Experimental approaches to establishing discreteness of intonational contrasts

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Abstract

A number of experimental techniques are reviewed that have been used to distinguish gradient differences from discrete differences between intonational pitch contours. The first are attributed to paralinguistically meaningful variation between different pronunciations of the same phonological contour, while the second are attributed to different phonological contours. Two 'same-or-different' paradigms are compared, the 'passable-imitation' test and the 'categorical perception' paradigm. In addition, three other approaches are discussed, the 'semantic task', the 'imitation task' and the 'pitch range task'. It is suggested that tasks should more explicitly engage listener's intuitions about phonological identity, so as to minimize interference of phonetic differences in responses to phoneticaly different but phonologically identical contours.

1 Introduction

In mainstream views of phonetics and phonology, the explanation of phonetic forms is divided into two parts. A phonetic form is first of all attributed to a cognitive representation, consisting of a grammatically legitimate combination of phonological elements, in principle observable in, or abstractable from, patterns of brain activation. This element would remain constant if a speaker were to repeat the utterance, and is inherent to the particular linguistic expression pronounced by the speaker.

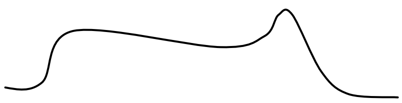
The variation that would be observable if a speaker were to repeat the pronunciation of the expression under a variety of circumstances is attributed to the phonetic implementation. Within this hypothetical set of repetitions, an infinite set of physical manifestations, there is no discreteness, only gradience. If we are to be able to state the phonological inventory and formulate the grammar of a language, the problem of distinguishing between phonological and phonetic differences must be solved.

Accordingly, a central issue in the analysis of intonation systems is that, given two utterances, how we are to know whether they came from the same phonological representation or from different phonological representations. The problem of distinguishing between these two sources of variation is particularly acute in intonation, because more so than variation in the segmental domain, phonetic variation in pitch is used to communicate, and signals 'paralinguistic meaning' (Ladd 1997).

The complicating factor here is that intonational meaning and paralinguistic meaning are in many ways similar. For instance, (1) and (2) have, on all accounts, different phonological structures, (1) having a high-pitched *se-* and (2) a mid-pitched or low-pitched one. In (1), the word *second* seems particularly important, and the example may sound as if there was a choice between *first* and *second*, while (2) might be a confirmation of the date of a meeting. (These interpretations are just possibilities, though, and both (1) and (2) could have either meaning.) The point is that (3) could be argued to be different from (1), in that it may be interpreted to mean the a third or fourth may also qualify ('it's minimally the second'), yet most analyses of English intonation would regard it as having the same structure as (1). Examples (1) and (3) would each consist of two equal peaks, analysed as %L H*L H*L L% in Gussenhoven (1983, 2004) or as L+H* L+H* L-L% in Pierrehumbert 1980, Beckman & Pierrehumbert 1986). The difference between the two is that second peak is carried out with greater pitch excursion in (3) than in (1). However, (2) is analysed as having a downstepped second peak, which is taken to be discretely different from the non-downstepped peak in (1) and (3).

(1) It's DEFinitely the SECond
%L H*L H*L L%

(2) It's DEFinitely the SECond
%L H*L !H*L L%



(3) It's DEFinitely the SECond
%L H*L H*L L%

Ideally, if these analyses are correct, any contour that is broadly similar to those in (1) and (2) ought to be assignable by native speakers to either of these types, but contours that fall between those in (1) and (3) might create the impression of really being the same, and assignable to either (1) or (3) on the basis of attentive listening to the pitch of the second peak.

2. Reviving an older experimental approach

In the large majority of cases, the structural discreteness that is assumed in analyses of intonation systems is rooted in native speaker intuition. It is only in the more subtle cases, such as when a language appears to have two kinds of rises or two kinds of falls, that the issue becomes problematic. In fact, the earliest operational criterion that was proposed is based on the explicit engagement of native speaker intuition. The IPO school of intonation analysis ('t Hart, Collier & Cohen 1990) distinguished between two levels of abstraction of the phonetic contour, referred to as 'close-copy stylization' and 'standard stylization'. In close-copy stylization, the contour is smoothed out with the help of the smallest number of straight-line sections as are needed to make the original and the stylization sound exactly the same (barring audible microprosodic effects). There may be more than one solution, and the process is one of trial and error. The original contour and the close copy should have 'perceptual equality'. An experiment with British English contours showed that this equality can be taken literally, in the sense that listeners hear no difference between the one and the other (de Pijper 1983).

Standard stylization can be achieved once the straight-line sections obtained from the close copies have been sorted and averaged, such that a set of standardized movements is formed. As the authors point out, '[t]he generalization should not go so far that it would do away with possible categorical differences between types of pitch movement' (1990). Contours can be subjected to standard stylizization with the help of line sections from this set. The two audibly different contours, the close copy and the standard copy, must now be heard as passable imitations of each other by native speakers of the language. To quote: 'For instance, some of the excursions may be audibly larger or smaller in the imitation than in the example, without an entire loss of similarity' (1990:47). Additionally, the standard version must be judged acceptable by native speakers. In our terms, contours whose standard stylizations are the same have the same phonological representations, while contours with different standard stylizations are phonologically distinct.

A number of experiments have been run to judge acceptability, but such experiments really only testify to the realistic nature of the particular phonetic forms of the standard stylizations. Only recently has there been an experiment that chose a task in which subjects had to judge whether one contour was a passable imitation of the other, Odé (2005). The issue here was whether the difference between two Russian intonation contours, which are readily heard as distinct when the accented syllable is non-final in the Intonational Phrase, are still distinct when the accented syllable is final, where truncation would appear to obliterate the difference between them. Impressionistic stylizations of the contours, provisionally analyzed as LH*L L% and LH* %, are given in Fig.1, from Odé (2005). The '%' by itself indicates an Intonational Phrase boundary without a boundary tone. The phonetic similarity between the two final-accented contours is high, as shown in Fig. 2. The answer to the question whether these contours are still discretely different is therefore anything but trivial.

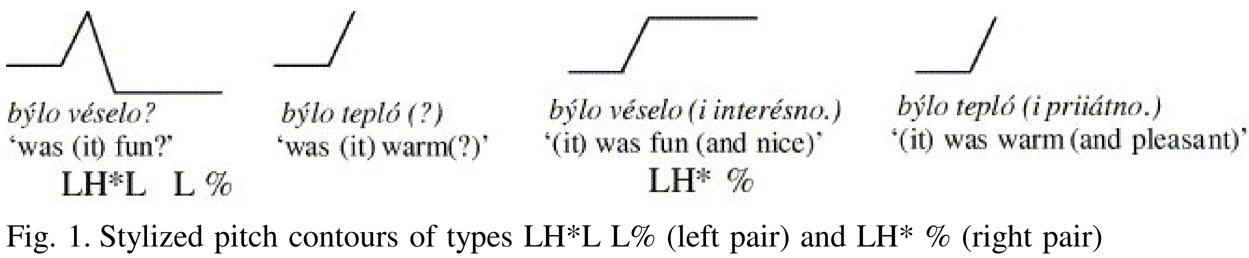


Fig. 1. Stylized pitch contours of types LH*L L% (left pair) and LH* % (right pair) realized in utterance-final words on antepenultimate and ultimate syllables.

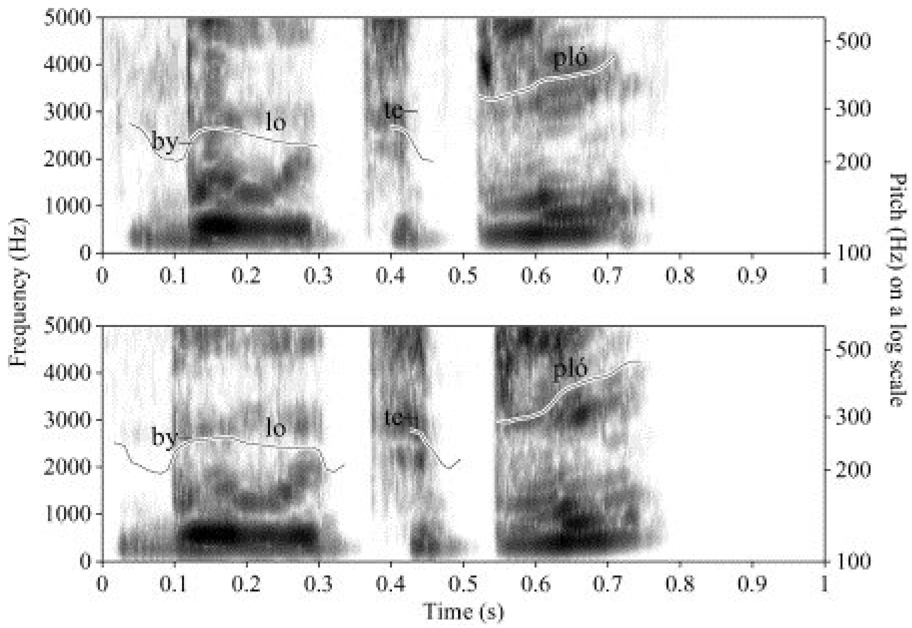
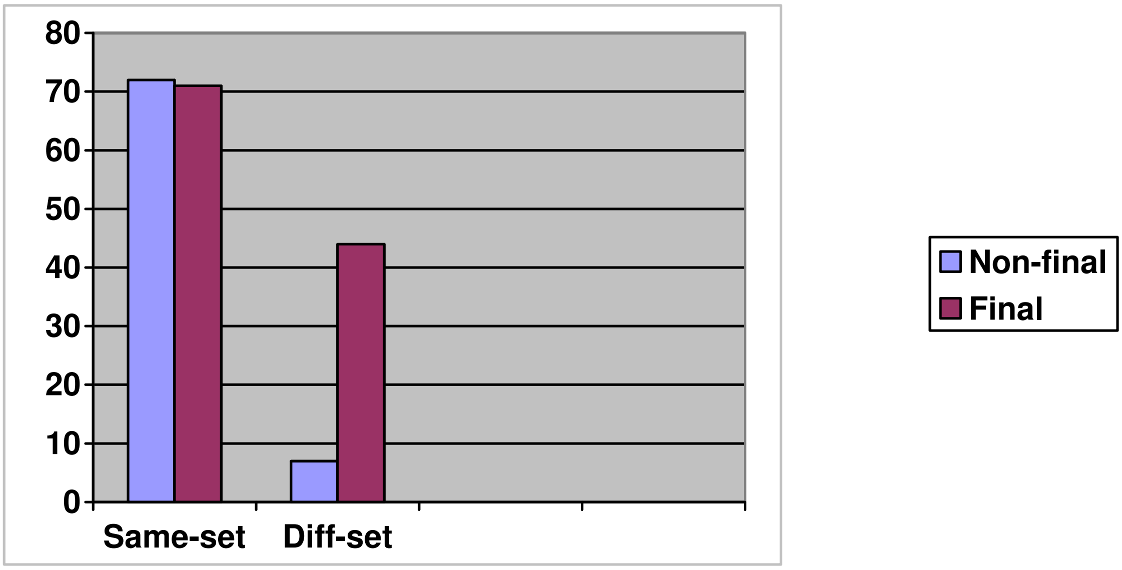


Fig. 2. Spectogram and pitch contour on a logarithmic scale of the utterance *býlo tepló* '(it) was warm' realized by a female speaker with contours LH* % (top) and LH*L L% (bottom).

Subjects were presented with naturally spoken utterances with the two intonation patterns as used in final and non-final position in the Intonational Phrase. These had been obtained from eight speakers who had been instructed to read a list of sentences that had both final and non-final accents, once with LH*L L% and once with LH* %. Pairs of stimuli were formed by combining utterances spoken by different speakers with contours from the same intonation contour (same-set pairs) and from different intonaton contours (different-set pairs). The members of each pair were always readings of the same written sentences, and thus had the last pitch accent in identical locations. The results are summarized in Table I. Subjects' responses to contours taken from within an intonational set were judged to be passable imitations of each other in 72% of cases in both final and non-final positions. This may be looked upon as a baseline value for the recognition of phonological identity of phonetically different contours. Pairs of contours taken from different intonational sets were judged to be passable imitations of each other in only 7% of cases when the accent occurred in IP-internal position, where discrimination was expected to be high. This may be seen as a baseline value for easily distinguishable differences between phonological contours. Crucially, in final position, listeners only judged the contours to be passable imititaions of each other in 44% of cases, significantly less than in the case of contours taken from the same set. Clearly, if there were neutralization, the contours should have been judged the same in many more instances. The fact that 'sameness' judgements reached 44% rather than the low baselnine value of 7% is attributable to the very similar phonetic contours with which they are realized.Odé's conclusion therefore is that there is no neutralization, and that the truncation graphically represented in Figure 1 occurs in the phonetic implementation, and does not amount to the deletion of tones, such as would cause LH*L L% and LH % to become identical, LH* %.



FFig. 3. 'Passable-imitation' scores for pairs of utterances with LH*L L% contours or LH* % contours (same set) and pairs of utterances contrasting LH*L L% and LH* % contours (different set) in final and non-final position After Odé (2005).

The successful resolution of an issue that is crucial to the correct analysis of the intonation of Russian by means this relatively straightforward procedure might profitably be explored further.

3 Implications for other appraoches

In Gussenhoven (1999), I reviewed four experimental approaches which have sought to determine the nature of intonational contrasts on the basis of the performance of subjects in other experimental tasks. I briefly return to these below. They are 'categorical perception', the 'semantic task', the 'imitation task', and the 'pitch range task'.

3.1 Catgorical perception

If listeners interpret stimuli covering the phonetic continuum between two phonological categories as belonging either to the one category or to the other, and do not hear much difference between the stimuli that are interpreted as representing the same category, they perceive the contrast as 'categorical' (Liberman et al 1957, Liberman et al. 1967). The classic case is that of the continuum of Voice Onset Times covering two canonical realisations of two stop phonemes, such as /p-/b/. Two separate tests are required to establish categorical perception. First, an identification task, in which listeners are presented with stimuli in a random order and are asked to assign each of them to either of the two phoneme categories, should reveal that there is a fairly abrupt perceptual shift somewhere along the continuum from one phoneme category to the other. Second, a discrimination task, in which listeners are presented with pairs of stimuli that differ by one acoustic step and are asked to indicate whether the two stimuli are the same or different, should reveal that between adjacent stimuli that are perceived as representing a single phoneme category listeners hear fewer distinctions than between the stimuli that lie on different sides of the perceptual boundary, even when acoustic differences are comparable.

As Newport points out, categorical perception is neither a necessary nor an exclusive property of linguistic contrasts. Phonological contrasts that are perceived categorically are voicing distinctions in plosives, while contrasts that are not may include vowel duration distinctions. Conversely, the non-linguistic distinction between a plucked string and a bowed string has been found to be perceived by listeners in the same way as the linguistic /p/-/b/ contrast (Cutting, Rosner & Foard 1976). In other words, categorical perception is not a property of linguistic stimuli, but of a class of acoustic stimuli that cross-cuts the linguistic - nonlinguistic distinction. While there have been a number of attempts to demonstrate the usefulness of the paradigm to intonational contrasts, these do not have the same power of conviction as Odé's result reviewed in section 2. It may thus be more effective to appeal to listener's intuitions in a more direct way, as in the 'passable imitation' paradigm, than to probe the listener's linguistic knowledge through a test that emphasizes his ability to discriminate between phonetically different forms, since the latter procedure may bypass the distinction the test is aimed to reveal, that between non-structural and structural phonetic differences.

Semantic task

The 'semantic task' amounts to asking subjects to give semantic judgements on stimuli that differ in their F0 contour only. The judgements can be gradient, for which a semantic scale is used running from the full presence of a meaning ('friendly') to its opposite ('not friendly'), or categorical, in which case subjects have to choose from a set of two or more meanings. An *a priori* difficulty with this task is that, as explained above, phonetic differences in intonation are typically meaningful. Ladd & Morton (1997) ran a series of experiments to test the hypothesis that English has a discrete difference between H and an 'extra High', a difference that is discrete in some tone languages. The difference between a high and a low pitch peak can be associated with different meanings in English, as shown in (9).

(9) a. A: He's Armenian
B: He's iRANian (with high H*+L peak: contradiction)

b. A: His name is Kameiny
B: He's iRANian (with neutral H*+L peak: neutral statement)

Similarly, Hirschberg & Ward (1995) showed that the meaning 'incredulity' is suggested by a low-peaked realisation of a rise-fall-rise, while ‘uncertainty’ is suggested by a high-peaked pronunciation of the same contour. This is shown in (8).

(8) A: I hear John and Mary are calling it quits

‘incredulity’
‘uncertainty’

B: [They're SEParating]

As made clear by Ladd & Morton, the fact that listeners assign different meanings to phonetically different forms need not mean that the two forms are discretely different, even if they are judging randomly presented sets of stimuli that represent a phonetic continuum between two forms. Such a result is a probable outcome of any task with two response categories (with or without a ‘don’t-know’ category). The mere fact that the curve plotting the pooled responses for each of these meanings has an S-shape, indicating that each end of the continuum is associated with each of the meanings, therefore tells us nothing about the nature of the contrast.

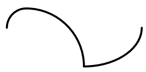
Before Ladd & Morton (1997), it was not uncommon to look upon the establishment of a semantic contrast as sufficient proof of a structural difference. A case can perhaps be made for meaning contrasts that are evidently non-paralinguistic. However, this line of argument is not without problems. First, paralinguistic meanings are so far defined on the basis of how they are expressed, not in terms of the meanings themselves. Even if we were to define paralinguistic meaning differences as differences that do not affecting the truth-value of the utterance, we will not be on safe ground. Ambiguities can be resolved through pitch range differences that are phonetic in nature. For instance, the past tense in *I THOUGHT so* can be interpreted as ‘I already thought so at the time, and I still think think so’, or as ‘I thought so at the time, but not any longer’. In the first case, the speaker is proved right, in the second case he is proved wrong, as shown in (1a) and (1b), respectively

(6) a. A: Did you see a shooting star?
B: I THOUGHT so. And I was right (compatible meaning)
b. A: Did you see a shooting star?
B: I THOUGHT so. But I was wrong (incompatible meaning)

It is imaginable that if we had a series of stimuli varying in peak height on the word *thought*, the lower peaks would be judged to be appropriate for meaning (1a) while the higher peaks would be associated with meaning (1b), in a forced-choice task. This would mean that even though the difference in form is to be accounted for in the phonetic implementation, the semantic difference is one that involves the truth-value of the expression.

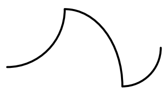
Nash & Mulac (1980) carried out exactly this experiment, with the addition of a ‘don’t-know’ response category, except that they didn’t vary peak height, but peak alignment (as well as pitch height on *I*, which variation didn’t produce any interpretable results). The peak alignment difference correlated with the meaning difference in (1a,b), such that early peaks were associated with (1a) and late peaks with (1b). In their case, the difference in form was in fact phonological. Contour (7b) is a more complex form of (7a), due to the addition of the prefix-L to the fall of (7a), adding an element of 'significance' to it (Gussenhoven 2004: ch15). However, the same result might have been obtained with stimuli that vary in peak height and which are phonologically identical.

(7) a.



[I THOUGHT so]
H*L H% ('fall')

b.

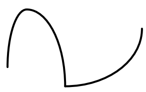


[I THOUGHT so]
L*HL H% ('rise')

Imitation task

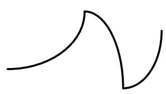
A new experimental approach to establishing discreteness was adopted by Pierrehumbert & Steele (1989). They were concerned with the same contrast that was investigated by Nash & Mulac (1980), shown in (10) with ToBI transcription (cf. Beckman & Pierrehumbert 1986).

(10) a.



[Only a MILLionaire]
H*+L L-H%

b.



[Only a MILLionaire]
L*+H L-H%

The peak of (10a) occurs inside the accented syllable, while that in (10b) will typically occur during the following unstressed syllable. The authors produced a continuum of 15 peak alignments in a set of resynthesised stimuli ranging between (10a) and (10b) in steps of 20 ms. Subjects were asked to imitate each of a series stimuli presented in a randomized order, paying particular attention to the intonation pattern. Pierrehumbert & Steele argued that if subjects were capable of reproducing the continuum in their imitations, the difference must be gradient. However, if subjects were to produce a binomial distribution of the peak times in their imitations, then the difference must be categorial. Four subjects produced 30 imitations of each stimulus, giving a total of 1800 utterances. For each utterance, the peak time was measured relative to the release of [m].

The results supported a categorical contrast: the distribution of the peak timings tended to be binomial. The fact that these subjects did not produce a continuum of peak alignments, but tended to have many early and late peak alignments and fewer intermediate ones, favours a discrete interpretation of the contrast. Since other research has shown that speakers can in fact produce gradually different f0 *peak heights* in production experiments in which they are asked to pronounce sentences at a prominence level as specified by a scale value on a 10-point scale (e.g. Liberman & Pierrehumbert 1984), we can have some confidence that results obtained in Pierrehumbert & Steele's experiment suggest discreteness.

The imitation task was put to the test by Redi (2003), Dilley (2005) with four phonetic continua in English. Two of these were peak continua and two were valley continua, as listed in (3). The continua consisted of two slopes, up and down for the peaks, and down and up for the valleys, where the peak or valley were shifted in 15 steps of 25 ms. The pitch before and after peak was high, and after valleys low. Continuum 2 was intended to represent phonetic variation, while the other three were assumed to correspond to phonological contrasts.

(3)

1. To Monrovia — ws Peak continuum: between peak on *mon* preceding downstepped !H* (H+!H*) and L+H* peak on *RO*.

2. Too minglingly — sw Peak continuum between peak on *ming* and peak on *ling*, both assumed to be H*, with variable alignment of peak.

3. To Monrovia — ws Valley continuum between early valley on *mon* (L+H*) and late valley on *ro* (L*).

4. They're non-linguistic — sw Valley continuum between early valley on *non*, interpretable as L*+H on *non*, and late valley on *ling*, interpretable asd L+H* on *guist*.

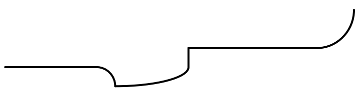
The results showed that subjects imitated peaks in a bimodal fashion, but the valleys were reproduced with continuum of alignments of the low points. This suggests that the imitation task needs to be re-evaluated. It is possible that the peak imitations are bimodal regardless of the nature of the input, but that valley imitations are not. Also, the continuum might be constructed by 'morphing' one canonical contour to the other, while stopping at a number of points on the way, instead of the manipulation of the alignment of a single point, as in these experiments. The latter procedure may lead to ambiguous end points in the continuum.As suggested by Bob Ladd (Dilley 2005: 103), the second continuum may have been interpreted as representing H* in the early peaks and L*+H for the late peaks. Additionally, it may be worth investigating whether a different task, one that more directly addresses speaker intuitions, gives better results. For instance, in their imitations, subjects could be asked to 'correct' the pronunciation of stimuli that are presented as having not quite acceptable intonation contours, rather than to reproduce the contours of the stimuli as best they can.

The imitation task was significantly expanded by Kochanski, Braun, Grabe & Rosner (ms), who designed an experiment in which subjects imitated their imitations of an initial artificial contour, which was constructed such that it did not obviously represent a well-formed English intonation contour. After four recursions, the end products represented a smaller number of well-formed contours, whereby each iteration approached the end product more closely. The task can reveal the non-phonological nature of phonetic differences if subjects' imitation of different contours end up as the same contour, and show that differences are discrete if they remain different in their end products.

Pitch range task

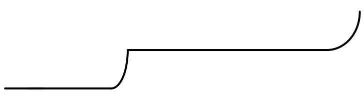
Gussenhoven & Rietveld (2000) illustrates an approach that provided information on which tones occurred in the representation. It was based on the assumption that differences in pitch span affect H-tones and the accent-lending L* differently. While higher realisations of H-tones correspond to increases in pitch range, L* may be lower as pitch range increases (Liberman & Pierrehumbert 1984). Gussenhoven & Rietveld (1997) exploited this fact to address the nature of the difference between the 'low rise' and the 'high rise' in Dutch. The 'low rise' begins low, rises to mid at the end of the accented syllable or immediately after the accented syllable, and has a further rise on the last syllable, as shown in (11a). The 'high rise' begins mid, usually after a low unaccented stretch which may continue as far as the CV-boundary of the accented syllable, then continues at the same mid pitch until it reaches the final syllable, where a - final rise to high occurs, as shown in (11b). When the accented syllable is IP-final, the rise due to H% will occur in the second half of the accented syllable. The gloss for (11) is 'Are there too many lemons?'

(11) a.



[Zijn er meLOENen teveel]
L*H H%

b.



[Zijn er meLOENen teveel]
H* H%

Using stimuli consisting of manipulated versions of four utterances, two with final accent and two with non-final accent, they asked subjects to rate the accented syllables for 'surprise'. Nine of the stimuli represented versions of the low rise, in which three values for the beginning of the rise (80, 90, and 100 Hz) had been crossed with three values for the end of the rise (185, 200, and 215 Hz), and nine stimuli represented versions of the high rise, in which three values of the beginning of the rise (130, 145, and 160 Hz) had been crossed with three values for the end of the rise (185, 200, and

215 Hz). (In the low rise contours, the mid level stretch was fixed at 145 Hz.)

It appeared that perceived surprise corresponded with lower beginnings of the low rise but with higher beginnings of the high rise. This finding represents strong confirmation of the hypothesis that (11a) and (11b) represent a phonological contrast, and also that the pitch accents are represented with L* and H*, respectively. If the stimuli were to form a set of phonetically pronunciations of the same phonological representation, perceived surprise would - incongruously - follow a U-shaped pattern, with a high degree of surprise for low and high beginnings and a low degree for mid-pitch beginnings. No such U-shaped behaviour was found for the end-point of the rise, which is linearly related to the level of perceived surprise. They concluded that perceived surprise increases with increases in pitch range, and that pitch range increases are achieved by lowering L* and raising H-tones.

This test, while yielding clear results in the case described, has more limited applicability than the imitation task, and depends on there being a paralinguistic meaning that is sensitive to pitch range expansion, like ‘surprise’, as well as a research question that involves a difference between H* and L*. In fact, other meanings that were elicited with the same stimuli, like ‘emphatic’ and ‘insistent’, didn’t yield the same results. Also, it is not clear that all L-tones go down when the pitch range is expanded, or even if L*-tones go down in all languages.

Conclusion

A reconsideration of the methodology proposed by ’t Hart, Collier & Cohen (1990) to establish phonological identity of phonetically different intonation contours suggests that subjects’ tasks in perception and imitation experiments should be more explicitly formulated as tapping into subjects’ intuitions. The aim here is to reduce the effect of phonetic differences that fall within a phonologocal category on the scores. Judgements involving sameness or difference can be more focused on structural differences by asking whether one contour can serve as a passable imitation of the other, instead of asking whether they are different, and imitation tasks can ask the subject to correct a phonetic contour that lies between hypothetical categories to its ‘intended’ pronunciation.

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