Intonation and Interpretation: Phonetics and Phonology

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Abstract

Intonational meaning is located in two components of language, the phonetic implementation and the intonational grammar. The phonetic implementation is widely used for the expression of universal meanings that derive from 'biological codes', meaning dimensions based on aspects of the production process of pitch variation. Three codes are identified, Ohala's Frequency Code, the Effort Code and the Production Code. In each case, 'informational' meanings (which relate to the message) are identified, while for the first two codes also 'affective' meanings (relating to the state of the speaker) are discussed. Speech communities will vary in the extent to which they employ those meanings, and in the choices they make when they conflict. What they will never do, however, is change the natural form-function relations that they embody. By contrast, grammaticalised meanings often mimic the natural meanings, but linguistic change may create quite arbitrary form-meaning relations when forms are phonologised, and the semantics is systematised. English grammaticalised intonational meaning concerns information status.

1. Introduction

A discussion of intonational meaning typically raises the issue of whether such meaning is universal or language-specific [1,2]. The position defended here is that both the universal and the language-specific perspectives are true, simultaneously, for any language, but that the universal part is exercised in the phonetic implementation, while the language-specific meaning is located in the intonational morphology and phonology. The universal meanings are based on metaphors of biological conditions that influence the speech production process, in this case F0. Three such metaphors, or 'biological codes, as I will call them, have been identified. Together, they amount to a theory of paralinguistic meaning in intonation. In each case, we are dealing with a number of different interpretations, each of which can be related to the more general meaning of the code.

Unlike paralinguistic meaning, linguistic meaning is potentially arbitrary, although the form-function relations between tones and meaning frequently mimic the paralinguistic form-function relations employed in phonetic implementation [3]. Grammatical meanings are like paralinguistic meanings, as when final H% indicates non-finality or final H% signals interrogativity. However, this is by no means always the case. Language change may create 'unnatural', arbitrary forms [5]. This response to the problem of the partially paralinguistic nature of intonation contrasts with earlier ones in which either an almost exclusively non-linguistic viewpoint was adopted [6], or an exclusively linguistic viewpoint (e.g. [2]), or in which the two aspects are reconciled with each other in a gradient conception of their difference (e.g. [7, p. 128],[8]). Below, I explain the notion of a biological code (section 2.0), and discuss each of the three codes in a separate section.

1.1. Three biological codes

The question arises what the expalnation is the of the nature of the universal paralignuistic meanings. This tacit knowledge derives from three biologically determined conditions. One is that the organs with which we produce speech, in particular the larynx, vary in size across speakers, causing differences in the fundamental frequency of adult speech and children's speech, and within adults, of male and female speech [9]. The second is that the production of speech requires energy, and that variation in this energy is detectable in the signal. The third is the energy is parcelled out in chunks that coincide with exhalation phases of the breathing process. Respectively, these codes are the Frequency Code [9], the Effort Code, and the Production Phase Code, or Production Code, for short [5].

A. *The Frequency Code*. Smaller larynxes contain lighter and smaller vocal cords, with which faster vibration rates are achieved for a given amount of energy. The correlation between larynx size and rate of vocal cord vibration is exploited for the expression of power relations. The many ramifications of this latter connection were dealt with by Ohala [9],[10][11]. The term for this form-function relation is his, and my labels for the next two relations are by analogy with his term. An alternative term would be 'Size Code'.

B. *The Effort Code* The amount of energy expended on speech production can be varied: putting in more effort will not just lead to more precise articulatory movements, but also to more canonical and more numerous pitch movements. Lavishing more care on the production process means less slurring together of these movements, causing them to be carried out with less undershooting of targets [e.g. 12].

C. *The Production Code*. The generation of energy is tied to the exhalation phase of the breathing process, and hence becomes available in phases, Lieberman's breath groups [13].This code associates high pitch with the beginnings of utterances and low pitch with the ends.

Together, the three biological codes explain what is universal about the interpretation of pitch variation. In each case, the general form-function relation acquires a number of more specific interpretations. Broadly, these can be classed as 'affective', in which case they signal attributes of the speaker, or 'informational', in which case they signal attributes of the

message. All of these concern meanings which are available to all humans. However, the universal meanings deriving from different codes may well be mutually incompatible, and there will be instances that speakers with different language backgrounds make different choices, or that listeners draw on a different code than the speaker intended. Moreover, the intonational grammar of a language may bias the exploitation of the universal codes, such that universal meanings which happen to be encoded in the grammar are more readily perceived by speakers of that language than by speakers of languages in which such meanings have not been encoded

1.2. Grammatical meaning

Typically, the intonational morphemes of a language will mimic the universal form-function relations. But of course, in such grammaticalisations of the universal codes, the function will be morphemic, the form phonological, and since we are now dealing with structural elements, these morphemes are subject to the normal forces of languages change. As a result, languages may come to possess form-meaning relation in their grammars which go against the universal, biological codes. In fact, this happens so commonly that Ladd [2] rejected the notion of universal form-meaning relations in intonation, on the grounds that if a universal is only in evidence, say, 70% of the time, there is little explanatory power to be derived from it. Crucially, in the present perspective, such 'unnatural' form-functions relations must be structural, i.e. discrete. When meanings are 'natural', it may not be easy to establish whether the phonetic difference is discrete, i.e. due to a phonological difference, or gradient, i.e. due to meaningful variation in the phonetic implementation [14], [15].

Grammaticalisation not only implies that the form is discretely coded in phonological structure, but also that the meanings are systematised. Intonation is used to route the semantic contents of particular morpho-syntactic constituents to semantic categories of information status. I will briefly work this point out at the end of the paper.

1.3. Divorcing cause and effect

Biological codes are based on the effects of physiological properties of the production process on the signal, but communication by means of the codes does not require that these physiological conditions are actually created. It is enough to create the effects. That is, the effects are not automatic, but have been brought under control. When we say that the meaning 'emphasis' as signalled by wide pitch excursions is derived from the Effort Code, on the grounds that greater effort will typically lead to wider pitch excursions, there is no implication that the speaker who signals emphasis by using the Effort Code actually expends greater effort on his speech production. The only thing he needs to do is choose his pitch range such that he will be understood to be exploiting this natural relation between excursion size and articulatory effort. Similarly, when using the Production Code to signal the end of a speaking turn, the speaker need not have his exhalation phase end with the end of his utterance, or even produce a more steeply declining overall contour shape, but need only lower the pitch of the last one or two syllables of his utterance. The indirectness of the relation between actual speaker behaviour and the natural connections between speech production and pitch are underscored by the the use of 'secondary' features like

delayed peaks as a substitute for high peaks [3]. Before this point is made, I will deal with informational and affective interpretations of each code in sections 2, 3 and 4.

2. The Frequency Code

The Frequency Code is essentially Ohala's extension to human speech of Morton's explanation for the widespread similarities in patterns of avian and mammalian vocalisations in face-to-face competitive encounters [16]. Vocalisations by dominant or aggressive individuals are low-pitched, while those by subordinate or submissive individuals are high-pitched. The explanation of this correlation is that lower pitch suggests the organ producing the vocalisation is larger. In fact, the exploitation of this correlation in nature is not confined to meaningful variation within individuals. In many species, it is hard-wired through dimorphism, the different biological developments of the male and female members of a species. In the front-to-back dimension, the male human larynx is almost twice the size of the female larynx, exactly the dimension which affects the fundamental frequency most. This arises at puberty, the age at which boy becomes man, ready to assume the role of defender or aggressor. To underscore the effect, the male larynx is positioned lower in the throat, causing the vocal tract, the tube leading to the lips, to be some 3.5 cm longer than the female vocal tract. The effect is that formant frequencies are lower in men, suggesting a larger creature. Other aspects of dimorphism in animals and humans point in the same direction: males may have extra feathers to be erected, antlers, thicker manes, or, in the case of humans, peripheral facial hair, all of which serve to make the creature look more imposing. Ohala's claim was that we associate pitch with this package of evolutionary meanings, for which reason intonation contours have come to have the distributional bias we observe.

2.1. Affective interpretations of the Frequency Code

Affective interpretations of the Frequency Code are rather numerous. Submissiveness, or 'feminine' values, and its opposite, dominance, or 'masculine' values, constitute one obvious dimension. Meanings that are associated with this dimension are (for higher pitch) 'friendliness' and 'politeness'. A closely related one is 'vulnerability' (for higher pitch) versus 'confidence', which may play out as 'protectiveness', or as its negative counterparts, 'aggression' or 'scathingness'. In the scores for 'masculinity' and 'feminity' perception in speech, Biemans [17] found a positive correlation between five artificial registers superimposed on a set of spontaneous male and female utterances and the scores on a 'femininity' scale, and a negative correlation with the scores on a 'masculinity' scale. High pitch commonly leads to high scores on semantic scales for 'polite', 'non-aggressive' and 'friendly' in perception experiments with intonation. As early as 1964, Uldall found that listeners associated high ending rises with both 'submissiveness' and 'pleasantness' [18]. In a recent experiment, it was found that the scores on four scales measuring affective meanings for eight Dutch intonation contours correlated highly with the mean fundamental frequency of the contours. The strongest correlations were found between these scores and the mean fundamental frequency of the last quarter of the contours, suggesting that in Dutch contour endings are used more for this purpose than earlier portions [19].

2.2. Informational interpretations of the Frequency Code

The other class of interpretations reflect on the linguistic message, such as 'uncertainty' (for higher pitch) vs 'certainty', and hence 'questioning' vs 'asserting'. In a classic experiment with a number of artificial intonation contours superimposed on a phrase which could be interpreted as either Swedish (för Jane) or English (for Jane), Swedish and American English listeners were asked to decide whether the utterance was meant as a statement or as a question [20]. The contours consisted of a single rising-falling peak on Jane, varying in peak height and end pitch. Essentially, the results for both groups of listeners were that the higher peak attracted more 'Question' judgements than the lower peak, while there was a clear correlation between end pitch and the 'Question' scores. Although the authors failed to point this out, the results also show the influence of the native language. Listener language appeared to interact with peak height: Swedish listeners differentiated more sharply between the superhigh peak and the high peak than the American listeners, showing a greater influence of this variable in their scores. It is reasonable to explain this result as due to the fact that Swedish does not use final rises as a cue for questions in the way English does, causing Swedish listeners to rely more strongly on other cues. Similarly, Japanese listeners are less inclined to hear interrogativity in high-peaked contours than Russian listeners [21]. Interestingly, Japanese uses a final rise for questions, while Russian employs a difference in peak height. In [22], Standard Chinese, Dutch and Hungarian listeners were asked to identify the question in pairs of intonation contours superimposed on identical segmental structures. These three languages have different ways of expressing interrogativity prosodically. Chinese raises the pitch register [23], presumably an effect produced in the phonetic implementation. Dutch uses final rises, phonologically marked by final H% [19], while Hungarian distinguishes peaks in stressed syllables in declaratives from phrase-final (i.e. boundary) peaks in interrogatives [24],[25]. The stimuli consisted of (hypothetical) trisyllabic CVCVCV structures, as pronounced by a speaker of Dutch with the stress on the penultimate syllable. The contours, which were similar in structure to the ones used in [20], varied in peak height, peak alignment, and end pitch. Unlike what is usual in other experiments, the listeners were told, quite untruthfully, that they were going to hear sentences from a little known language spoken on a South Pacific island. Regardless of language background, listeners associated higher peaks and higher end pitch with questions, as in the 1964 experiment (see Figure 1). Moreover, there was also an interaction between language group and peak height, which showed that Hungarian speakers were more sensitive to the peak height variable than the other two language groups, paralleling the behaviour of the Swedes vis-à-vis the Americans.
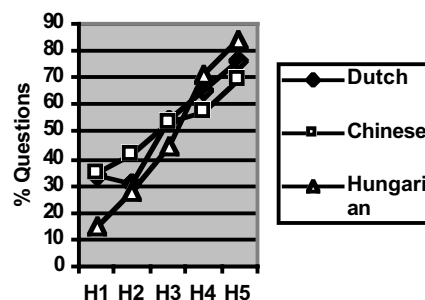

Figure 1. Percentage "Question" judgements as a function of peak height by three groups of listeners with ordinal interaction between listeners' language and peak height. From [22].

2.3. Grammaticalisations of the Frequency Code

Grammaticalisation of the informational uses of the Frequency Code is commonplace. As said above, over 70% of the languages in the world are estimated to have rising intonation contours, while the use of rising intonation for statements is exceptional [1]. In fact, many languages have more than one rising pattern. Dutch has four phonologically different contours, H*L H%, H* H%, L*H H%, and L* H% [26,27]. Malay distinguishes statements from questions by having an initial boundary %L in the former and %H in the latter (Indirawati Zahid, personal communication).

Grammaticalisation of peak height is less common. Possibly, this is due to the widespread communicative use of pitch range in the phonetic implementation. Somewhat roundabout ways of doing this can be found, however. Bengali has two phonologically different contours, each with a final peak which in selected contexts can occur on the final syllable, one signalling contrastive declarative focus and the other signalling the yes-no interrogative. Phonologically, the two peaks differ in the status of the H-tone, which belongs to the phonological phrase in the case of the contrastive declarative (H_p) but to the intonational phrase in the case of the interrogative contour (H%). The point is that the tone of the intonational phrase is pronounced at considerably higher pitch [28].

'Unnatural' form-function relations appear to be quite liberally available in the case of interrogative intonation, in which case they are falling, and more rarely in the case of declarative intonations, in which case they are rising. Chickasaw is a striking case: the interrogative is H* L%, the declarative H* H% [29]. There must be many scenarios leading to falling introgative intonation and rising declarative intonation. In [5], I sketched a probable development of falling questions from rising questions as a result of the introduction of a lexical tone in the dialect of Roermond. The motivation for the fall was the preservation of a lexical tone contrast under interrogative intonation. In the declarative context, the tone contrast was phonetically realised as a steep fall to low (Accent 1) versus a slow fall to mid (Accent 2). In the interrogative, a falling component was added to the rising intonation in the case of Accent 1, which later led to a generalised interrogative intonation contour L*-HL%. (This contour also occurs in Bengali and Greek [28],[30].) Arguably, the presence of a high final peak can be still said to

be a manifestation of the Frequency Code, despite the fall to low.

A likely source of rising statements is truncation of delayed peaks. As argued in section 6, delayed peaks may occur as replacements of high peaks. The resulting rising-falling pitch accents may be truncated on final syllables, and when such truncated falls are interpreted as L*H%, generalisation of this form to other contexts may result.

3. The Effort Code

Increases in the effort expended on speech production will lead to greater articulatory precision, but also a wider excursion of the pitch movement. Speakers exploit this fact by using pitch range to signal meanings that can be derived from this effect of the expenditure of effort. A frequent interpretation is that the speaker is being forceful because he believes the contents of his message are important, an informational meaning. Narrow range may be used to signal negation, a withdrawal of information. In addition to the more obvious meanings of 'surprise' and 'agitation', affective meanings include 'obligingness': the speaker is here concerned to help the listener to understand what he is saying.

3.1. The informational interpretation of the Effort Code

The most obvious informational interpretation of the Effort Code is 'emphasis': the speaker is concerned that his message should come across. The overall pitch range of utterances in British English radio news bulletins correlates with informational salience, as determined independently of the acoustics [31].

Many perception experiments, beginning with [32], have shown that higher pitch peaks sound more prominent, everything else being equal. Interestingly, the effect is not simply due to peak height. Rather, it is an estimate of how wide the pitch excursion is, given some choice of pitch register, and the listener's impression therefore results from an estimate of the pitch span in relation to some choice of pitch register. The most straightforward way in which this can be demonstrated is by having listeners judge the prominence of peaks in identical pitch contours superimposed on a male and a female voice, as reported in [33]. In this experiment, the original utterances, which had been recorded by a woman with a fairly 'deep' voice, were provided with artificial spectra by multiplying the first formants with a factor or less than 1, so as to create a set of stimuli that sounded as if they were spoken by a man. A second set of stimuli was obtained by multiplying the original formant values by a factor of more than 1, so as to create a set that sounded as if they were spoken by a woman whose voice was subjectively more feminine than the original voice. Listeners rated pitch peaks in the artificial male voice as more prominent than the equivalent pitch peaks in the artificial female voice, even though the pitch contours were identical. These results can be explained if we assume that prominence judgements are made relative to some hypothesised reference line, as represented by the the contour's register. Since the hypothesised register of the 'female' speaker was higher than that of the 'male' speaker, perceived prominence of the female stimuli was less than that of the male stimuli. Thus, the Effort Code is about inferred pitch excursion size, not height of pitch *per se* (see Figure 2). In section 6, where pitch register is argued to be

usable as a substitute for pitch range, this point is made in a different way.

An interesting exploitation of the Effort Code is the use of compressed pitch range to express negativity, the withdrawal of information. This is reported for the Bantu tone language Engenni, where high tones are lowered and low tones raised in negative VPs [34].

3.2. Affective interpretations of the Effort Code

Affective interpretations of the Effort Code include 'surprise' and 'helpfulness'. As for the latter meaning, going to some lengths in realising pitch movements may be indicative of an obliging disposition. Speech addressed to children would frequently appear to have this suggestion of 'a little help' to the listener. The perception of pitch range would appear to be tied to the distance between L-realisations and H-realisations, not the F0-width of just any movement. This was shown for the perception of 'surprise' in Dutch in [35]. When the contour's main pitch rise was a realisation of H* H%, perceived surpise went up with the raising of the targets of both H* and H%. However, when the rise was a realisation of L*H H%, perceived surprise went up when the target of L* was lowered, and that of H% raised (see Fig 2).
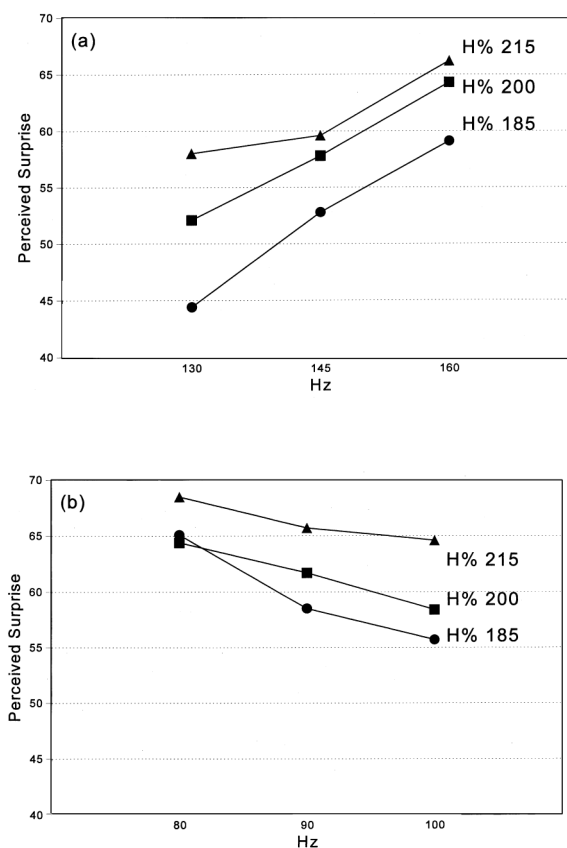

*Figure 2. Perceived surprise scores as a function of beginning and end of nuclear contour, separately for H*H% (panel a) and L*HH% (panel b). From [35].*

The earliest perception research into intonational meaning found that rising-falling and falling-rising contours (representing a change of pitch direction and contrasting in the

experiment with stimuli having less pitch excursion) signalled the meanings 'authoritative' and 'pleasant'. This result illustrates, respectively, the informational and the affective interpretations of the Effort Code [36],[18].

3.3. Grammaticalisation of the Effort Code

Grammaticalisation of the informational interpretation of the Effort Code is commonplace in the expression of focus. In such cases, the intonational structure will favour a situation whereby focused information will be characterised by relatively wide pitch excursions. Germanic languages and, to a lesser extent, Romance languages use pitch accents to mark focused parts of sentences, removing these in the sentence constituents after the focus. Because it is mediated through a grammar, the expression of focus through deaccentuation will be subject to restrictions that vary from language to language. The constituent that allows focus contrasts to be expressed is at least as small as the word in Dutch, which allows contrasts like *ZWARTE driehoek* vs *zwarte DRIEHOEK* 'black triangle' to signal the known informational status of *driehoek* and *zwarte,* respectively. By contrast, Italian does not allow NP-internal contrasts, and as a result *TRIANGOLO NERO* 'black triangle' is the neutralising translation of both Dutch expressions [36]. In Basque, the focus constituent requires the presence of a pitch accent, but oddly, since the presence of pitch accents is largely lexically determined, not all words are equally focusable [38]. In Japanese, compound words that consist of a single accentual phrase do not allow the focus constituent to be confined to a sub-compound constituent [4].

A different type of grammaticalisation occurs in languages that use different pitch accents for narrow (contrastive) focus and neutral focus, like Bengali [27] and European Portuguese [39]. In such cases, a one-word utterance with contrastive focus is phonologically different from a neutral citation pronunciation of the same word. In line with the Effort Code, the contrastive pitch accent will be realised with greater pitch excursion on the accented syllable. In European Portuguese, the narrow focus pitch accent has a peak in the accented syllable (H*+L), while the neutral pitch accent has a fall that ends inside the accented syllable (H+L*), causing the contrastively accented syllable to have the wider pitch excursion. The Bengali case is given in section 6. A third way in which pitch excursion has been grammaticalised is through the suspension of downstep. In Japanese, prosodic phrasing is sensitive to focus structure, and the most salient consequence of this is that an otherwise automatic lowering of the pitch range cannot take place in a focused constituent.

A grammaticalisation of the 'obligingness' interpretation may have been found by [40]. They investigated the pragmatic effects of high-pitched and low-pitched realisations of the utterance-initial unaccented syllables before the first pitch accent in Dutch. High onsets (%H) before a low-pitched accented syllable (L*) were more positively evaluated than low onsets (%L) on each of four scales measuring the speaker's disposition towards the hearer, Non-aloofness, Friendliness, Politeness and Non-aggressiveness. However, low onsets were more positively evaluated before high-pitched (H*) accented syllables than high onsets. In other words, movement towards the accented syllable, regardless of direction, was positively evaluated and absence of movement received negative evaluations. Arguably, choice of onset represents an 'obligingness' morpheme, a grammaticalisation

of the affective interpretation of the Effort Code. This morpheme would consist of an initial unspecified boundary %T, whose identity (%H or %L) is determined by the identity of the following T*, as summarised in Table I.

Table I. Positive speaker evaluation of negative polarity of initial boundary tone in Dutch. After [35]

POSITIVE EVALUATION	%H L*	%L H*
NEGATIVE EVALUATION	%L L*	%H H*

I have no examples of 'unnatural' grammatical focus expression. At best, expressions with and without focus may have equal pitch excursions, in situations in which focus is expresed in the morpho-syntax, as in Wolof [41].

4. The Production Code

A very different interpretation of the process of energy generation relies on the fact that speakers appear to spend more effort on the beginning of utterances than on the ends. This impression originates from a correlation between utterances and breath groups: at the beginning of the exhalation phase, subglottal air pressure will be higher than towards its end. A natural consequence of the fall-off in energy is a gradual drop in intensity, and a weak, gradual lowering of the fundamental frequency [13], known as 'declination' [42]. The communicative exploitation of this effect is the Production Code, which associates high pitch with the utterance beginning and low pitch with its end.

4.1. Informational interpretations of the Production Code

As far as the Production Code is concerned, the significance of declination does not lie in its slope. Rather, it is variation at the edges that is interpreted in terms of initiation and finality. Thus, high beginnings signal new topics, low beginnings continuations of topics. A reverse relation holds for the utterance end: high endings signal continuation, low endings finality and end of turn. Grammaticalisations of these relations is commonly found for the utterance end, when a H% signals continuation, but may also be found in the use of initial %H to signal topic refreshment. The Production Code would appear to have informational meanings only.

The interrogative and continuative meanings of final rises in languages like Dutch [43], therefore, have quite different explanations under the present account, since the first is derived from the Frequency Code and the second from the Production Code. Earlier, these meanings had been collapsed as 'open' in [44],[8]. Various research results suggest that where both cues exist, the continuation cue is lower than the interrogative cue. This is true for Dutch, where L*H or H* followed by a level pitch until the intonational phrase boundary, is likely to be interpreted as a continuation cue, while the addition of H%, which is realised as an additional rise at the boundary, will cause a shift towards question interpretation [43]. Overall slope in Danish, used

concomitanty with variation in end pitch, is similarly linked to interrogativity for the least steep slopes, with continuation for the medium slopes, and with statements for the steepest slopes [45]. Arguably, this result follows from the fact that, for the purposes of the Production Code, the variation at the end of the utterance falls within a lower frequency band than that at the beginning of the utterance, while the variation for the Frequency Code is free from this downward bias. Conversely, we would expect that interrogativity marking at the beginning of the utterance, like H% in Malay, can have lower pitch than that used for the signalling of a new topic.

The downward slope is commonly grammaticalised, as downstep. In a frequent type, H after L is pronounced at a categorically lower pitch than a preceding H. Such grammaticalisations may be purely phonological, i.e. meaningless (except for the information provided by the fact that the downstep context is confined to some prosodic constituent, which will indirectly reveal the morpho-syntactic structure). Final Lowering, like the raising of the pitch at the beginning of phrases, in gradient in English, but it may be phonologised too, as it is in various African tone languages.

5. Substitute variables in F0 variation

An important aspect of the present conception of intonational meaning is that while the nature of the meanings is related to the way our speech organs produce pitch variation, there is no implication that the physical conditions that lie at the basis of these meanings need to be present in order to create the forms. Speakers and listeners know what these form-function relations are, and will produce the forms in the way they see fit. To indicate the start of a new topic, the idea is not that the speaker should breathe in at the beginning of his utterance, but that he should produce sufficiently high pitch at that point to convince his listener of his communinicative intention. It is in fact possible to use substitute features, phonetic forms that the listener can associate indirectly with the primary form. Two cases are discussed. First, peak delay can signal high pitch, and thus all the meanings of high pitch, and second, that high pitch can be used to signal wide pitch span.

5.1. Peak delay as a substitute for peak height

A higher pitch peak will take longer to reach than a lower one, if rate of change is the same. Therefore, higher peaks will tend to be later than lower peaks, as suggested by Figure 3. Speakers and listeners have tacit knowledge of this mechanical connection, providing them an opportunity to bring it under control. Peak delay can therefore be used as an enhancement of, or even a substitute for, pitch raising.
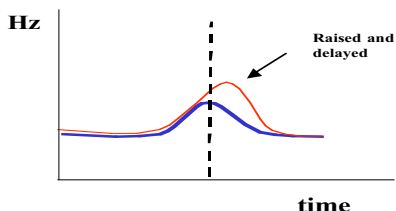

Figure 3. Hypothesized relation between high peaks and late peaks. From [3].

As a result, the meanings derived from the three biological codes that are associated with high pitch may also be signalled by late peaks. First, due to the Effort Code, late peaks sound more prominent than early peaks. Strictly speaking, this is a two-step inference on the part of the listener: (1) high peaks can indicate wide pitch span, and (2) late peaks can indicate high peaks. Indeed, both higher and later peaks elicit more 'unusual occurrence' interpretations than 'everyday occurrence' interpretations of one-peak realisations of *The aLARM went off*, as shown by [46], suggesting that listeners perceive late peaks as if they were higher. Moreover, in research on the difference between wide focus and narrow focus in the Hamburg dialect of German, it was found that narrow focus was realised by later peaks, suggesting again that speakers use it to signal high pitch [47].

A grammaticalisation of late peak vs early peak occurs in European Portuguese, which has H*+L for narrow focus and H+L* for neutral focus [39], which latter pitch accent, again, is also lower, as noted in section 4.1. In these cases, the later peak does not conflict with the primary variable, pitch span, since the pitch span in the accented syllable will not be smaller than in the neutral syllable. However, the use of peak delay for emphasis is constrained by the competition from primary correlate of the Effort Code, the pitch span. Since the nuclear syllable is a prime location for the pitch span cue, narrow focus is often indicated by a pitch accent describing a fall *within* the stressed syllable, while the pitch fall in the neutral focus case falls outside it [47]. For instance, prenuclear pitch accents would appear to be L*+H in Spanish, and nuclear, focal ones H*+L [49].

As for the Frequency Code, there have been reports of languages that use a later peak to mark question intonation and an earlier one for statement intonation, such as southern varieties of Italian [50]. The difference is interpreted as categorical by Grice, suggesting that we are dealing with a grammaticalised form of an informational interpretation of this secondary effect of the Frequency Code. Recently, it has been found that nuclear peaks in Dutch questions are 40 ms later than in declaratives [51]. Here, the effect is almost certainly phonetic. An affective interpretation of the Frequency Code can be found in the fact that delayed accentual peaks in Japanese are associated with female speech [52]. A demonstration of the universality of the connection between peak delay and interrogative intonation was provided in the experiment reported in [22]. In addition to end pitch and peak height, their stimuli also varied in peak alignment. Regardless of language background, Hungarian, Chinese and Dutch listeners associated not only higher peaks and higher end pitch with questions, but also later peaks. This results showed quite ambiguously that humans know both the direct and indirect manifestations of the Frequency Code (see Fig 4).

Finally, the Production Code: [31],[53] found that first peaks of intonational phrases containing new topics in British English were later than other first peaks. This finding can be related to this code, which links high beginnings to new topics. The high beginning is expressed in the first accentual peak, whose late timing enhances the high pitch.
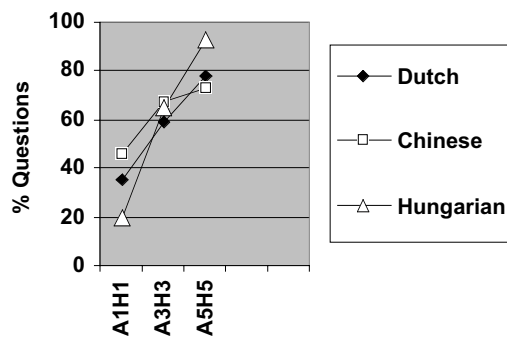
Figure 4. Percentage "Question" judgements as a function of peak condition by three groups of listeners, with ordinal interaction between Language and Peak Condition. From [22].

5.2. High register as a substitute of pitch span

High register may be used as a substitute of wide pitch span, as demonstrated by the results of [54], to be reported at this conference. They show that, unlike British English listeners, Dutch listeners are prepared to interpret high register as signalling emphasis. An interesting corrolary of this appears to be that for Dutch listeners, high register is 'occupied' by the Effort Code. In [55], Dutch and English listeners were asked to rate stimuli which varied in overall register for 'friendliness', in Dutch and English stimuli, respectively. Dutch listeners were considerably less inclined than British English listeners to perceive the variation in register in terms of 'friendliness' variation, as shown in Figure 4.
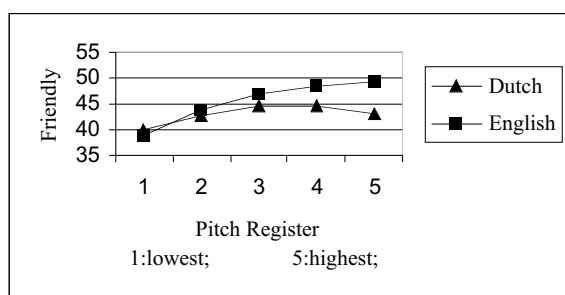

Figure 4 Interaction of Language and Register for perceived friendliness scores in British English and Dutch. From [55].

6. Grammatical meaning

So far, a picture has been painted whereby form-function relations are available to all humans, which language learners will grammaticalise, after which language change may destroy them, such that grammatical forms may have meanings that are the opposite of what would be expected. As a broad frame of reference, this picture has served well to make sense of many well-known form-function relations, and of the fact that intonation is at the same time structural, discrete, and often has arbitrary form-function relations, while on the other hand seems overwhelmingly iconic, both to

monolingual speakers and to researchers interested in intonational typology. There are many details to be explained, such as the impression - if it is correct - that the Frequency Code more easily gives up its iconicity than the Effort Code or the Production Code. Also, the question of how much liberty speech communities have in exploiting these codes – to what extent the expoitation of the phonetic space by their grammars limits them in their use, and to what extent speech communities can decide to use one meaning rather than another where meanings are conflict, as in the case Dutch listeners' interpretation of high register as 'emphatic' rather than'friendly'. The experience of the former British Prime Minister Margaret Thatcher is illustrative. She was apparently following the advice of speech consultants when lowering her pitch with an aim to sound authoritative (Frequency Code), but was frequently interrupted by interviewers as a result, because the way she moved to low pitch resembled the way she produced end of turn signals (Production Code) [56]. Conventionalisations must of course remain within the semantic/pragmatic framework operative in the phonetic implementation: they cannot reverse the universal form-function relations.

Another point is that grammaticalisation not only refers to the phonology, but also to the semantics. This is particularly clear in the case of the meanings of pitch accents and of pitch accent distributions in English, which form a system whose complexity goes beyond what seems possible in the phonetic implementation. I give a brief example of each.

6.1. Contours

Within autosegmental approaches to intonation, there have been two proposals for the semantics of intonation contours, [57],[58]. It is hard to evaluate the compatibility of these proposals, but for the sake of the argument, I summarize three elements of [57, ch 6].

a. H*L-type contours label the linguistic constituents for **addition** to the discourse model: the speaker commits himself to the inclusion of the information in the model;
b. H*L H%-type contours label the linguistic constituents for **selection** from the discourse model. The speaker acts as if the discourse model already contained it;
c. L*H-type contours label the information as potentially belonging to the discourse model, the hearer being invited to resolve this. This was labelled **testing**.

Meanings b. and c. in particular seem too specific for them to be directly derivable from the biological codes. Ward and Hirschberg [58] give (1a) to show that the speaker cannot appeal to the listener to consider pies to be part of the set of likeable things to which jello belongs, as he knows this to be untrue. In (1b), the implication goes through. With a fall, the implication, and with it the contradiction, disappears.

(1) A: Do you have jello?
a. B: We have \pie/
b. #B: We have \pie/, which we know you won't eat
c. B: We have \pie, which we know you won't eat.

The system in [57] is compositional, but to a lesser extent than advocated by [58], who essentially consider every tone a morpheme. The compositionality of [57] comes in as 'modifications', to be expressed as affixes or tone deletions,

which meaning components apply to classes of contours. An example is L*-prefixation, which adds significance to every one of the three meanings ('delay').

6.2. Pitch accent distribution

The same point can be made with respect to pitch accent distribution in English. There are precise semantic effects of the type illustrated in (2). In (2a), the usual rendering of the proverb, the presence of accent on *spoil* is obligatroy for the interpretation whereby the many cooks in the subject are only potential. Without the accent, as in (2b), the proposition becomes eventive [57, ch 2], such the the speaker commits himself to the belief that there actually are too many cooks spoiling the broth.

(2) a. TOO many COOKS SPOIL the BROTH (proverb)
  b. TOO many COOKS spoil the BROTH
(implying e.g. that soups need to be taken off the menu)

6.3. Negotiating shared understanding

The grammatical meanings of intonational morphemes are labels that tell the listener to what extent the information represents an update of the shared understanding he is negotiating with the speaker. The first distinction is between status-quo information (background, old information) and update information (focus, new information). Status-quo information is deaccented: no pitch accents appear after the focus constituent. (Before the focus, pitch accents may be added for rhythmical reasons.) The meanings of the pitch accents(-cum-boundary tones) concern the relation of the focus to the background [60],[57],58],[61]. I illustrate the above three meanings in Table X.

Table II. Three meanings acquiring different interpretations depending on whether the speaker's or the hearer's conception of the shared understanding is being modified.

	Expression	Speaker-serving	Hearer-serving
ADD	*It's John*	INFERENCE	SUPPLY INFO
SELECT	*It's John*	REALISATION	REMINDER
TEST	*It's John*	REQUEST INFO	CHALLENGE

A falling contour can be an inference, when the addition is to the speaker's own conception of the shared knowledge, but supplies information to the hearer when the latter's conception of the model gets updated. A falling-rising contour can be a puzzled realisation when made for the speaker's own benefit, but a reminder when made for the hearer's benefit. Finally, a rising contour for the speaker's benefit represents a question, a request for information, but is a challenge when performed for the hearer's benefit ('Are you really sure this is part of our background?').

  Accent distribution is used for distinguishing between updates of the historical record, in which case the hearer will know the world is a different place from what he believed it to be before processing the speaker's utterance, from attendant circumstances, where the update concerns his knowledge of things that already were that way before he processed the utterance. The former type was labelled EVENTIVE is [56]. The proverb (2a) is non-eventive: the world is the same before and after an instantiation of (2a), but

it is different after an instantiation of (2b). Non-eventive sentences fall into two categories, DEFINITIONAL, which update the attendant circumstances, and CONTINGENCY, which does the same, but had the additional meaning that the speaker claims not to know if the update is at all relevant (see Fig. 5). The three types have different forms in English. First, eventive sentences have no accent on the predicate if it is adjacent to an accented argument (subject or object). Definitional sentences only allow unaccented focused predicates when adjacent to an accented object. Contingency sentences are distinct from definitional sentences in requiring accent on the negator in the VP, and in requiring accent on the predicate even when adjacent to an accented object. The three types are distinct in a negative subject-predicate sentence, therefore, as shown in (3), (4) and (5).

(3) (A: What's that scuffle?)
  B: Our CUSTomers aren't admitted! (Eventive)
(4) CUstomers aren't adMITted
 (This is the way it is: Definitional)
(5) Our CUSTomers AREN'T adMITtEd
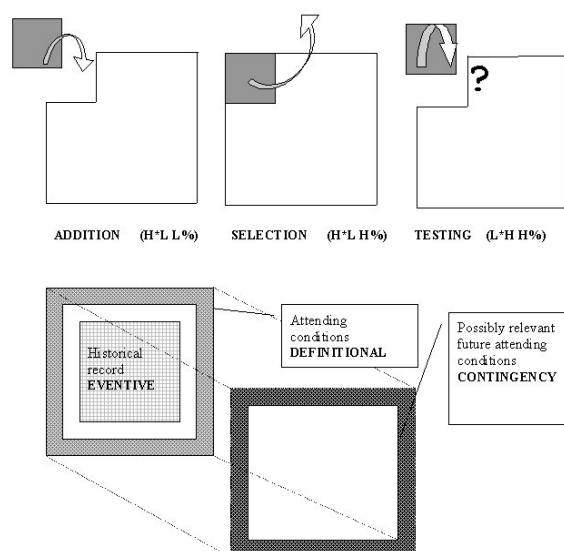 (In case you had forgotten: Contingency)

Figure 5. Graphical representation of three meanings of intonational contours, and three meanings of pitch accent distribution. The shaded area represents the focus constituent, the larger area the shared understanding.

7. Summary and Conclusion

Universal meaning in intonation derives from three biological codes, the Frequency Code, the Effort Code and the Production Code. The codes are biological in the sense that they represent aspects of the speech production mechanism that affect rate of vocal cord vibration. Speakers have brought these effects of the 'hardware' under control. The fact that speakers take charge of these aspects of speech production fits into a larger picture of speaker control [62]. Speakers control the phonetic implementation of linguistic expression for a wide variety of reasons, among which are social positioning, maximisation of the discriminability of phonological contrasts, and the recruitment of iconic uses of the voice to aid the

expression of the meaning of their linguistic expression. The exploitation of the biological codes in intonation is similarly controlled during phonetic implementation.

It was stressed that in order to express these meanings, speakers need not create the physiological conditions which are associated with them through any of the three codes. In at least one case, this would be physically impossible: we cannot reduce or enlarge the size of our larynx to manipulate pitch for the purposes of the Frequency Code. Similarly, they do not have to take in more air to produce higher utterance beginnings signalling new topics (Production Code), or speak slovenly so as to have low pitch excursions signalling a lack of interest (Effort Code) (even though in these latter cases they might).

A number of interpretations of the Effort Code were identified. An informational interpretation is emphasis, which is due to the interpretation of effort as the speakers's intention to underscore the importance of the message. Affective interpretations include surprise and obligingness. The latter meaning is due to the interpretation of effort as the speaker's intention to appear clear and unambiguous. The Production Code is due to the effect of energy dissipation in the course of the utterance. Its interpretations are informational only: high beginnings signal newness of topic, low beginnings the opposite, and high endings signal continuation, low endings its opposite. The Frequency Code is widely used for the expression of affective meanings. These include masculinity, authoritativeness/ assertiveness, and protectiveness (low pitch) and femininity, submissiveness/friendliness, and vulnerability (high pitch). The informational interpretation is 'certainness', leading to distinctions in 'sentence mode', the difference between statements and questions.

Grammaticalisations of the paralinguistic meanings are common in the case of the informational interpretations. In fact, the only case of an 'affective' morpheme was presented for Dutch, which arguably has a polar %T signalling 'obligingness'. Informational grammatilisations concen the significance of (parts of) the message (Effort Code), to continuation vs end of turn (Production Code), and question vs. statement (Frequency Code).

Pitch height in peaks can in part be enhanced or taken over by peak delay, due to the mechanical connection between high peaks and late peaks, which explains why later peaks sound more prominent (Effort Code), are more likely to signal when data are represented by the mean F0 over utterances, as in [63]). Also, due to the way their phonologies use the available phonetic space differently, languages will vary in the scope they allow for the expression of universal meanings. This may be the explanation of the fact that the wide-span L*HH% contour sounds more aggressive on answers to questions in Dutch than in British English: in order to signal the TESTING meaning assumed to be responsible for the negative effect ('challenge') the speaker must go beyond the usual kind of pitch span that signals friendliness. Since Dutch uses a narrower pitch span than British English, a difference in interpretation could result [64].

When the universal form-function relations become grammaticalised, and thus are encoded in the discrete prosodic structures of the language, there is no longer a guarantee that they are maintained. Loss of iconicity seems common in the case of the informational interpretation of the Freuqency Code, i.e., in the case of question and statement intonation.

Grammaticalisation will also affect the semantics of tonal forms. There would appear to be a systematisation of meaning for the expression of information structure which goes beyond what would be expected of a direct form-function relation of the type found in animal communication and paralinguistic meaning. Meanings like SELECTION and CONTINGENCY were given as examples.

The account of the position of intonation in language presented here presupposes a principled distinction between phonetics and phonology, and to the extent that it is convincing, amounts to a further argument for making it: without it, we lose the basis on which we distinguish the universal, non-linguistic (in the sense of non-structural) system of communication employed in phonetic implementation, and the linguistic system, which is embedded in the grammar, and for that reason potentially invested with arbitrary (i.e., non-iconic) meanings. questions or femininity (Frequency Code) and are more likely to signal new topics (Production Code). Similarly, wide pitch span may be signalled by high pitch register.

The exploitation of these universal meanings will to some extent be conventionalised within speech communities. For instance, mean F0 of German speakers was found to correlate positively with ratings for such personality traits as lack of autonomy, dependability and likeability, while in the case of American males, mean F0 correlated positively with dominance, authority and competence [63]. Evidently, the German speakers were understood to be signalling the feminine meanings of the Frequency Code, while the American speakers were understood to be signalling the significance meanings of the Effort Code. This difference in interpretation may just be culturally determined, in which case the phonetic parameters might well have been the same, or else the German speakers showed less pitch excursions than did the American speakers (information which is lost when data are represented by the mean F0 over utterances, as in [63]). Also, due to the way different phonological systems use the available phonetic space differently, languages will vary in the scope they allow fro the expression of universil meanings. This may be the explanation of the fact that the wide-span L*HH% contour sounds more aggressive in answers to questions in Dutch than in British English. In order to signal the TESTING meaning ('challenge') the speaker must go beyond the usual pitch span, and since Dutch has a narrower pitch span than British English, this effect is more obtained more readily in Dutch [64].

When the form-function relations become grammaticalised, there is no longer a guarantee that they are maintained, since they are subject to the forces of phonological change. Loss of iconicity seems common in the case of the informational interpretation of the Frequency Code, i.e., in the case of question and statement intonation. Of these, statement intonation is less commonly non-falling than question intonation is non-rising [1]. This may have to do with the fact that high pitch for questions need not be located at the end of the utterance.

Grammaticalisation will also affect the semantics of tonal morphemes. Theer would appear to be a systematisationof meaning for the expression of information strcuture which goes beyond what would be expected of a direct form function relation of the type found in paralinguistic meaning.

The account of the position of intonation in language presented here presupposes a principled distinction between phonetics and phonology, and to the extent that it is

convincing, amounts to a further argument for making it. Without it, we lose the basis on which we distinguish the universal, non-linguistic (in the sense of non-structural) system of communication employed in phonetic implementation from the linguistic system embedded in the grammar, with its potentially arbitrary form-meaning relations.

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