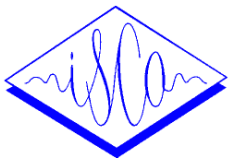

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PERCEPTION OF PREPAUSAL TONAL CONTOURS: IMPLICATIONS FOR AUTOMATIC STYLIZATION OF INTONATION

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ABSTRACT

Interactive adjustment tests were carried out to determine how a silent interval influences the perception of the preceding tonal contour. Results from 16 subjects show a strong influence of silence on tonal perception indicating that silence increases sensitivity for the preceding tonal endpoint with subjects showing greatest response consistency for the stimuli with the longest pause where adjustment is based on endpoint frequency in a nasal consonant before the pause. The implications of these results for automatic stylization and models of intonation are discussed.

1. INTRODUCTION

In both read and spontaneous speech, a prosodic phrase boundary is often accompanied by a silent pause which is preceded by a tonal contour marking the boundary. Considerable attention has been directed to the respective roles of silent pauses and boundary tones as markers of prosodic phrase and syntactic boundaries, see e.g. [1], [2], [3], [4], [5], [6], [7], [8] and [9]. The central question approached by this investigation is whether a silent interval influences the perception of the preceding tonal contour and, if so, what implications this may have for models of intonation and automatic stylization of tonal movement.

A number of general questions concerning boundary tones relate to the central issue of this investigation. Boundary tones may have several functions in addition to boundary signalling, e.g. signalling feedback seeking or turn regulation in spontaneous dialogue [10]. Are the tones and functions perceived categorically and, if so, does a silent interval facilitate perception?

In a previous study [11] it was shown that in synthesized VCVCV sequences where V= [a] and C= [m], the tonal configuration in vowels is perceptually more salient than in consonants. It can be conjectured, however, that if a silent interval is inserted before a vowel, tonal perception in the preceding consonant may be sharpened due to effects of auditory short-term memory. This could give the final tonal level in the consonant greater perceptual significance than when immediately followed by a vowel. Thus, the following specific questions are addressed by this investigation: 1. Does a silent interval influence tonal perception? 2. Are final sonorant consonants important tone carriers? 3. Is perception of the tonal endpoint before a pause sharpened by the pause, and if so, does this sharpening increase with increased pause duration?

2. METHOD

2.1 Stimuli and task

To answer these questions, a set of adjustment tests was designed. Stimuli consisted of synthesized [amamam] sequences in three temporal conditions: 1) no pause between segments, 2) a 100 msec pause between the fourth and fifth segment [amam.am] and 3) a 1000 msec pause between the fourth and fifth segment [amam.....am]. Formant synthesis was used to generate the stimuli [12].

The subjects' task was to match different tonal configurations within each temporal condition. Matching was done interactively using a mouse pointer on a computer screen (Sun workstation, ESPS-Waves+ environment). The tonal configurations were 1) a falling F0 contour where the fall occurred through both the second vowel and second consonant and 2) a falling F0 contour through the second vowel only with a constant F0 throughout the second consonant. 10 Hz steps between 140 and 60 Hz were used to create 9 different stimuli in each tonal configuration making a total of 18 different stimuli for each temporal condition, i.e. a total of 54 stimuli for all three temporal conditions and both tonal configurations. See Figure 1 for stylized samples of stimuli.

Where endpoint frequency is most salient, subjects would be expected to match tonal configurations having the same endpoint frequency regardless of whether the contour falls in the vowel only or in both the vowel and consonant.

If endpoint frequency is of less perceptual importance, subjects would be expected to match contour shapes. This would result in subjects matching a lower endpoint for a vowel-consonant fall with a higher endpoint for a vowel only fall.

2.2 Test configuration

The middle five stimuli in the frequency continuum of nine stimuli in each tonal configuration were presented

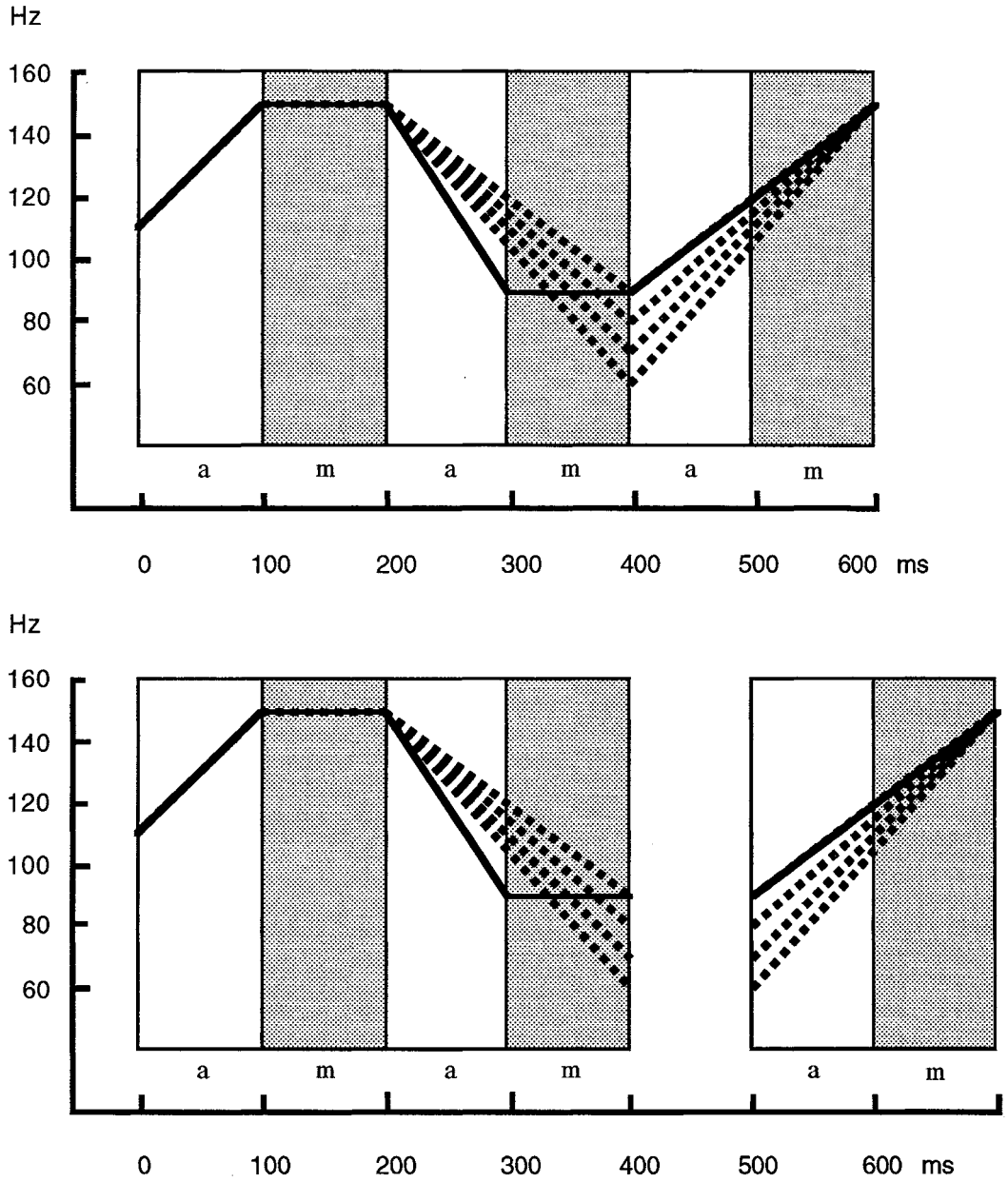

Figure 1. Stylized contours of some example stimuli. The upper panel represents the temporal condition "no pause" while the lower panel represents "short pause". The dotted lines represent tonal contours falling in both vowel and consonant (VC-fall) while the solid lines represent tonal contours falling in the vowel only (V-fall).

as original stimuli. This resulted in six blocks of five stimuli each for a total of 30 presented original stimuli. Stimuli were randomized in each block and block order was randomized between listeners. Subjects were asked to match each original stimulus to one of the nine stimuli having the same temporal conditions but the different tonal configuration. The test was presented as an adjustment procedure as in [13] with the nine choices presented in frequency order on the computer screen. All screen input was logged to a file.

Each subject began the test with a practice/calibration block in which the original stimulus was identical to one of the nine choices. The entire test took an average of 33 minutes with a minimum individual time of 13 minutes and a maximum of 55 minutes.

2.3 Subjects

16 subjects participated in the experiment. The majority of subjects were students and staff at the Dept. of Linguistics and Phonetics, Lund University, and all but two were native speakers of Swedish. Subjects were not paid, but were rewarded with chocolate and coffee after their participation in the test.

3. RESULTS

Results were very consistent between subjects: one factor ANOVA df=15, F=0.69, p>0.05, and within

subjects df=2, F=43.17, p<0.0001. Figure 2 shows the percentage of same endpoint responses for the three temporal conditions and for the two tonal configurations within each condition.

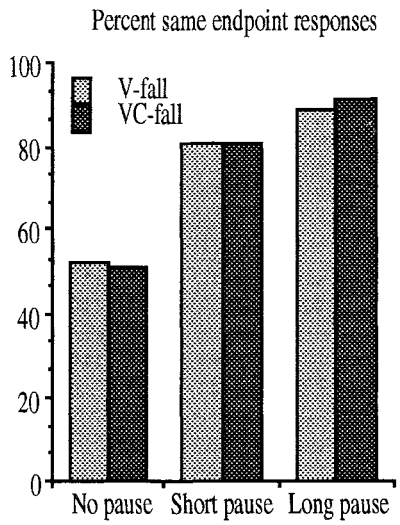

Figure 2. Graph showing percentage same endpoint responses as original stimulus when original is V-fall (falling contour in vowel only) and VC-fall (falling contour in vowel and consonant).

A strong effect of pause on endpoint perceptual salience can be seen. In the no-pause condition, only half the responses were same endpoint, while the other half were in the direction of a lower endpoint for vowel-consonant fall (VC-fall) being matched with a higher endpoint for the vowel fall (V-fall). Table 1 shows the response distribution where the direction is from the vowel fall. Endpoint salience also seems to increase somewhat with pause duration.

Table 1. Endpoint response distribution for the three temporal conditions. Direction is frequency of endpoint related to endpoint of tonal contour falling in vowel only.

	Lower	Same	Higher
No pause	76	83	1
Short pause	28	130	2
Long pause	12	144	4

A chi square test of independence on the above distribution results in $\chi 2=76.54$, df=4, p<0.001. One way ANOVA shows a significant difference comparing no pause with short pause F(2,45)=21.13, p<0.001 and comparing no pause with a long pause F(2,45)=40.5, p<0.001, but not when comparing a short pause with a long pause F(2,45)=3.13, p>0.05.

4. DISCUSSION

4.1 Effect of silence

The results demonstrate a strong effect of silence on the perception of the tonal contour. They also demonstrate the importance of a sonorant consonant as a tone carrier when followed by silence.

In the pause stimuli, matching seems to be based primarily on endpoint frequency before the pause, while in non-pause stimuli, listeners seem to be attending more to fall gradients or to average frequency through the fall. An interpretation concerning auditory memory may serve to help explain the results. If short-term auditory memory for frequency is sharpened by the presence of a pause, then subjects should find endpoint frequency a more salient cue even if the final segment is not a vowel. In the pause condition, there is more time for the final frequency to be extracted and stored as a discrete frequency level. In the no-pause condition, auditory memory may be forced to rely more on the tonal contour or on an averaging of frequency information through the vowel and consonant since endpoint frequency in the consonant seems to be rendered less salient by the following vowel.

This interpretation may be modified by the fact that, due to test construction constraints in the no-pause condition, there was also some information after the pause which listeners could have used as well as the endpoint information before the pause. The fact remains, however, that the presence of the pause significantly influenced perception of the tonal contour.

This can have implications for perception of such tonal phenomena as boundary tones and discourse markers. The presence of a pause may therefore sharpen perception facilitating the use of a tonal gesture as both a boundary tone and a discourse marker.

4.2 Implications for stylization

This effect of silence may be an important consideration for algorithms for automatic stylization of intonation. Recent work clearly shows the value of applying the results of perception experiments to the problem of automatic stylization [13] and [14]. The interaction of F0 and duration in the perception of phrasing has also been documented [5].

In an algorithm designed for automatic recognition of Swedish word accents [15], stylization was based partly on perception results obtained by House [11]. In this algorithm, linear stylization was carried out using the analyzed fundamental frequency 32 msec after vowel onset and 32 msec before offset of the final sonorant in each tonal segment (syllable). However, no distinction was made between prepausal contours at phrase boundaries and continuous contours within phrases. Listener reactions to synthesized, stylized contours indicated that tolerances to differences between the original and stylized contours were greater within a

phrase than in phrase-final positions (i.e. prepausal). These reactions are consistent with the perception results described above.

Silence, therefore, while serving to demarcate a phrase boundary, also seems to throw more perceptual weight on the preceding tonal endpoint. It can be argued that greater precision is necessary in modelling prepausal boundary tones for speech synthesis and automatic stylization of intonation than is necessary for phrase internal contours.

In current research involving the use of resynthesis to test intonation modelling in spontaneous speech in Swedish, F0 stylization is carried out using a prosodic transcription as input [16]. In the model, an F0 value in Hz is specified as a baseline floor which is realized before each transcribed phrase boundary. Precise control of this parameter in developing and testing an intonation model for spontaneous speech appears to be an important aspect of automatic stylization.

5. ACKNOWLEDGMENT

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