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Effects of Time Pressure on the Phonetic Realization of the Dutch Accent-Lending Pitch Rise and Fall

Abstract

The goal of this experiment is to find the most important phonetic features of Dutch accent-lending pitch movements, in terms of shape, pitch level and alignment with the segmental structure. Time pressure is used as a heuristic method to isolate important phonetic aspects of pitch movements, assuming that under time pressure the speaker will preserve those aspects. In a production experiment, accent-lending rises ('1') and falls ('A') were realized under various types of time pressure. The pitch rise is time-compressed under all pressure types, which would mean that the shape of the rise is relatively unimportant. The segmental alignment of the rise proved to be more important: the onset of the rise is synchronized with the syllable onset. For the fall no fixed synchronization point was found, but its shape was relatively invariant, indicating that shape rather than exact timing is the more important feature of the fall.

Introduction

A Question of Methodology

It has often been observed that speech is a redundant code: it contains more detail than is normally needed for successful communication. Much phonetic research has been aimed at distinguishing the relative communicative importance of the various properties of spoken utterances. This type of research is motivated by scientific curiosity per se, but its results can readily be used in technological applications. For example, if the designer of a text-to-speech system, limited by memory space and processing capacity, has to make a choice as to which properties to include in his talking ma-

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chine, and what to leave out, he may want to draw on the results of fundamental research. This type of research has its main history in segmental phonetics, where, by now, a substantial body of knowledge has been assembled on the relative importance of spectral and temporal features of speech sounds. In more recent years the research has been extended towards prosody, in particular to intonation.

The most favored research methodology has been analysis-by-synthesis. Synthetic copies of natural utterances are produced from which one or several of the original properties have been eliminated or simplified. As long as the impoverished utterances remain intelligible and acceptable, only properties of secondary importance must have been affected. Crucially, the choice of the properties to be manipulated in this research paradigm is under the conscious control of the experimenter, who, more often than not, has to go by trial and error.

It occurred to us that, in the field of intonation studies, a different methodology might be applied. In order to separate the properties of pitch movements into categories of greater or lesser importance, one might put a speaker under time pressure, i.e., induce a speaker to execute more movements in the same limited time span, or execute the same number of movements in less time. We assume that in such circumstances, the speaker would have to sacrifice properties of lesser communicative importance while preserving the more essential ingredients as much as possible. The implicit choices made by speakers under time pressure may then serve as heuristics for the speech researcher working within the synthetic speech paradigm.

In our research, time pressure is used as an experimental tool for focusing on the communicatively important properties of pitch movements in Dutch, a language whose formal intonational characteristics have been extensively studied over the past 30 years ['t Hart et al., 1990].

In principle, a speaker may use two strategies when put under time pressure: (i) deleting complete accent-lending or boundary-marking pitch movements, or (ii) adjusting the shape of the intonation contour or the shape of the individual pitch movements. In earlier experiments [Caspers and van Heuven, 1991; Caspers, 1990, 1991], we found that (naive as well as professional) speakers economize on the number of prosodic boundaries when speaking fast, whereas the number of accents remained virtually constant, showing a slight tendency towards simpler intonation contours (i.e. with fewer pitch movements). This means that in most cases the accent-lending pitch movements have to be adapted to a shorter time scale. The present experiment concerns the adjustment of the phonetic properties of individual accent-lending pitch movements under time pressure, when the distribution of accents over the sentences is kept constant.

A Question of Substance

In the Dutch Intonation Grammar ['t Hart et al., 1990], ten perceptually relevant pitch movements are distinguished, characterized by four features, most of which are binary. The *direction* feature splits the inventory into five rises and five falls, which may be either abrupt or gradual (the *rate of change* feature). Furthermore, movements may differ in global excursion *size:* full versus half. Finally, the *timing* of a movement relative to the segmental structure of the syllable is a distinctive feature: movements can be early, late and very late in the syllable. Functionally, abrupt movements may be accent-lending or boundary-marking. The most frequent rise is the accent-lending rise '1', which is abrupt, full-size and early in the syllable. 't Hart et al. [1990] specify the timing of rise '1' as follows: the rise should reach its terminal frequency at 50 ms after the vowel onset. The most frequent accent-lending fall is type 'A', which is abrupt, full-size, and occurs late in the syllable. No precise specification of the segmental synchronization for the fall is given in 't Hart et al. [1990].

The effects of time pressure on the following phonetic aspects of rise '1' and fall 'A' were examined: the shape (in terms of excursion size, duration and slope), the overall pitch level and the alignment with the segmental structure. The pitch movements have to be adjusted to the shrunken time, by adaptations of one or more of these phonetic properties. We were looking for phonetic aspects that are relatively invariant under time pressure, such as fixed synchronization points between the pitch movement and the segmental structure ('anchor points').

Approach

Time pressure can be imposed on a speaker in a number of ways. First, there is the obvious possibility of inducing a speaker to talk fast. In fast speech (time presure type i), the segments will be shorter than in normal speech, so that less time will be available for the execution of pitch movements, resulting in the adaptation of one or more properties of the movements. This type of time pressure was used by Kohler [1983], who reported that the sacrifice was made along the size dimension, i.e. the movements were smaller in fast speech. Interestingly, the pitch peaks maintained their target values, but the pitch valleys were raised, which, to us, would indicate that reaching the peak values is more important than preserving the low baseline pitch.

Secondly, we may shorten the available time for the execution of a pitch movement by choosing target syllables containing phonemically and phonetically short versus long vowels (time pressure type ii).

Thirdly, we may cause a speaker to execute multiple pitch movements within a short time span (time pressure type iii). In Dutch, the same sentence may be spoken with only one accent-lending pitch movement, or with two (or more) pitch movements, which may occur on nonadjacent syllables, on adjacent syllables, or even on the same syllable. Intuitively, these conditions embody an ascending order of time pressure. When, for example, a rise and a fall have to be executed within the same syllable, some sort of a compromise will have to be struck. It will then be possible to see whether the preservation of features of the rise takes precedence over preserving features of the fall. Since the synchronization is clearly specified in 't Hart et al. [1990] for the rise, but not for the fall, we expect the synchronization feature to be more important for the former than for the latter. In our search for relevant synchronization points we shall consider six candidates in the segmental structure of the syllable: beginning and end of voicing, beginning and end of vowel, and beginning and end of syllable. The better candidate can be isolated from this set of candidates by including syllable types with voiced versus voiceless onset and coda consonants.

We assume that under the time pressure types chosen, natural speech will be produced: the subjects were asked to speak at a normal and a moderately fast speaking rate, pronouncing existing Dutch words, realizing common intonation contours (in fact, the contour with highest pressure, i.e. a rise and fall on the same syllable, is the most frequently used accent-lending pitch configuration in Dutch). It seemed important, for the purposes of our research, not to push the speakers beyond their articulatory limits; we wanted to avoid unrealistic adaptations of pitch movements.

In our experiment, we did not want to choose any one implementation of time pressure over another. Rather, we decided to

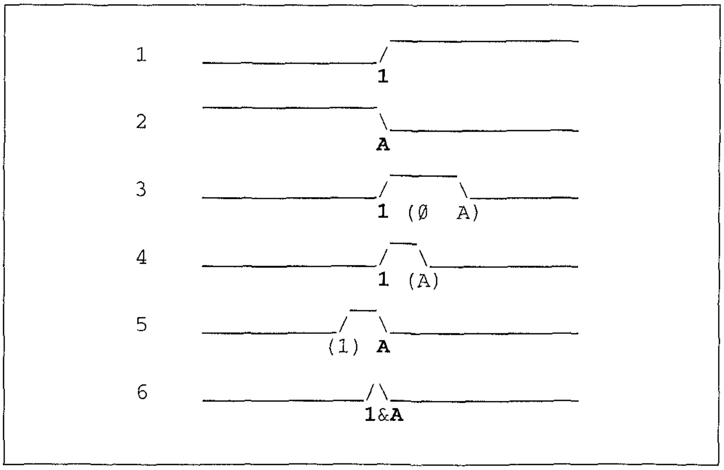

Fig. 1. Time pressure type iii: six F_0 contours used in stimulus material. Target movements are in bold face; movements outside the target syllable are in parentheses.

systematically vary all three types of time pressure discussed above.

If one wants a speaker to pronounce the same sentence with a number of specific intonation patterns, one cannot enlist naive speakers. This is because only the position of accents can be guided by the stimuli, not the choice from the inventory of accent-lending movements (such as the choice between rise or fall, cf. 'Introduction'). In our experiment we therefore explicitly instructed intonologists, who were well acquainted with the Dutch intonation system, to produce the required pitch movements, which were identified for them in terms of the Intonation Grammar.

Method

The accent-lending pitch rise ('1') and fall ('A') were incorporated in different intonation contours in order to vary the time available for the crucial pitch movements (time pressure type iii). The six contours are illustrated in figure 1. Contours 1 and 2 contain only one pitch movement, so that the space available for the speaker to produce the pitch movement is practically unlimited. Contours 3, 4 and 5 are made up of an accent-lending pitch rise, followed by an accent-lending pitch fall in the first or second syllable after the syllable containing the rise (a 'flat hat'). It is possible that a pitch movement in the direct vicinity of the target syllable produces some pressure on the target movement itself. The sixth contour contains a 'pointed hat', i.e., a rise and fall executed on one syllable. We assume that contours 1–2, 3, 4–5, and 6 represent steps in an ascending order of time pressure.

The target syllable consists of an initial consonant (C_1), a vowel (V) and a final consonant (C_2). V could be one of two low vowels: phonologically (and phonetically) long (/a:/) versus short (/ɑ/). The opposition between long and short target vowels constitutes the second type of time pressure (ii). In order to be able to choose between the various possible anchor points, both voiced and unvoiced onset (/p/, /b/, /m/) and coda (/n/, /s/) consonants were included. For experimental details we refer to Caspers [1992].

Two phonetically trained native speakers (1 male, 1 female, i.e. the present authors) produced the required intonation contours on the carrier sentences at a normal speech tempo and as fast as they could comfortably manage (time pressure type i). Recordings were made in a sound-proof cabin, using a Sennheiser MKH-416 directional condenser microphone and a Revox B77 MKII tape recorder.

Analysis

The recordings were A/D-converted (10 kHz, 12 bits, 4.5 kHz LP, 96 dB/oct) and stored on computer disk. The digital waveform was analyzed into 10 LPC coefficients (256-point analysis window, 10-ms time

Table 1. Excursion size, duration and F_0 slope for the accent-lending pitch rise and fall in normal and fast speech, broken down by speaker

Shape		Speaker VH			Speaker JC		
		mean	SD	cases	mean	SD	cases
Excursion size, ST							
Rise ('1')	normal	6.8	1.2	60	8.1	1.5	63
	fast	6.7	1.6	64	7.4	1.6	64
Fall ('A')	normal	8.4	1.2	48	10.8	1.8	48
	fast	10.0	2.2	48	9.9	1.4	48
Duration, ms							
Rise ('1')	normal	194	65	64	173	57	64
	fast	165	58	64	139	47	64
Fall ('A')	normal	205	62	48	169	47	48
	fast	174	59	48	147	36	48
F_0 slope, ST/s							
Rise ('1')	normal	40	17	60	51	16	63
	fast	47	23	64	59	25	64
Fall ('A')	normal	44	13	48	67	18	48
	fast	62	16	48	71	15	48

Means, SD and number of cases are given.

shift). F_0 was determined using the method of subharmonic summation [Hermes, 1988], followed by an automatic tracking procedure. The pitch determination algorithm also made the voiced/voiceless decision.

In line with the principles of the Dutch Intonational School ['t Hart et al., 1990], the F_0 curves were stylized into a minimal series of straight lines, such that the resynthesized pitch contour sounded identical to the (resynthesized) original. Relevant time-frequency coordinates of line sections were stored in a database.

Using a high resolution waveform editor, the boundaries between relevant segments of the stimuli were marked, using criteria for segmentation based on visual information as formulated in Van Zanten et al. [1991].

Results

Our data analysis revealed that the 2 speakers differed substantially along several dependent variables; therefore the results are not averaged, but will be presented separately for each speaker. Unless stated otherwise, statistical backing is based on one-way analyses of variance, assuming fixed effects.

Effects of Time Pressure on the Shape of Rise and Fall

Time Pressure Type i (Normal versus Fast Speech). The first type of time pressure was sought in the fast speaking condition. The mean speech rate in the normal speaking condition was 6.3 syllables/s for speaker VH and 6.4 syllables/s for speaker JC; in the fast speaking conditon VH uttered 8.1 and JC 7.9 syllables/s. Table 1 contains mean excursion size in semitones (ST), duration (ms) and F_0 slope (ST/s) of the accent-lending pitch rise and fall in normal and fast speech, broken down by speaker. Both speakers decrease the duration of the rise in fast speech [VH $F(1,127)=6.9$, $p<0.01$; JC $F(1,127)=13.5$, $p<0.001$]. Also, the duration of the fall 'A' diminishes in fast speech for both speakers [VH $F(1,95)=6.2$, $p<0.05$ and JC $(F1,95)=6.9$,

Table 2. Excursion size, duration and F_0 slope for the accent-lending pitch rise and fall, on target syllables with long (/a:/) versus short (/ɑ/) vowels, broken down by speaker

Shape		Speaker VH			Speaker JC		
		mean	SD	cases	mean	SD	cases
Excursion size, ST							
Rise ('1')	/a:/	6.5	1.3	62	7.5	1.8	63
	/ɑ/	7.1	1.5	62	8.0	1.3	64
Fall ('A')	/a:/	8.8	2.0	48	10.0	1.4	48
	/ɑ/	9.6	1.9	48	10.7	1.9	48
Duration, ms							
Rise ('1')	/a:/	191	58	64	162	55	64
	/ɑ/	168	66	64	150	54	64
Fall ('A')	/a:/	193	68	48	153	39	48
	/ɑ/	185	57	48	163	46	48
F_0 slope, ST/s							
Rise ('1')	/a:/	39	18	62	50	16	63
	/ɑ/	49	21	62	59	24	64
Fall ('A')	/a:/	50	14	48	68	15	48
	/ɑ/	57	19	48	70	19	48

Means, SD and number of cases are given.

$p<0.01$]. Speaker JC increases the slope of the rise in fast speech [$F(1,126)=4.8$, $p<0.05$], whereas the slope of the fall increases in fast speech for speaker VH [$F(1,95)=34.4$, $p<<0.001$]. No systematic influence of speech rate was found on the excursion size of either rise or fall. Generally speaking, the pitch movements become shorter in fast speech, with a tendency for the F_0 slope to steepen, which suggests time compression (rather than frequency compression) of pitch movements in fast speech.

Time Pressure Type ii (Long versus Short Target Vowel). In table 2, the shape of the accent-lending rise and fall, broken down by vowel length and speaker, is displayed. The excursion size of the rise is increased for VH when the vowel is shortened [$F(1,123)=4.7$, $p<0.05$); for JC the increase is not significant [$F(1,126)=2,7$, NS]. The excursion size of the fall is influenced by vowel length for both speakers: an increase in size of the fall occurs when the vowel is short [$F(1,95)=4.0$, $p<0.05$ for VH, and $F(1,95)=5.2$, $p<0.05$ for JC]. For speaker VH the duration of the pitch rise decreases when the vowel is short [$F(1,127)=4.5$, $p<0.05$]. JC also shortens the rise, but the effect does not reach significance [$F(1,127)=1.5$, NS]. VH increases the slope of both rise and fall when the vowel is shortened [$F(1,123)=8.5$, $p<0.005$ and $F(1,95)=4.1$, $p<0.05$]. JC has a steeper rise on a short vowel [$F(1,126)=6.9$, $p<0.01$], but shows no difference in slope of the fall as a function of vowel length [$F(1,95)<1$]. To sum up, the influence of vowel length on the shape of the accent-lending pitch rise and fall is small, but rather straightforward: on a short vowel the movement tends to become shorter, steeper and larger than on a long vowel.

Time Pressure Type iii (Contour Type). Table 3 presents the shape of the accent-lending pitch rise and fall, broken down by contour type and speaker. Contour types are listed in

Table 3. Excursion size, duration and F_0 slope for the accent-lending pitch rise and fall in the different contour types (target movements in bold face; movements outside target syllable in parentheses), broken down by speaker

Shape		Speaker VH			Speaker JC		
		mean	SD	cases	mean	SD	cases
Excursion size, ST							
Rise	**1**	5.3	0.9	32	8.3	1.7	32
	1(∅A)	7.8	1.2	28	7.6	1.3	31
	1(A)	6.4	0.8	32	8.3	1.2	32
	1&A	7.8	1.0	32	6.7	1.6	32
Fall	**A**	9.8	1.7	32	10.8	2.0	32
	(1)**A**	8.5	1.8	32	10.1	1.4	32
	1&**A**	9.3	2.1	32	10.2	1.6	32
Duration, ms							
Rise	**1**	227	61	32	192	59	32
	1(∅A)	188	55	32	164	46	32
	1(A)	179	56	32	168	37	32
	1&A	123	28	32	102	28	32
Fall	**A**	206	57	32	167	51	32
	(1)**A**	189	68	32	136	37	32
	1&**A**	172	60	32	171	30	32
F_0 slope, ST/s							
Rise	**1**	26	10	32	46	12	32
	1(∅A)	45	12	28	49	12	31
	1(A)	39	14	32	52	13	32
	1&A	66	18	32	72	31	32
Fall	**A**	51	15	32	70	22	32
	(1)**A**	50	17	32	77	13	32
	1&**A**	59	18	32	61	9	32

Means, SD and number of cases are given.

(what we assumed would be) an ascending order of pressure. The duration of the rise is shortened when competing falls are present [VH $F(3,127)=21.8$, $p \ll 0.001$, for JC $F(3,127)=24.4$, $p \ll 0.001$] and the F_0 slope of the rise is steepened [VH $F(1,123=46.5$, $p \ll 0.001$, JC $F(1,126)=12.3$, $p \ll 0.001$], reflecting the ascending order of pressure assumed. When multiple pitch movements have to be executed within a short time span, it appears that the same compression strategy is used for the accent-lending pitch rise as in fast speech (time pressure type i): both speakers shorten and steepen the rise. The shape of the accent-lending fall is not systematically influenced by the presence of a competing rise. Roughly speaking, the fall has the same shape, regardless of the presence of a nearby rise. Notice incidentally that the steepness of the accent-lending pitch rises and falls remains well below the upper limit of 120 ST/s [Sundberg, 1979], showing that the articulatory limits were not reached.

Effects of Time Pressure on Pitch Level

No influence of vowel length (time pressure type ii) and competing pitch movements (time pressure type iii) will be presented, because the effects appeared to be small and uninterpretable [Caspers, 1992].

Table 4. Pitch level relative to 50 Hz of peaks and valleys, and F_0 range in normal and fast speech, broken down by speaker

		Speaker VH			Speaker JC		
		mean	SD	cases	mean	SD	cases
Pitch level, ST							
Peak	normal	19.9	1.5	80	30.9	1.2	80
	fast	22.6	1.4	80	31.4	0.9	80
Valley	normal	12.4	1.0	80	21.3	1.3	80
	fast	14.4	1.6	80	22.7	1.3	80
F_0 range, ST	normal	7.5	1.4	80	9.7	1.7	80
	fast	8.2	2.3	80	8.7	1.5	80

Means, SD and number of cases are given. Cases pertaining to contour type 3 (16 per speaker) were excluded so as to balance the influence of potentially converging F_0 topline and baseline.

Table 4 presents the mean pitch level of all peaks and all valleys (i.e., the data for rises and falls have been collapsed), as well as the mean F_0 range for each speaker in normal and fast speech. Table 4 shows that, for both speakers, valleys as well as peaks are raised when the speech rate is increased. However, VH raises his peaks more than his valleys [$F(1,159)=137.2$, $p<<0.001$ for peaks, $F(1,159)=101.2$, $p<<0.001$ for valleys], thereby *in*creasing his F_0 range in fast speech [$F(1,159)=4.4$, $p<0.05$], whereas JC raises her valleys more than her peaks [$F(1,159)=46.3$, $p<0.001$ for valleys, $F(1,159)=7.0$, $p<0.01$ for peaks], thus *de*creasing the F_0 range with approximately 1 ST [$F(1,159)=13.6$, $p<<0.001$].

We expected a reduction of the F_0 range when the speech rate is raised, brought about by an elevation in pitch for the valleys of the accent-lending pitch movements [Kohler, 1983]. Only JC's behavior conforms to this expectation. Apparently it is not obligatory to economize on the F_0 range of pitch movements when increasing the speech rate.

Effect of Time Pressure on the Alignment of Pitch Rise and Fall

The offset of the rise relative to the segmental structure (vowel onset, end of vowel, end of voicing, end of syllable) varied considerably under time pressure, mainly as a result of the presence of an accent-lending fall (but there are secondary effects of vowel length and speech rate), forcing us to reject the end of the rise as a viable anchor point.

The onset of the rise, however, displayed little effect of the various types of time pressure, and therefore the search for an anchor point for the accent-lending rise concentrated on the onset of the movement. We considered syllable onset, beginning of voicing, and vowel onset as possible alignment points for the start of the accent-lending rise. Syllable onset proved to be the superior anchor point: the distance (in milliseconds) between the start of the rise and the start of the syllable was scarcely affected by the three time pressure types and by the voicing feature of the initial consonant (which had a large effect on the distance between the start of the rise and the candidate anchor points voice onset and vowel

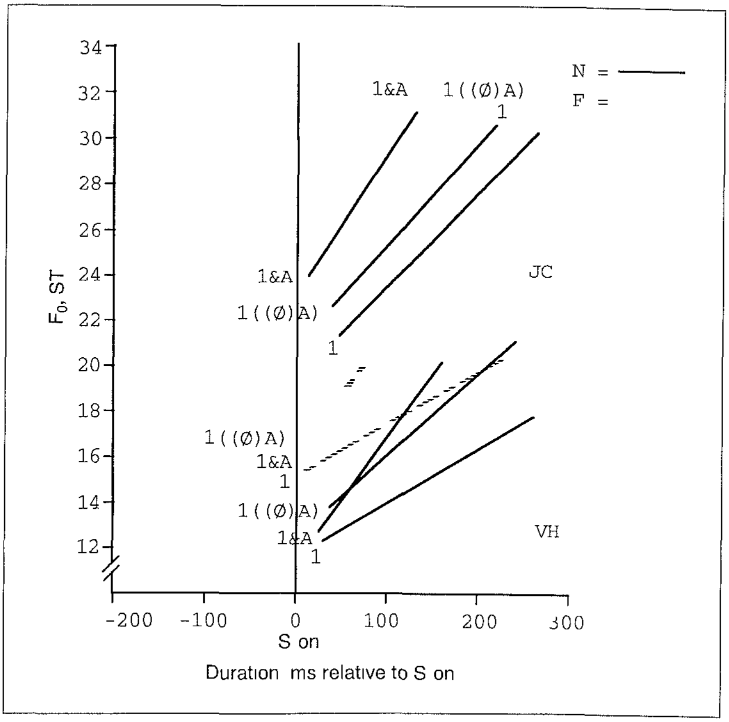

Fig. 2. Time (in milliseconds, *relative to syllable onset) and* frequency (in semitones, relative to 50 Hz) coordinates of the accent-lending pitch rise in normal (N) and fast (F) speech for speaker VH and JC, broken down by contour type

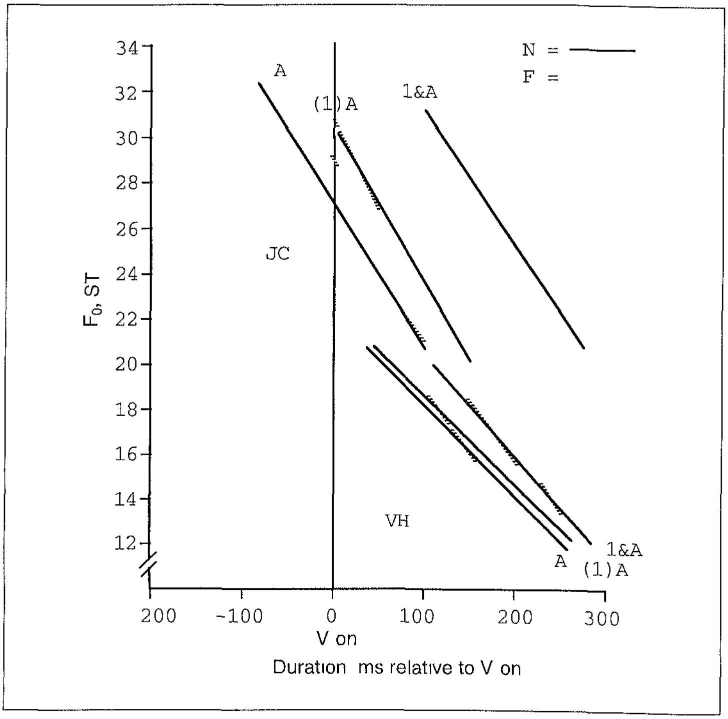

Fig. 3. Time (in milliseconds, relative to vowel onset) and frequency (in semitones, relative to 50 Hz) coordinates of the accent-lending pitch fall in normal (N) and fast (F) speech for speaker VH and JC, broken down by contour type

onset). For lack of space we cannot present all the relevant figures and statistical backing; we refer to Caspers [1992]. The suitability of the syllable onset is sufficiently demonstrated, however, by figure 2, which presents the time (relative to syllable onset) and frequency coordinates of the rise in contours 1, 3, 4 and 6, in normal and fast speech for both speakers. For the sake of clarity, rises are collapsed over both types of flat hats (3–4).

Figure 3 displays the time and frequency coordinates of the accent-lending fall for the different contour types in normal and fast speech, for both speakers separately. The vowel onset was chosen as the synchronization point, because it yielded the least unsatisfactory results relative to the other candidate anchor points. It is apparent from figure 3 that the fall has no fixed synchronization point in the segmental structure. Due to pressure from a preceding rise, the fall is shifted away from the beginning of the target syllable. Rather large alignment differences between speakers are visible. The timing of the accent-lending fall relative to the segmental structure seems to be free, within a relatively wide time margin. Finally, figure 3 shows, more clearly than table 3 above, that the shape of the falls per speaker is more or less constant across contour types.

Conclusion and Discussion

In this research we examined the effects of three types of time pressure on the phonetic realization of the accent-lending pitch rise and fall in Dutch. Three aspects of the phonetic realization were studied: shifts in overall pitch level, shape of individual movements, and segmental alignment of movements.

Effect of Speech Rate on Pitch Level. In fast speech both speakers raised pitch peaks and valleys; there seems to be no obligation to shrink the frequency range, since VH increased the range when speaking fast, whereas JC decreased it. This means in our view that the precise level of valleys as well as peaks are of lesser importance.

Effects of Time Pressure on Shape of Rise and Fall. When time pressure is created by increasing the speech rate, both the accent-lending pitch rise and fall are time-compressed rather than frequency-compressed. The influence of substituting a phonologically short vowel for a long vowel is small, but there is a tendency towards simultaneous frequency expansion and time compression. The rise and fall are steeper in short vowels than in long vowels, which probably means that the speakers know that they have less time to complete the pitch movement. The increased steepness may lead to an overshoot of the target, resulting in the counterintuitive finding that the excursion size of the movements is increased a little. When multiple pitch movements have to be executed within a limited time span, the accent-lending rise is strongly compressed in time. No such effect was found for the accent-lending fall.

Effects of Time Pressure on Alignment of Rise and Fall. The onset of the rise seems to be synchronized with respect to the syllable onset, but the alignment of the end varies, mainly depending on the presence of a competing fall. The rise steepens and is terminated sooner as the onset of the following fall is nearer. No anchor points were found for beginning or end of the fall.

Summarizing the influence of time pressure on the shape as well as the alignment of the accent-lending pitch rise, the movement is shortened and steepened, roughly maintaining a synchronization of the onset of the rise with the onset of the syllable. In our view this means that the precise shape of the rise is relatively unimportant, whereas the alignment of the start of the movement with the segmental structure is the more important feature of the rise. For the accent-lending fall the opposite seems to be true: the timing of the fall is less rigid, but the shape of the fall is relatively invariant (within speakers), and therefore the shape seems to be the more important feature for the fall.

Our conclusion that it is the onset of the rise that is anchored in the segmental structure is in contrast to earlier suggestions that the relevant anchor point for the rise is in the offset, at 50 ms after the vowel onset ['t Hart et al., 1990]. In the phonological school of intonation, as well [Pierrehumbert, 1980; Gussenhoven, 1988], the *peak* rather than the *onset* of the rising tonal accent (at least in 'hats') is regarded as the more important feature: the end of the rise is called the 'target' and is associated with the accented syllable ('H*'). It seems reasonable to assume that (i) the 'target' is anchored in the segmental structure, such that (ii) the high tone level coincides with the earliest part of the accented syllable with high intensity, i.e. with the vowel onset or CV junction [Ohala and Kawasaki, 1986]. Our results, however, indicate that this is not the case: (i) the peak is not anchored in the segmental structure, but the start of the rise seems to be attached to an invariant point, and (ii) the synchronization point is not the high intensity CV junction, but the intensity minimum (syllable onset).

In a recent experiment [Caspers and van Heuven, in press], the perceptual relevance of our synchronization of the accent-lending rise was tested, resulting in a preference for a synchronization of the onset of the rise with the syllable onset, over an anchoring of the end of the rise relative to the vowel onset.

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