Boé [1975]; for Danish, Thorsen [1980 a]; for Russian, Svetozarova [1975]; for a tone language, Ho [1977]; for a number of other languages, Lieberman [1967]).

We may conclude that as for pauses, the natural tendency for F_0 to decline has been integrated into the linguistic code, in the form of controlling or entirely suppressing the F_0 decline. However, its role is probably of minor importance in spontaneous speech, even though it may contribute to naturalness.

b) Resetting of the Baseline

A direct consequence of this tendency for F_0 to decline is that F_0 values tend to be lower near the end of breath-groups than at the beginning. After a pause, they are generally reset. We may suppose that resetting of F_0 values after a respiratory pause is a natural physiological tendency, although the relation between resetting and breathing is not entirely clear.

Together with the declination tendency and pauses, the resetting of F_0 may contribute to characterizing sentences and clauses as acoustic entities. It has been shown (by Maeda [1976] for English; by Carlson and Granström [1973] for Swedish; and by Fujisaki et al. [1979] for Japanese) that resetting of the baseline can be simulated between two phrases, even in the absence of a pause. The resetting is used as a boundary marker, and the degree of resetting indicates the importance of the boundary.

A stepping down of the baseline at major syntactic boundaries has been reported in a few languages [e.g. Ford, 1975]. To decide on the general use of baseline resetting, either upward or downward, acoustic data for a larger number of languages, particularly tone languages, must be compared and described within a common framework.

The physiological basis of the relations among pause, breathing, declination and resetting is difficult to establish, since speakers may pause without breathing, or reset the baseline without pausing; moreover, as noted above,

declination has also been seen as a by-product of the perceptual system. Despite these difficulties, the considerable cross-linguistic similarities suggest a physiological explanation.

c) Normal Frequency Range and the Control of Range

The range of F_0 variation generally narrows as a function of time (the range is often widened at the very end of the breath-group with the realization of an optional continuation rise). In general, the local F_0 maxima and minima decrease from the beginning to the end in simple declarative sentences; the local maximal values tend to decrease more rapidly than the local minimal values (Fig. 5.1).

This diminution of F_0 range seems to be a natural physiological tendency, since it has been attested in simple sentences in a large number of languages. Most of the physiological explanations for such a phenomenon relate to the production apparatus. It has been shown in singing that an upward pitch change takes longer than a downward pitch change, suggesting that it is easier to lower pitch than to raise it [Ohala and Ewan, 1973]. (Note that a difference in difficulty between the two opposite gestures has also been observed in deaf people [Salles, 1980].) As a consequence of this tendency, the increase in amplitude of successive F_0 rises does not entirely compensate for the decrease in falls, resulting in a narrowing of the F_0 range. A perceptual explanation is sometimes advanced: it has been argued that the speaker tends to keep the same number of octaves above the baseline.

The largest rise (and consequently the highest F_0 value) is generally located in one of the first three or four syllables of the utterance (that is, within the first lexical word). This seems to be common to the languages that have been studied so far. However, speakers are able to counteract this supposed natural tendency to a certain extent, creating a local widening or narrowing of the expected range. Such a strategy has been attested in several languages for marking boundaries or emphasis in complex sentences.

Another observation is that speakers have a tendency to be at a low fundamental frequency, generally the lowest in the sentence, when they cease voicing. The final fall is often accompanied by a lower intensity and by a lengthening of the final elements, which all help to indicate to the listener that the utterance is ending. This tendency is sometimes interpreted as an (early) relaxation gesture [Lindblom, 1968]. Again, however, speakers may counteract this tendency in order to convey linguistic information. The terminal contour of the last syllable is the most important feature in distinguishing simple declarative statements from yes/no questions in a number of languages (for Danish, Thorsen [1980 b]; for Italian, Magno-Caldognetto et al. [1978]; for French, Contini and Boé [1975]; for Japanese, Nishinuma [1979]; for Romanian, Dascălu [1979]). When used for marking interrogation, a rising terminal contour is often accompanied by a suppression of the declination

tendency. It has been noted, however, that this effect is language specific: in some languages interrogatives can be characterized by a falling intonation, and in others a rising contour may be typical for declaratives. Even in yes/no questions, where the interrogative mode is indicated by the syntax, and in wh-questions, a rising contour is optional.

The terminal contour inside a declarative sentence is also often used to contrast between terminal juncture (at the end of the sentence) and non-terminal juncture (before a non-final pause). (See Delattre [1963] for a comparative study of German, French, Spanish and English; Svetozarova [1975] for Russian and Nishinuma [1979] for Japanese.) We have noticed that in non-terminal juncture, in contrast to yes/no questions, the declination tendency is maintained. The presence versus absence of the declination tendency may contribute to the perceptual differentiation between interrogation rise and continuation rise in a number of languages. Cross-linguistic perceptual experiments are needed to test this hypothesis.

d) Rising Versus Falling F_0 Movements

Perhaps because a F_0 rise is mainly realized by tensing the vocal folds, and a F_0 fall by relaxing the tension, an upward change of F_0 between two successive vowels seems to be associated with the notion of beginning and a downward movement with the notion of end. This tendency seems to be reflected particularly by the manner in which lexical entities are acoustically combined in spoken sentences to form a single acoustic entity. Such an acoustic entity is related to the notions of "stress group" as defined by Thorsen [1980a] for Danish, the "hat-pattern" in Dutch [Collier and 't Hart, 1975] and in English [Maeda, 1974], the "rhythmic unit" [Lehiste, 1975] or the "prosodic word" in French [Vaissière, 1974, 1975], and the "syntagma" in Russian [Kozhevnikov and Chistovich, 1965; Svetozarova, 1975]. The number of prosodic words for one sentence is not fixed; i.e. it is not entirely determined by grammatical structure. It depends on several factors, such as rate of speech and a speaker's individual choice. However, in carefully spoken sentences, where the speaker tends to stress every meaningful word (generally the lexical words as opposed to the function words), the number of prosodic words (comprising essentially a successive rise and fall) tends to be equal to the number of lexical words, or one fewer (the fall on the next to last lexical word may be suppressed so that a larger fall, the sentence-final fall, is superimposed upon the last word (for French, Vaissière [1975]; for Russian, Svetozarova [1975])). Such an observation is more easily made with sentences composed of multisyllabic words, or sentences where one or more grammatical words occur between the monosyllabic words, that is, where it is possible to establish perceptual contrast between successive stressed and unstressed syllables. This characteristic appears to be language independent.

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Many languages seem to use suprasegmental variation to achieve acoustic grouping of semantically related words such as a noun and an adjective which precedes or follows it. (See the above references and, for Chinese, Zee and Maddieson [1979]). This is done firstly by reducing the number of F_0 movements that would be attached to the words if they were spoken separately: the regrouped words tend to receive the F_0 pattern of a single word. Secondly, grouping requires that there be no more than one rise and no more than one fall in the phrasal group; if both occur, the rise has to precede the fall. Figure 5.2 illustrates some regroupings comprising a F_0 rise in the first lexical word and a F_0 fall in the last word: "to the technical progress", "of the past twenty years" (English), "des progrès technologiques" (French), "en los últimos veinte años" (Spanish).

5.2.3 Durational Features and Intensity Phenomena

a) Final Lengthening

There is a tendency to lengthen the final elements in an utterance, particularly the last vowel, before a pause (see illustrations of prepausal lengthening for French, English, German and Spanish [Delattre, 1966]; for Italian [Marcel, 1971]; for Russian [Zlatoustova, 1954]; for Swedish [Lindblom, 1968]). However, there seem to be languages in which there is little (if any) final lengthening, e.g. Finnish [Lehiste, 1965], Estonian [Lehiste, 1965] and Japanese [Han, 1961].

It has been suggested that slowing down at the end is a natural tendency characterizing all motor sequences or planning units: similar patterns have been found in music, in birdsongs, in insect chirps and of course in speech [Cooper, 1976]. The lengthening of final elements in words, phrases and sentences in speech is an intriguing phenomenon. It seems that lengthening, like F_0 fall, is associated mainly with the notion of termination.

Lindblom [1968] refers to Öhman's [1967] model of word and sentence intonation, in which there is a "general relaxation of speech gestures toward the end of the utterances". Making the assumption that the same amount of physiological energy is expended for each syllable (excluding stress variations), Lindblom concludes that the increased duration of final syllables compensates for the lower intensity per unit of time. However, Oller and Smith [1977], who approached the issue from a developmental perspective by studying the linguistic production of infants, concluded that final-syllable lengthening constitutes a learned behavior, since infant speech does not display such a tendency.

Lengthening a final element without a pause helps to mark the end of a word or phrase (for English, Delattre [1966] and Oller [1973]; for French, Delattre [1966]; for German, Zingle [1974]; for Russian, Zlatoustova [1954]; for Spanish, Delattre [1966]; for Swedish, Lindblom [1968]). It has been

observed that phrase-final lengthening has a larger range than word-final lengthening. Cooper [1976] has noted a related tendency in music. Variations in relative lengthening of different elements, if perceived, contribute to the recovery of syntactic structure by the listener: the greater the lengthening, the more important the syntactic break (see the experiment by O'Malley et al. [1973] on the recovery of the syntactic structure of algebraic expressions).

In addition to lengthening of the very last syllable in a word or phrase, there may be three other kinds of lengthening phenomena: first, lengthening of the last stressed syllable in a phrase, even if it is followed by one or more unstressed syllables; second, lengthening of the entire last word in a phrase [Umeda and Quinn, 1981]; and third, lengthening of the last sentence in a read paragraph [Lehiste, 1975].

The bulk of final-syllable lengthening (which may be used as a right boundary marker) seems to be carried mainly by the vowels [Oller, 1973]. By contrast, word-initial consonant lengthening has generally been attested as a left boundary marker, a function associated with rising F_0 (for English, Lehiste [1960]; for Italian, Nespor [1977]; for Swedish, Carlson and Granström [1973]).

b) Other Lengthening Phenomena

While lengthening of the final element seems to have essentially a demarcative function, lengthening in a non-final context is largely used for emphasis marking. The lengthening of a single syllable is commonly used to mark emphasis and contrastive stress [Coker and Umeda, 1973]; deceleration in speaking rate is a strategy that may be used by some speakers to emphasize a word, an entire sentence or a clause [Kloker, 1975].

5.2.4 Intensity and the Syllable

Prosodic phenomena such as tone, stress and accent are customarily considered qualities of a syllable. The syllable is the minimal unit for F_0 , duration and intensity contrasts. Even the mora, which may be more adequate than the syllable for describing the suprasegmental system of languages like Ancient Greek [Garde, 1968], is defined relative to the syllable. Despite language-specific rules for grouping phonemes into syllables, there is a universal tendency to bring the structure of the syllable as close as possible to the ideal described by de Saussure [1916] and Jespersen [1933].

A common definition of the syllable is that it corresponds to a peak of intensity. Intensity has a demarcative function at different levels. First, the presence versus absence of intensity over a period of time signals pauses and divides speech from non-speech sequences. Second, during articulated sequences, the gross variations in intensity and the location of local peaks and

valleys chunk the continuum into syllable-like segments. The peaks generally correspond to syllable nuclei (vowels) and the valleys to consonants.

The linguistic function of the relative intensity of syllables in continuous speech is not easy to determine. As mentioned by Sorin [1981], intensity has been less well studied in the past than the two other prosodic parameters, F_0 and duration. There is very little information on the specific contribution of intensity to perception. Intensity seems to share some of the functions of both F_0 variation and durational variation. The interrelation between intensity and fundamental frequency has a physiological basis. Intensity and fundamental frequency are regulated by the same mechanisms (increase in pulmonary effort and in subglottal pressure, tension of the vocal folds, etc.), and, as may be expected, higher fundamental frequency is generally correlated with an increase in intensity (see an illustration of this tendency in Fig. 5.2). Similarly, the F_0 decrease at the end of sentences is matched by an intensity decrease. Higher intensity of a syllable is also often correlated with longer duration. An increase in global articulatory effort to produce perceptual prominence via intensity may also require additional time, and consequently may result in a lengthening of the underlying phoneme. For example, emphasis is often marked by both an increase in intensity and a lengthening of the underlying segments.

Generally speaking, higher F_0 , higher intensity and longer duration naturally tend to characterize the same segments in a sentence. Such a tendency is particularly obvious in emphasis and prominence marking. However, different languages have counteracted this natural tendency to a greater or lesser degree in establishing their specific suprasegmental code. We will see in the next section that a particular relationship between intensity, F_0 and duration may in fact be a characteristic of a language.

5.3 Prosodic Differences Among Languages

The broad similarities among languages should not mask the considerable variations indicated by cross-linguistic comparison of prosodic systems [Ladd, 1981]. There seem to be three basic principles which guide the comparison and description of such differences.

5.3.1 Differences in Timing

In English [Maeda, 1974], Italian [Magno-Caldognetto et al., 1978] and Dutch [Cohen and 't Hart, 1967], pitch movements (either upward or downward) are mainly limited to the so-called stressed syllables (with an optional continuation rise on the last unstressed syllable). Together with higher inten-

sity and longer duration, they help to assign prominence to stressed syllables relative to the surrounding syllables. The position of the stressed syllable in a word is largely predictable from the phonological and morphological structure of the word. In French, F_0 movements occur in relation to word boundaries: a rise is superimposed on the beginning of the word, and the word-final syllable carries a large variety of accentual contrasts (large rise, rise, level, fall, large fall). In the former three languages, F_0 , duration and intensity variations are mainly "timed" with the stressed syllables, while in French, they are bound to the first and last syllable of the word.

Moreover, the exact position of rises and falls in so-called stress languages varies from one language to another. The movements are not always simultaneous with the stressed syllable. In Danish, for example, a stressed syllable in neutral speech is relatively low, and is followed by a high-falling tail on the following unstressed syllable, a pattern which is not common in English. The stressed syllable(s) may be associated in Danish with two different accents, which are mainly distinguished by the presence or absence of a kind of glottal stop (called *stod*), rather than by a F_0 movement [Gårding, 1977].

The direction of the pitch change, either rising or falling, is determined by language-specific factors. We have noted that in French, the importance of the juncture following the word determines the "accentual pattern" (rising, falling or level) of the word-final syllable. The F_0 pattern superimposed on a word in that language is mainly determined by the sentence context. In Swedish, by contrast, one syllable in the word may receive primary stress (the position of which is predictable from the phonological and morphological structure of the word), and one syllable with primary stress may carry one of two typical accents [Gårding, 1977]. Syntactic structure also seems to play a role in Swedish in determining the actual F_0 pattern realized upon a word embedded in a sentence, but to a lesser degree than in French. In a tone language [Pike, 1945], where there is a lexically significant tone on each syllable, the syntactic structure may be expected to play an even smaller role in determining the fundamental frequency contour than in Swedish.

As a consequence, word boundaries, morphological and phonological word structure, and juncture phenomena may all contribute to the determination of F_0 contour in such languages. The relative importance of each factor is language specific.

Differences in the timing of the same movements are also one way of explaining dialectal varieties in a given language. The best demonstration is probably given by the work of Bruce and Gårding on Swedish [Bruce and Gårding, 1978; Gårding, 1975 a]: F_0 peaks may occur more or less early in the stressed syllable, or even in the post-stressed syllable, depending on the dialect spoken (see also Fujisaki and Sugito [1976] for Japanese).

A different timing rule has also been attested for speakers of the same community. It has been shown, for example, that native speakers of French may start a continuation rise at the onset of the syllable, or later, in the vowel [Vaissière, 1975].

5.3.2 Different Orders of Priorities

As the notion of differing orders of priorities is relatively new, we shall illustrate it through examples.

a) Due to the physical constraints imposed by the vocal apparatus producing F_0 curves, and to the limitation of the F_0 range, it is necessary for upward and downward F_0 movements to be produced alternately, so that a large fall is preceded by a rise, and vice versa. In English and in French, a rise may serve different purposes: it may indicate a non-terminal juncture (continuation rise) in both languages, and/or be used to mark a stressed syllable (in English) or the beginning of a word (in French). In a language like English, a lowering of F_0 occurs on the last stressed syllable in a phrase. If the last stressed syllable is the final syllable of that phrase, and if this phrase is followed by a non-final pause, either a fall may occur on that syllable to mark the last stressed syllable of the phrase, or a rise may occur to mark that the phrase is non-terminal: data clearly show that priority is given to the fall (stress marking), and that the fall is followed by an optional continuation rise. In French, the continuation rise has higher priority than the fall, which is a usual cue for a right word boundary inside the phrase. As a consequence of this, the fall is overridden by the continuation rise.

b) Both English and French tend to show lengthening of word-final syllables. In English, the acoustic correlates of word boundaries are only traces: marking of word boundaries competes with lexical stress marking, and priority is given to the latter. For example, the longest syllable in the word is generally the stressed syllable, despite a lengthening of the word-final syllable. In French, the marking of word boundaries is not in competition with stress marking: the lengthening of final syllables is "reinforced". The differences between these two originally related languages may be considered a historically different choice of which feature to assign priority: stress or boundary.

Slight differences in priority may also explain dialectal differences. In French, for example, both right and left word boundaries can be perceptually marked. At a normal rate of conversation, however, it is not possible to put prominence on two successive syllables: the prominence assigned to one syllable is achieved at the expense of the syllables immediately preceding and following. In dissyllabic words, native speakers of Southern French give more perceptual prominence to the word ending, while Parisian speakers tend to give almost equal weight to the two syllables. Some speakers, particularly politicians and radio announcers, tend more frequently to "stress" the word beginnings. In words of more than two syllables, it is possible to contrast the two extreme syllables relative to the intermediate syllable(s): the dialectal and individual differences are smaller.

5.3.3 Different Relationships Between F_0 , Duration and Intensity

As was noted in the first part of this contribution, intrinsic fundamental frequency, duration and intensity of individual sounds reflect the nature of the speech mechanism in general, and the same intrinsic tendencies seem to exist across languages [Chen, 1970; House and Fairbanks, 1953; Delattre, 1962]; *ceteris paribus*, for example, higher vowels tend to be uttered with a higher fundamental frequency. Extrinsic variations, which are not due to segment identity, but rather to lexical stress position, accent pattern, or syntactic boundary position, show correlations between the three parameters which may be more or less intimate. In English, the syllables which bear pitch movements (the stressed syllables) are also usually more intense and longer. In French, the last syllable, which carries a variety of F_0 contours, is also the longest syllable in the word; it is not clear whether it is more intense, particularly in level or falling F_0 contours. In that language speakers tend to give a more equal intensity to sequences of sounds than do speakers of English. The three suprasegmental parameters seem to be less systematically correlated in French than in English. In both languages, a longer duration characterizes the syllables carrying pitch movements. But again, such a correlation between F_0 change and duration may not hold equally for all other languages. It has been shown that in Japanese, accent placement has a smaller effect upon segment duration than it does in English [Hirose et al., 1978; Mitsuya and Sugito, 1978].

It is difficult to evaluate the mutual influence of suprasegmental and segmental aspects of one language. Rising fundamental frequency with a suprasegmental origin, for example, is mainly achieved by a tensing of the vocal folds. But the tense consonants, too, are uttered with more tense vocal folds than the lax consonants. An upward change of pitch seems to be favored by the presence of a tense consonant, in comparison with other environments, e.g. lax consonants or vowels. In French, the F_0 maximum after the word-initial rise is located on the word-initial syllable if the word begins with a voiceless consonant; but it may be delayed to the second syllable if the word-initial phoneme is a vowel or voiced consonant; i.e. the position of the turning point in the F_0 curve is determined by a combination of suprasegmental and segmental features. In English, a F_0 rise (stress-marking rise) results in aspiration of tense consonants beginning the syllable on which it is realized. Both phenomena, rising fundamental frequency and aspiration, correspond to a tensing of the vocal cords, and they are generally concomitant in this language. In French, by contrast, a F_0 rise in the onset of a word may or may not be accompanied by aspiration, depending on whether or not the speaker wants to put emphasis on that word.

Suprasegmental aspects of each syllable affect the segmental characteristics of the nucleus. Delattre's comparative study of vowel reduction phenomena in French, English, German and Spanish [Delattre, 1963] illustrates important cross-linguistic differences.

66 5. Language-Independent Prosodic Features

It is possible that the specific *interrelations* between the three suprasegmental features (F_0 , duration and intensity), and the relation between segmental and suprasegmental aspects, rather than each feature taken individually, are the most salient characteristics differentiating between languages, dialects, and individual ways of speaking. If this is true, most of the existing descriptions of prosodic systems (including our own work on French) are incomplete, since they describe only one parameter at a time. Compensatory effects between the three parameters have occasionally been noticed. We have learned from our experiments on automatic speech recognition that with some speakers, the longer duration of final syllables is a reliable cue for automatic segmentation of speech into prosodic word-like units, while with other speakers, F_0 variations are more efficiently used.

5.4 Conclusion

This contribution has been based on the hypothesis that the suprasegmental similarities between languages are most likely due to identical constraints exercised by the production and perception apparatus. Its aim was to show how a number of related and unrelated languages have tended to assign the same primary functions to physiologically related phenomena: the necessity of pausing for breath while speaking is commonly used for grouping, the natural tendency for F_0 values to decline with time serves to characterize neutral declarative sentences, and F_0 movements corresponding to a tensing of the vocal folds (resetting of the baseline and local F_0 rises) are associated with the notion of beginning, while falls are associated with ending. We have mentioned examples of how the natural, physiologically conditioned tendencies are controlled in position and amplitude, suppressed, counteracted or simulated to carry linguistic information which is similar in a number of languages: non-respiratory pauses serve as juncture phenomena, the length of pauses is adjusted according to the importance of the juncture, the rate of F_0 declination is adapted to the length of the sentence, the tendency to decline and to end speaking with a F_0 fall are counteracted to provide a contrast between declarative and interrogative modes, and so on.

On the other hand, considerable cross-linguistic differences exist. We have proposed three basic sources of these: different timing of essentially comparable phenomena, different orders of priority for the realization of comparable conflicts between prosodic phenomena, and different relationships between or different mutual effects of F_0 , duration and intensity.

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