FINE PHONETIC DETAIL AND INTONATIONAL MEANING

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ABSTRACT

The development of theories about form-function relations in intonation should be informed by a better understanding of the dependencies that hold among different phonetic parameters. Fine phonetic detail encodes both linguistically structured meaning and paralinguistic meaning.

Keywords: Intonational meaning, paralinguistic meaning, fine phonetic detail, tonal alignment.

1. INTRODUCTION

Fundamental frequency (F0) varies along a number of phonetic dimensions, such as F0 range, register, shape, velocity of change, and alignment with the segmental string. They cue intonational meaning in complex ways, because they simultaneously express multiple functions: lexical tone, indexical, paralinguistic and linguistic information (e.g. focus, syntactic and discourse structure) e.g. [35]. Intrinsically discrete components of meaning thus coexist and interact with continuous components. For instance, a bigger pitch excursion on a rise can sound simultaneously more questioning and more polite, where the rise is discretely different from a fall signaling assertion and the range varies gradiently with a less polite realization.

The complex relation between F0 variation and meaning is slowly being unraveled in research within the Autosegmental-Metrical (AM) framework [3, 49, 35, 24, 31], especially where F0 scaling and alignment are concerned. Hypotheses about the phonetic realization of intonational categories, like the coordination of segmental and tonal elements, naturally follow from the central claim that intonation contours are best analyzed in terms of high and low turning points which align with specific locations in the segmental string.

However, the focus on variation in the timing and height of F0 peaks and valleys contrasts with a relative neglect of factors like contour shape (but see [33,56,10,42]), the assumption perhaps being that detailed variation belongs to paralinguistics. Moreover, a growing body of evidence emphasizes the role of other prosodic parameters in signaling meaning – duration, pauses, relative loudness, tempo, and voice quality – which may interact in unexpected ways to enhance linguistic contrast or shades of meaning (e.g. [63]).

Focusing on relations between intonational cues and segmental structure, we argue that phonetic dependencies among parameters such as tempo, rate and direction of f0 change, temporal alignment, and voice quality will advance our understanding of intonational meaning. This work will benefit from the insight that intonation resides in two components of language: a linguistically structured part in which form-function relations are in principle language-specific, arbitrary and discrete, and a part which is iconic and largely independent of the individual language [23, cf. 29]. Our discussion of FPD centers on the former.

2. PARALINGUISTIC MEANING

Paralinguistic meaning has recently been analyzed as due to metaphorical interpretations of biological conditions influencing rate of vocal fold vibration. Ohala [46] derived meaning dimensions like 'submissive vs autoritative' and 'question vs statement', signaled by high vs low pitch, from the relation between larynx size and rate of vocal fold vibration. In addition to this 'frequency code', Gussenhoven [23] recognizes a 'production code', based on f0 declination across utterances, according to which high-pitched beginnings signal new topics and low-pitched beginnings continuation, with low endings signaling ends of turn and high endings continuation. A third code, the 'effort code', associates wider excursions with meanings derived from hyperarticulation, like greater 'significance' and 'cooperativeness'. Strikingly, cross-linguistic differences in f0 register and excursion size affect interpretation [6]. Dutch listeners tend to associate these with greater meaning differences than British English listeners, who are accustomed to wider f0 excursions. Also, British English listeners associate raised registers with greater friendliness, where Dutch listeners interpret greater emphasis. This suggests that when conflicting metaphorical meanings can be derived from different 'codes' (friendliness form the frequency code, and emphasis from the effort code), speech communities may make different choices. Paralinguistic meaning of intonation thus appears to be a much more complex concept than might appear without a detailed acoustic account of just what meanings are conveyed, and how much meaning is conveyed, by a given f0 contour. The linguistic experience of the listener appears to be intimately involved in the interpretation of universal physiological and anatomical factors determining vocal fold vibration rates.

3. LINGUISTIC MEANING

Linguistic meaning tends to be language-specific, even in cases where the codes conspire to reinforce a universal interpretation. In Belfast English, for instance, rising pitch is used to signal questions as well as statements, unlike most other varieties of English [21].

Cross-linguistic and cross-varietal comparisons also indicate that, like any other aspect of the grammar, the complexity of intonational structure varies across languages. As in segmental systems, the number of primitives and legal combinations of primitives may differ widely. A striking example is provided by the grammars of French and English, which specify the possible tone sequences in the Intonational Phrase, as shown in (1) (cf. [48]).

(1) a. French tonal grammar [52]:

$$\begin{Bmatrix} L_I \\ H_I \end{Bmatrix} \quad (H^*\,(L))^{n}_{0} \quad (H+)H^* \quad \begin{Bmatrix} L_I \\ H_I \\ \varnothing \end{Bmatrix}$$

b. English tonal grammar [24]:

$$(\text{[DOWNSTEP]}) \begin{Bmatrix} L_I \\ H_I \end{Bmatrix} (L) \begin{Bmatrix} H^*\,(L(H)) \\ L^*(H) \end{Bmatrix}^{n}_{0} \rightarrow (H+)(L) \begin{Bmatrix} H^*(L) \\ L^*(H) \end{Bmatrix} \begin{Bmatrix} L_I \\ H_I \\ \varnothing \end{Bmatrix}$$

NOSLUMP $*HL_I$

(1a) states that French Intonation Phrases (*I*) are marked by a low or a high boundary tone on either side, while the final boundary may be unspecified for tone. *I* can contain any number of prenuclear H* pitch accents optionally followed by a low tone, and there is a choice between H* and H+H* for the nuclear accent. By comparison, the specification in (1b) is much more complex, with more elements in more positions, and more possible combinations between them.

This implies that English has grammaticalized a greater number of pitch shapes, and that more grammatical distinctions can be made to express linguistic meaning. Is there correspondingly more scope for conveying paralinguistic or indexical meaning in grammatically 'poorer' languages like French? This question conflicts directly with (a presumed) principle of equal complexity, according to which languages will tend to equalize overall complexity across their subsystems, resulting in comparable levels of complexity cross-linguistically (see e.g. [40] for a discussion). This principle finds little support from comparative typological data that are currently becoming available in syntax, lexicology, morphology, and segmental phonology, cf. large-scale projects such as the World Atlas of Language Structures [25] and the UCLA Phonological Segment Inventory data base [39]. Cross-linguistic differences in structural complexity should help elucidate form-function relations in intonational meaning.

Also the uses to which primitives are put vary. Some languages mark focus by means of distinct pitch accents (e.g. European Portuguese [19], Neapolitan Italian [11], and Zagreb Croatian [61]), whereas in others it is the distribution of pitch accents that signals different focus types or size differences of the focus constituent (e.g. French, Dutch and English) [27, 24].

Little is currently known about prosodic complexity, which is partly due to lack of agreement on the methodological and theoretical principles which should constrain the construction of an intonational grammar. Consequently, descriptions of intonation systems tend not to be directly comparable. For instance, different numbers of categories are proposed for accent-lending falls in British English (1, 2 or 3 categories [32, 22, 7]). Hopefully, the developing field of prosodic typology will soon help to rectify this situation (see e.g. [24, 27, 31]).

The fact that distinct formal categories can also be used to convey paralinguistic differences in meaning further complicates cross-linguistic comparisons. For example, the reply *It's not!* to the utterance *There's our train* conveys a statement of fact whether it is realized with a fall or a rise, but in the latter case, it is likely to be interpreted as resentful [43:58]. English may rely on this type of form-function relation more than French.

Finally, parameters other than F0 may be more important in signaling linguistic meaning than current models of intonation suggest (see §5). If so, the fine phonetic detail of what superficially seems to be the same intonation contour may in fact carry contrast. The next section shows that F0 alignment is such a case.

4. FPD: FUNDAMENTAL FREQUENCY

4.1. F0 timing in production

Studies in various languages (e.g., Catalan, Dutch, English, Greek, Spanish and French) suggest that tune and text are systematically synchronized (*tonal alignment).* When right-hand prosodic effects are excluded (i.e., when the tonal features under investigation are not in the vicinity of pitch accents or boundary tones), the alignment of f0 peaks might be consistently governed by "segmental anchoring". Alignment effects are pervasive under changes of syllabic/segmental structure and speech rate ([1] for Greek, [37] for English and [67] for Chinese; see also [38] for Dutch, [2] for German; and [33] for intonational plateaux in English). Hence, the *segmental anchoring hypothesis (SAH)* states that the phonetic targets of pitch accents are anchored to specific points in the segmental string (e.g. CV boundaries) [37]

However, a strict interpretation of the SAH seems untenable, since alignment effects have been observed for segmental/syllable structure, speaker and speaking rate [12]. For instance, syllables with sonorant codas have later peaks for H* accents than syllables with no coda in American English [64], and similarly, the peaks in L+H* and L*+H accents are aligned later in closed syllables in Neapolitan Italian, leading to potential ambiguities in accent identity [10, 15]; cf. [20] for Pisa and Bari Italian, [26] for Egyptian Arabic, and [65] for French. Moreover, H(igh) targets in British English LH rises are more variably aligned across speakers, while L(ow) targets appear to be consistently 'anchored' to the onset of the accented syllable [37]. Speech rate gives more mixed results: some studies showg stability of peak alignment under rate changes [37,4], and others significant variation, though not always consistently [62,58,68,30,14].

These conflicting results might be reconcilable with the SAH if we better understand the structures that are relevant to determining the anchor points for particular tonal targets. For instance, D'Imperio [10] compared latency measures in order to test whether tonal alignment is more sensitive to the right or left edges of syllables and segments in Neapolitan Italian. She found a significant effect only when H peak latency was measured relative to the right edge of the syllable. In contrast, for prenuclear LH rises in Catalan, Prieto [51] found peak delay was timed relative to syllable onset, while peak latency was also sensitive to the presence of upcoming word boundaries. These examples not only show that different anchors may be relevant to particular tones in different languages, but also properties may interact, which a strict version of the SAH cannot account for.

4.2. F0 timing in perception

Details of alignment affect modality and pitch accent [e.g. 51, 55, 13, 10], word boundaries [e.g. 36, 52] and even lexical identity [e.g. 15, 48]. The study in [54] on Dutch showed, for instance, that the nature of the coda consonant in the stressed syllable affects the perception of two accentual categories, in that sonorant codas shift the category boundary to the right.

More global features of the signal can also affect pitch accent categorization. Intriguingly, the boundary between questions and statements in Neapolitan Italian was shifted as a function of the source utterance used in resynthesis [10]. A declarative source utterance induced a later category boundary than an interrogative source utterance. Differences in formant frequency, spectral balance, and tilt may have caused this shift. A similar conjecture was made to account for the late boundary shift (at two thirds of their stimulus series) by Pierrehumbert and Steele [50], who suggested that their subjects might have been biased towards L+H* responses because of some property of the source utterance used for their stimuli, such as a rise-fall F0 shape, spectral tilt and relative amplitude.

Effects of tonal alignment on word segmentation were observed by [36], who found that it can disambiguate the syllabic affiliation of a consonant in pairs like *Norma Nelson/Norman Elson*, where the L valley between the two consecutive accents on the test words consistently aligns with the onset of the second accented syllable. This type of disambiguation was also observed in pairs like *Mirà batalles* '(s)he watched battles' vs. *Mirava talles* '(s)he used to watch carvings' in Catalan LH prenuclear accents [51].

Tonal alignment can also signal lexical contrast, even when syllable stress is constant. D'Imperio et al. [15] show that fine details of tonal alignment help listeners in the identification of closed versus open syllables in singleton/geminate minimal pairs like *nono* "ninth" and *nonno* "grandfather" in Neapolitan Italian. Peak alignment was manipulated in resynthesized natural speech (carrying a yes/no question L*+H accent), ranging from earlier points typical of open syllables to later points typical of closed syllables (see §4.1.). The manipulation produced a category boundary shift in the *nonno* base stimulus series, supporting the hypothesis that alignment helps to disambiguate lexical items. Thus, F0 alignment might be part of the phonological specification of these items (see [47] for singletons/geminates in external sandhi).

4.3. Effect of F0 contour 'shape' on meaning

Variation in F0 timing can also result in different contour 'shapes', such as relatively flat vs. sharp accentual peaks, shallow vs. steep rising and falling transitions, or convex vs. concave transitions. Peak shape and slope potentially affect accent category identification [10, 42, 55]. For instance, [10] found a difference in the perception of target location in peak stimuli and plateau stimuli in Neapolitan Italian. In plateau stimuli, the equivalent of the perceived target in peak stimuli roughly corresponds to plateau offset, and not plateau onset.

5. FPD: OTHER CUES TO MEANING

The finding that the contrast between Neapolitan Italian questions and statements is maintained in perception when F0 is factored out [10:126] shows that parameters other than F0 may cue linguistic meaning. For instance, speaking rate was faster in the questions than the statements in [10]. Pausing strengthens the interrogative interpretation of Swedish utterances [28]. Voice quality can be more tense on prominent words in interrogatives than in declaratives in English [16] and more lax at the end of questions in languages spoken in Africa [53], while breathy voice interacts with speech act in Japanese [5].

Prominence (or stress) can be strongly cued by parameters other than F0. In English, loudness was a more reliable predictor of prominence judgements than pitch [34], and in English and Dutch, spectral balance rivaled duration as the strongest cue [60, 16]. Such cues may enhance one another. Increases in energy tend to be accompanied by higher pitch, greater loudness, longer duration, changes in spectral slope, and stronger obstruent releases [e.g. 63]. Acoustic interactions can enhance perception: pitch discrimination can improve with a more tense voice quality [56]; cf. [28] for pause and peak delay, and [42] for intensity and peak timing.

Apart from their role in signaling emotions or attitudes, laryngealisation and glottalisation have been found to provide strong cues to prosodic boundaries (phrases and words) [e.g. 58, 50], and are used to signal turn-taking in conversations [44]. Other properties that may interact to signal conversational turns include pitch and loudness register shifts, glottal holding pauses, and pitch and loudness matching. Just like other types of linguistic meaning, the cues to conversational turns are language-specific [17].

Duration is also a cue in turn-taking. Speeding up and slowing down can signal agreement versus disagreement [45]. Such rate changes, which crucially depend on the sequential environment of the turn in the conversational interaction, combine with changes in pitch span, loudness, and degree of stricture in articulations, and more or less dynamic pitch movements on accented syllables [45].

Duration also signals information structure (e.g. word duration distinguishes different focus types [58]), and it marks prosodic boundaries of various sizes and levels in a cumulative way (i.e. syllables, prosodic words, phonological phrases, intonation phrases, and utterances) [e.g. 67]. These durational boundary effects are additive to pitch effects [62].

Final lengthening in larger prosodic domains is often accompanied by initial articulatory strengthening of the linguopalatal contacts [18], cues that are exploited in word segmentation [41].

6. DISCUSSION AND CONCLUSION

Fine Phonetic Detail can be used to distinguish many paralinguistic and linguistic interpretations of intonation contours. If we think of acoustic phonetics in multidimensionial space, linguistic categories can be thought of as centers of density. Within the centers, differences in FPD are interpreted indexically and paralinguistically; in the rarified areas between them, FPD can tip the balance between one category and the next. The synchronization of F0 variation with the phonological structure may cause FPD to lead to discrimination between contrasts in the segmental domain, like that between onsetful and onsetless accented syllables (*Norma(n E/ Ne)lson*) or that between coda-ful and codaless accented syllables (*no(n)no*) [15, 36]. Conversely, changing the segmental composition around a particular alignment point may cause different intonation categories to be perceived. This may happen when a given F0 alignment with reference to the vowel beginning leads to the perception of a downstepped H* pitch accent in an onsetless syllable and a sonorant coda, while the same alignment is perceived as a non-downstepped pitch accent on a syllable with an onset and a voiceless coda [54].

Enhancement of F0 cues by other phonetic parameters, like duration, pausing and voice quality, is common, and has perceptual effects. It complements cue trading within the domain of F0 variation, like that between peak timing and peak height.

Despite growing interest in these dependencies between cues, they are still poorly understood, especially where cues other than F0 are concerned. Promising areas of study include: laryngealisation in conjunction with other cues in signaling finality in European languages; interaction of vocal cues in signaling the modality of 'the same' F0 contour (e.g. rises for questions and continuations); and the role of speaking rate in signaling modality. Such data could help establish to what extent our system imposes boundaries on variation in each phonetic dimension, perhaps such that certain cut-off points can be distinguished in the linguistic and paralinguistic uses of the cues, which may vary cross-linguistically.

Paralinguistic and linguistic meaning cannot absolutely be equated with universal and language specific meaning. Paralinguistic meaning is influenced by the conventional features of the language in question. The conventional shapes of intonational categories may be used or modified to express paralinguistic meaning simultaneously with the linguistic meaning. The AM model has proved to be an excellent vehicle for separating these components, as well as allowing us to see how they are to some extent intertwined.

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