

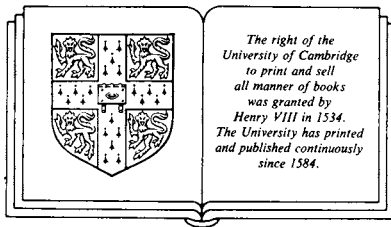
# A perceptual study of intonation

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An experimental-phonetic approach to speech melody

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## Introduction

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As humans' most sophisticated means of communication, the code of language exploits numerous formal devices in order to get the meaning of the message across. When words are strung together, the resulting meaning of the whole structure is a function of the semantic properties of the individual lexical items and of the syntactic relations that hold among them. It is also a function of the linguistic and situational context in which the utterance is produced. When speech is uttered, the vocal organs are set into motion in order to generate the sound pattern that corresponds to the underlying linguistic elements. In this generation process the speaker does not merely articulate the successive speech sounds that make up an utterance, but simultaneously controls other vocal features such as loudness, tempo, rhythm, pitch, voice quality, etc. The latter variations do not shape the phonetic identity of the segmental speech-sounds, but constitute a truly 'suprasegmental' or 'prosodic' layer in the sound pattern. The prosody of an utterance adds an expressive dimension to the communication process: by modifying the prosodic features the speaker can supplement his utterance with elements of meaning that are not explicitly contained in its lexical and syntactic make-up. This added meaning must be taken in the broad sense of 'communicatively relevant information', and may be given widely different paraphrases, such as: this is the topic of my discourse; this is a polite request; I don't believe you; I am bored; I don't mean what I say; I mean the opposite of what I say; I emphasize this word; this is the end of my message; etc. The communicative value of prosodic features is evidenced by the fact that novelists and playwrights are frustrated by the impossibility of coding them in conventional orthography (a defect already taken up by J. Steele, 1775, 1779), and by the fact that the same text can be said in many different ways. The few punctuation marks that are available, or the use of italics and capitals, are insufficient means to express the added shades of meaning conveyed by prosody. They have to be paraphrased in plain words.

Both linguists and phoneticians, in as far as they are interested in the communicative function of language and speech, have been convinced for a long time that prosody is a legitimate issue in their fields of interest, but they

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have also been aware that it is fairly elusive subject matter. By their very nature as utterance-long components, prosodic features are more difficult to observe, transcribe and analyse than are their segmental counterparts, and attested formal differences along any prosodic dimension cannot be given a functional interpretation as easily as is the case with a segmental contrast of the type /p<sup>h</sup>i:k/ (*peak*) vs /bi:k/ (*beak*). Given the formal and functional complexities of prosodic features, one cannot investigate all of them at the same time.

We have chosen to concentrate on just one prosodic feature, viz. intonation, which we define as the ensemble of pitch variations in speech caused by the varying periodicity in the vibration of the vocal cords. Even with this limitation, the domain of our investigation remains vast and complex. Indeed, intonation can be approached from a variety of angles, all of which are equally indispensable if one wishes ultimately to understand how speech melody functions in human communication. Ideally, a theory of intonation should comprise a phonetic and a linguistic component. The phonetic part of the theory should account for the physiological, acoustic and perceptual aspects of intonation, and elucidate the relation between them. The linguistic component of the theory should aim at a phonological interpretation of the phonetic facts and at a pragmatic explanation of how intonation functions in the communicative interaction between speaker and listener. Finally, the theory should comprise a natural link between the linguistic and phonetic components: it should clarify how the melodic performance of the language user results from the interaction between his communicative intent and the peripheral means of his vocal and perceptual apparatus. Admittedly, to develop such a unified theory of intonation is a formidable task and our own research programme is a far less ambitious enterprise. In the remainder of this chapter we will first present a number of considerations that have led to our choice of goals and means. Secondly, we will give a survey of the contents of this monograph, thus offering a preview of the topics that we consider to be important in our work.

### **1.1 A dilemma**

The most fascinating and intriguing thing about language is that it functions so eminently well in human communication. Therefore, the evident goal of linguistic analysis is to lay bare the properties of language that support its communicative role in the speech community. Undoubtedly, intonation is one of the vocal means that can be put to use in conveying a message from speaker to listener. However, in order to investigate how speech melody contributes to the overall meaning of an utterance, one needs a metalanguage in which one

can talk about the phenomenon. The vocabulary of such a metalanguage should consist of suitable descriptive units with which one can refer to entities and structures at various levels of observation.

At the start of our efforts, some twenty years ago, it turned out that a reliable description of the formal properties of intonation was still lacking. There was no consensus regarding the way in which speech melody could best be described, much in contrast with the established agreement in the study of segmental speech phenomena. In the latter domain the units of description present themselves quite naturally. Indeed, it seems intuitively satisfying to assume that the individual speech sounds are the basic segments into which the stream of speech can be decomposed. Some notorious difficulties notwithstanding, many of these units can be recovered as discrete elements in both the waveform and the spectral representation of the signal. They can also be viewed as the consecutive targets in production and as the unitary percepts in the interpretation of the speech signal. The plausibility of the individual speech sounds as descriptive units is attested by the success of alphabetic writing, both in conventional and in phonetic notation. However, this fortunate state of affairs only holds for the segmental level of speech analysis. No such evident descriptive units can be thought of when intonation is the object of study. Speech melody is a continuously varying attribute that encompasses linguistic units as long as complete utterances, and it is far from evident whether, and if so how, it can be segmented into smaller units. The reason for the absence of self-evident melodic units may perhaps be found in the lack of a 'distinctivity criterion', comparable to the one that led to a breakthrough in segmental phonology. Indeed, the emergence of phonology in the late twenties led to a fundamental distinction between 'language' and 'speech', and the powerful concept of the phoneme provided a means to define the functional properties of speech sounds. At the heart of this functional definition was the criterion of *distinctivity*: a minimal phonetic difference between speech sounds is functional if it supports a semantic distinction in the language. In practice, this criterion appeared to be straightforward to apply in so-called 'minimal-pair' tests, in which the phonologist could rely on his phonetic knowledge, combined with either his own semantic intuition or that of a native informant. Phonology thus appeared to perform successfully a much desired reduction on the wealth of phonetic data: it abstracted the 'linguistic code' from the amalgam of physical distinctions, and it provided a principled criterion to decompose the flow of speech into phoneme-sized descriptive units.

Early attempts to apply the distinctivity criterion to speech melody have not been successful. The semantic distinction was commonly limited to the dichotomy of 'statement' vs 'question', which led to a typology of 'falling' vs

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'rising' intonation patterns. Clearly, such an approach runs the risk of seriously underdifferentiating important melodic features. In retrospect, it seems as if the successes of segmental phonology have tempted the students of intonation to focus immediately on its distinctive function without going through the preliminary phase of systematic observation. Of course, scholars such as Jones (1909) and Armstrong and Ward (1926) have taken great pains over systematically observing pitch variations in speech, but their phonetic observations had a dubious empirical status: impressionistic auditory descriptions remain difficult to interpret and may not be representative of other listeners' perceptions.

Admittedly, in those days no techniques were available to measure speech melody in a simple way. The automatic extraction of fundamental frequency became possible only in the thirties, with, e.g., the 'pitch meter' of Grützmaier and Lottermoser (1937). In fact, the use of this device and of its more sophisticated successors created more problems than it solved: the minute physical variations that could be recorded were almost impossible to interpret in perceptual and communicative terms. Once more the researcher was confronted with the difficulty of finding suitable descriptive units.

In summary, the student of intonation faces a dilemma: either he chooses the linguistic approach at the risk of overlooking phonetically important features, or he opts for an instrumental-phonetic angle, thus increasing the chance of missing the communicatively relevant essentials.

### **1.2 A way out**

In the preceding section we have argued that progress in the study of intonation cannot be achieved unless one has procured suitable descriptive units. The latter cannot be found by applying a gross linguistic criterion of distinctivity to unreliable auditory impressions, nor by carefully inspecting the acoustic details revealed by the use of a pitch meter. For one thing, whatever information is carried by speech melody may not be confined to linguistic distinctivity; for another, it is very unlikely that all the minute variations in a pitch curve have been intended by the speaker. Such considerations have led us to believe that a very promising solution to the multitude of linguistic and phonetic problems may reside in the development of a 'model of the listener'. Such a model should eventually answer the many questions subsumed under the more general one: *what does the listener make of pitch in speech?* To answer this question implies that one brings to light which melodic units the listener distinguishes, how he structures them to the overall percept of a pitch contour, how he relates perceived contours to more abstract melodic entities (intonation patterns), how he integrates melodic and textual information into one

linguistic message, etc. To discover the kind of structure a listener imposes on the melodic variations in speech amounts to revealing major aspects of his intonational competence.

A language user's intonational competence not only comprises knowledge about melodic form, but also about melodic function. However, the assessment of the formal properties of intonation takes logical precedence over the study of its linguistic and expressive use. Eventually we want to come to grips with the communicative value of intonation, but our immediate concern is to develop a descriptive framework for the melodic properties of speech and for the intonational features of language. In other words, the task has to be approached from the bottom end, i.e. from the phonetic level of observation. But also at this level a further choice has to be made between a physiological, an acoustic, or a perceptual approach. Our predilection for the perceptual angle in the phonetic domain is based on the consideration that perception acts like a filter that performs a much needed reduction on data of acoustic or physiological origin, which are overspecified: they contain far more information than need be relevant for the purpose of communication. Thus, our ultimate aim of explaining the role of intonation in speech communication accounts for our immediate goal of unravelling the *perceptual* structure of intonation, captured in a model of the listener.

Our emphasis on the listener should not be confounded with a psychoacoustic approach to pitch perception. Of course, there certainly are acoustic variations that go unnoticed because they fail to reach the known thresholds of auditory perception. But it is to be expected that much larger tolerances exist in the domain of speech pitch and that they are of a phonetic-linguistic, rather than of a purely psychoacoustic nature. On the other hand, we do not anticipate that all the perceivable elements of speech melody fulfil a communicative function. Psychoacoustic thresholds and communicative relevance constitute the lower and upper boundaries that delimit the province of our perceptual quest.

To study intonation from the listener's point of view does not exclude a genuine interest in speech production and acoustics. We are convinced that the auditory impressions should be studied systematically in relation to the properties of the acoustic signal, in particular to those that result from voluntary physiological action on the speaker's part. Thus our central concern is not so much the question 'What melody do we perceive?', but rather 'Which properties of the acoustic signal are relevant for our perception of speech melody?' and, subsequently, 'Which physiological mechanisms control these perceptually relevant acoustic features?' Our concern with objective methodology does not force us to solely rely on electronic measurement techniques, but it does compel us not to study perception in isolation from the

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physiological and physical factors that control it. Objectivity might be sought in the domain of acoustic or physiological measurement, but such data seldom speak for themselves: they are hard to interpret in terms of what ultimately matters, viz. the contribution of intonation to the communication process. Indeed, physiological recordings do not tell us much about what pitch inflections the speaker actually intended to produce, nor do acoustic tracings foretell what information is relevant for the listener.

On the other hand, a perceptual approach is subjective *per se*. In order to formulate warranted generalizations about the perception of speech melody, one needs to ascertain whether a particular melodic impression can be reproduced in the same listener as well as in other listeners. This requires the use of reliable experimental techniques. Therefore, our approach can best be characterized as an experimental-phonetic study of how the listener's intonational knowledge is brought to bear on his perception and interpretation of spoken language.

### 1.3 Overview of the contents

This book offers a comprehensive treatment of the philosophy, the methodology and the major results of intonation research in the tradition of the Institute for Perception Research (IPO) in Eindhoven, The Netherlands. As such, this volume is not a textbook: it does not cover the subject matter of intonation study in a broad sense, offering a historical perspective in which successive or competing theories are juxtaposed. In fact, we will have little to say about the 'state of the art' in general, but will rather limit ourselves to an in-depth treatment of what has become known as 'The Dutch School' of intonation. Readers who are less familiar with the field may find general information on intonation studies in overviews by Cruttenden (1986), Ladd (1980), Bolinger (1986) and others.

In chapter 2, 'Phonetic aspects of intonation', we provide succinct information on the physiological mechanisms that determine the rate of vocal-fold vibration. We also discuss how intonation is embedded in the speech signal, and how the relevant information can be extracted from the signal in more or less automatic ways. Finally we devote attention to the perception of pitch. The latter treatment is more extensive, in accordance with our emphasis on the perceptual approach to the phonetic aspects of intonation. We start with an overview of psychoacoustic insights in the auditory impressions of pitch, of pitch distance and of pitch change, both in terms of absolute and differential thresholds. In particular, we examine whether these insights, based on experiments with rather short and simple signals, can help to explain the

perception of pitch in longer and more complex speech stimuli. In many respects the answer is negative: in the dynamic and complex speech signal, the perception of pitch is, in general, less accurate than in the stimuli usually applied in psychoacoustic experiments.

Chapter 3, 'The IPO approach', sketches the general framework of our perceptually oriented analysis of intonation. It introduces our basic assumption and the descriptive units with which we operate at different levels of analysis. Most importantly, we give an exhaustive and explicit account of the experimental procedures that we use, so that they can be duplicated by interested researchers.

First we explain how the artificial manipulation of fundamental frequency ( $F_0$ ) is at the core of a series of procedures that yield descriptive units of increasing complexity. Indeed, the *stylization* of an original  $F_0$  curve and the evaluation of the perceptual consequences of such an operation are the basic tools of our approach. With this technique we are able to isolate perceptually relevant  $F_0$  changes and to explore along which melodic dimensions they are distinct from one another. We can also examine within what limits the original and the stylized  $F_0$  changes result in either identical or equivalent perceptions, so as to be able to propose *standard* acoustic specifications for each of the perceptually distinct *pitch movements*.

Next, we elucidate how the atomistic pitch movements can be used in the construction of a global *pitch contour*, through the intermediate unit of the pitch movement *configuration*. Again we explain how these sequential constraints of the pitch movements can be discovered, how they can be formalized in a *grammar* of intonation, and how the validity of the predictions made by this grammar can be assessed.

Finally, we discuss how perceptually distinct pitch contours may be related to more abstract categories, the *intonation patterns*. Here, too, we describe the experimental techniques with which one may explore the nature of this relationship.

Chapter 4 is entitled 'A theory of intonation'. The analytic and experimental techniques presented in chapter 3 have produced a fairly coherent body of results that we present as our theory of intonation. We formulate the acquired insights in the form of ten propositions. In support of these propositions we summarize the experimental findings that have accumulated in the course of our study of Dutch intonation, and we adduce additional evidence from more recent analyses of English, German and Russian intonation.

The first six propositions pertain to the *phonetic* part of our theory. They primarily deal with our melodic model of intonation and with the relation



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between the perceptual and the acoustic or physiological manifestations of intonation. The next three propositions concern our views on certain functional aspects of pitch in speech, viz. the role of intonation in sentence accentuation and syntactic-boundary marking, and its contribution to the overall meaning of an utterance. The last proposition regards a psycholinguistic issue, viz. the amount of preplanning that is required for a speaker to successfully integrate melodic and functional requirements in the control of his pitch.

Chapter 5 is devoted to declination. The theoretical issues raised in the propositions of chapter 4 all pertain to intonation in so far as it manifests itself in the form of conspicuous major pitch changes. Nothing has been said about declination, i.e. the actual or virtual tendency for a pitch contour to gradually drift downward in the course of an utterance. The chapter is subdivided in three phonetic sections (acoustics, production and perception), followed by a fourth in which some functional aspects of the phenomenon are at issue. The acoustics section discusses the difference between *topline* and *baseline* declination and illustrates how our stylization technique can be used to reliably measure the declination rate. Predictions about the variable rate of declination are stated in a formula. The first section ends with a discussion of *declination resetting*. The second section explores the possible physiological causes of declination and examines to what extent it may be actively controlled by the speaker. The perceptual side, dealt with in the third section, raises the issue of the psychological reality of declination. In the final section of this chapter we address the possible influence of declination on the overall interpretation of an utterance.

In chapter 6, 'Linguistic generalizations', we attempt to further reduce the phonetic structure of Dutch pitch contours to its essential properties. In the first part of this chapter we introduce and define a number of descriptive units and categories, and show how they apply to abstract intonational structures. Then we present a set of derivation rules that convert underlying intonation patterns into more elaborate, concrete melodic entities. Finally we show how melodic structures and textual elements can be mapped onto each other. In the second part of the chapter we compare our treatment to a more orthodox phonological analysis of Dutch intonation.

In chapter 7, 'Applications', we consider a number of actual and potential applications of our phonetic results. To date, actual applications are to be found in the areas of foreign-language teaching and aids for the handicapped. Our findings have been translated in non-technical terms in a 'Course of

Dutch intonation' and they have been incorporated in the design of an intonable electrolarynx. Our specification of the melodic possibilities of Dutch, English and German have also been implemented in algorithms that are components of full-fledged text-to-speech systems, still under development. Finally, our melodic models of Dutch and English intonation provide a formal phonetic description of sufficient detail to allow for further explorations of more functional, linguistic issues.

Finally, in chapter 8, 'Conclusion', we recapitulate the main points that we have tried to make in establishing the feasibility of our perceptual approach. We look back upon the considerations that have motivated our initial choices and we examine to what extent we believe our endeavours have contributed to a better understanding of the phenomenon of intonation.