ON THE MULTIPLICITY OF FACTORS AFFECTING P-CENTER LOCATION

BERND POMPINO-MARSCHALL HANS G. TILLMANN

Institut für Phonetik und
Sprachliche Kommunikation
Universität München, FRG

ABSTRACT

In a series of experiments using the technique of metronome speech it could be shown that the p-center location in production is not solely dependent on the duration of the segments of the uttered syllables but on context and on position within alternating syllable sequences as well.

INTRODUCTION

Generally, it is assumed that the location of the p-center - the psychological moment of syllable onset - of monosyllables is solely dependent on the duration of the initial consonant(s) and that of the syllable rhyme. This should hold true for perception [2] as well as for production [1] As a description of the results of his perception experiments Marcus [2] gives the following formula:

$$P = .65 * C + .25 * VC + const.$$

where P is the p-center location measured relative to the acoustical beginning of the syllable, C the duration of the syllable-initial consonant, VC the duration of the syllable rhyme, and const. a constant. The following experiments were run to test the predictions of this formula in production of systematically varied monosyllabic material.

GENERAL METHOD

In a series of production experiments in which subjects had to utter sequences of the same or alternating monosyllables in beat with a computer generated metronome signal we measured the position of the beginning of the metronome signal relative to the onset of the the vowel as indicator of relative p-center location.

FIRST SERIES OF EXPERIMENTS

The material of the first set of experiments was of the form /C+ak/ (C = /p/, /b/, /f/, /v/ or /m/; in experiments 3, 5-8 also /ʃp/ or /ʃm/). The monosyllables were uttered in sequences composed of two alternating syllables or as homogeneous sequences of seven repetitions of one single syllable in beat with the metronome presented via headphones. At the same time the utterances of the subject were digitally recorded at a sampling rate of 20 kHz and the beginning of the DA-output of the metronome signal was marked in the digitized input for later processing of the data. Measurements of metronome beginning relative to the acoustic signal and of segment durations were made from the oscillogram trace using the speech editing program at the institutes PDP 11/50. The measurements were made for the second till sixth syllable of all sequences. The experiments were run with two experienced male subjects (odd numbered experiments: subject one; even numbered: subject two). For the first two experiments we used a metronome rate of 60 beats per minute with a 5 msec 3-kHz tone burst as metronome signal, the second set was run with a rate of 90 and the same metronome signal. The third set of experiments was also run at a rate of 90 but with the syllable /vak/ as metronome signal.
The metronome position data were analysed by two-factorial analyses of variance with measured syllable and context syllable as factors.

Results.
The metronome position results are summarized in Table I. It can be seen that in contrast to the general view, the p-center position is not independent of context [2] but significantly influenced by the phonological structure of the second syllable in the same sequence in almost all of the experiments.

Table I:
Metronome position relative to vowel onset
levels of significance for the factors
S = measured syllable, C = context,
I = interaction
for the first series of exeriments

	number of experiment					
	1	2	3	4	5	6
S	.01	.05	.001	.01	.001	.001
C	n.s.	.01	.05	.001	.05	n.s.
I	n.s.	.05	n.s.	n.s.	n.s.	.001

With respect to metronome rate (experiments 1 and 2 vs. 3 and 4) only subject one shows a significant effect on metronome position ($F(1,4) = 9.4$; $p < .05$): with the slower rate (60) of the metronome it is on average 8.5 msec less delayed relative to vowel onset than with a rate of 90 beats per minute.
Experiments 5 and 6 were run to test the influence of the p-center of the metronome signal. Here we used a /vak/-signal with measured metronome delay of 40 msec relative to acoustical syllable onset as metronome. There is a clear effect for both subjects: in this experiment as to be expected the metronome onset is on average 42.1 msec earlier than in experiment 3 for subject one ($F(1,6) = 158.38$; $p < .001$) and 46.2 msec earlier for subject two ($F(1,4) = 121.7$; $p < .001$). For subject one furthermore there is a significant interaction between the effect of metronome signal and measured syllable ($F(6,36) = 3.64$; $p < .01$).
Concerning the predictions of the Marcus formula [2] with respect to the dependency of p-center position on segment durations our results in general are clearly negative. No clear correlation between metronome position and segmental durations could be found for single syllable-context combinations as well as for all measurements of one experiment in single item analysis. A tendency for the predicted depencency can only be found if one considers the pooled data of the single syllable-context combinations. This result seems to suggest that this dependency only holds for phonologically differently composed syllables but not for articulatory variants of phonologically identical syllables.

SECOND SERIES OF EXPERIMENTS

In a second series of experiments we used German monosyllabic verbs varying either the initial consonant, or the vowel length and the syllable final consonance or both. Experiments 7 and 8 were run with verb forms of German "backen" and "packen": /bak/, /bakt/, /bakst/, /pak/, /pakt/, and /pakst/ in all possible syllable-context combinations. In Experiment 9 and 10 we used verb forms of German "spuken" and "spucken": /ʃpu:k/, /ʃpu:kt/, /ʃpu:kst/, /ʃpuk/, /ʃpukt/, and /ʃpukst/ in all possible combinations. Experiment 11 and 12 both were run with subject one. The material consisted of ten repetions of the four possible combinations of "back" and "packst" and of "pack" and "backst", respectively. The metronome rate was set at 50 beats per minute for all experiments.

Results.
The metronome position results are summarized in Table II. Again it can be seen that in almost all experiments there is an influence of context on the position of the p-center.

Table II:
Metronome position relative to vowel onset
levels of significance for the factors
S = measured syllable, C = context,
I = interaction
for the second series of exeriments

	number of experiment					
	7	8	9	10	11	12
S	.001	.001	.05	n.s.	.001	.001
C	n.s.	.001	.001	.05	.01	.05
I	n.s.	.05	n.s.	.05	.001	.001

With respect to the predicted dependency of p-center position on segmental durations our results again are negative: there is no clear correlation to be found in single item analysis.
In experiments 8 and 10 (subject two) parallel to the acoustic recording the glottal opening gesture for the syllable final consonant(s) was registered using an FJ-Photo-Electroglottograph and in experiments 11 and 12 (subject one) orbicularis oris activity was recorded parallel to the acoustic signal using a DISA EMG-Amplifier. For both physiological recordings no correlations with the position of the p-

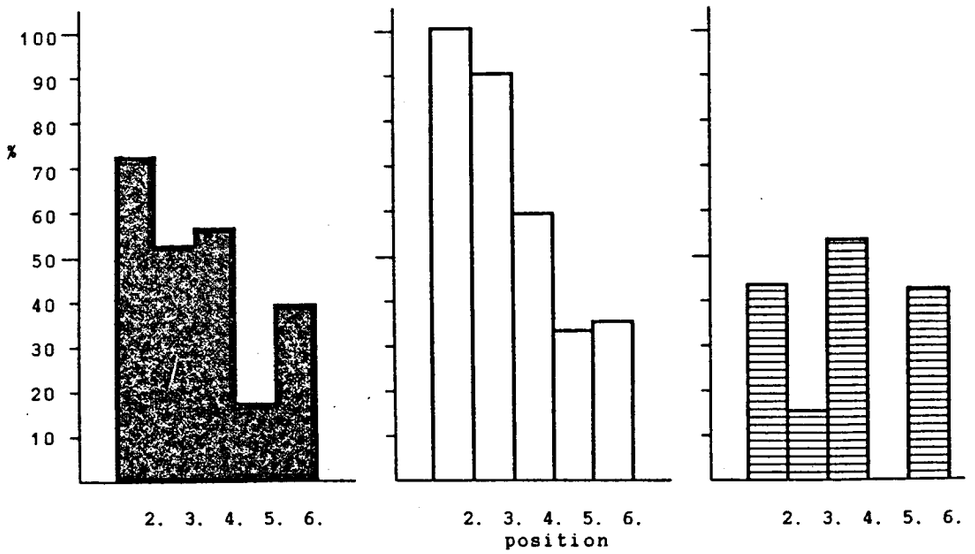

Fig. 1: Delay of the metronome beginning relative to the vowel onset in "packst" in percent total variation (100% = 86.7 msec; 0% = 6.4 msec); left: mean; middle: homogeneous sequences; right: alternating sequences

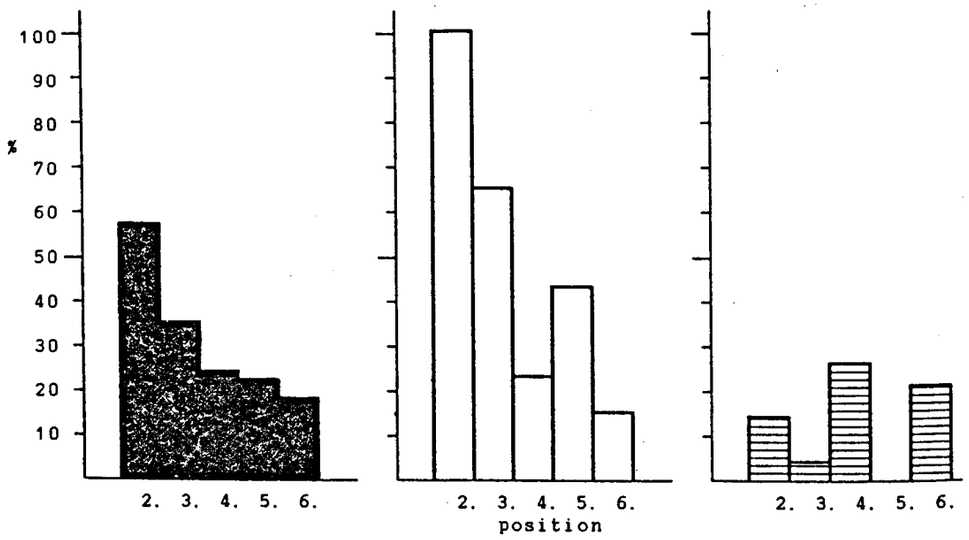

Fig. 2: Delay of the metronome beginning relative to the vowel onset in "backst" in percent total variation (100% = 91. msec; 0% = 7.1 msec); left: mean; middle: homogeneous sequences; right: alternating sequences

center could be found in contrast to the results reported by Tuller & Fowler [3].
The acoustical data of experiment 11 and 12 were reanalysed with respect to a possible effect of position of the measured syllable within the sequence on the metronome position. The results are depicted in Figure 1 and 2 for these items of experiment 11 and 12 that show significant effects of position. Two-factorial analyses of variance with as first factor homogeneous vs alternating sequences, and as the other factor position within one sequence showed no effects on metronome position for the items "back" and "pack", but a clear effect for "packst" and "backst": For the item "packst" the metronome position relative to vowel onset is affected by the nature of the sequence ($F(1,89) = 26.2$; $p < .001$), the position within the sequence ($F(4,89) = 8.22$; $p < .001$) and an interaction of both factors ($F(4,89) = 5.69$; $p < 001$): In homogeneous sequences the metronome delay is longer for the second and third than for the fourth to sixth position, in alternating sequences the second and fourth position (i.e. items of sequences beginning with "back") show longer metronome delays than the third and fifth position (i.e. items of sequences beginning with "packst") and the sixth position differing significantly from the fifth. The simple main effect of the nature of the sequence only is significant for the second, third and fith position: here the metronome delay is longer in the homogeneous sequences.
For the item "backst" the metronome position relative to vowel onset is also affected by the nature of the sequence ($F(1,90) = 17.86$; $p < .001$), the position within the sequence ($F(4,90) = 2.71$; $p < .05$) and an interaction of both factors ($F(4,90) = 4.45$; $p < .01$). The simple main effects are not as pronounced as in "packst": In homogeneous sequences the metronome delay is longer for the second than for the fourth to sixth position and longer for the third than for the fourth and sixth position, but in alternating sequences the tendency paralleling the results of experiment 11 does not reach significance. The simple main effect of the nature of the sequence only is, in parallel to the item "packst", significant for the second, third and fifth position: here the metronome delay is longer in the homogeneous sequences.
This effects seem to result from two general effects: first, metronome delay decreases with position within sequences and second, metronome delay is less for the items with complex syllable final consonance in these alternating sequences beginning with these items.

DISCUSSION

The main result of our experiments shows that for articulatory variants of phonologically identical syllables the p-center position does not show a systematic dependency on segment durations. This dependency can only be seen with regard to the mean values of phonologically differently composed syllables. Moreover, in contrast to the general view, the p-center position is not only an effect of single syllables but significantly influenced by context, i.e. in our experiments by the phonological structure of the second syllable in alternating sequences. It seems therefore that there cannot be a simple acoustical explanation of p-center location based on segmental durations alone.
Nor do our physiological data support a simple articulatory explanation of the p-center phenomenon: in our tests we could not find any correlation between the timing of physiological signals and the position of the metronome onset marked in the acoustical speech signal. The variation of p-center location found in syllables with complex consonantal rhyme alternating with simple CVC syllables, i.e a dependency of p-center position on whether the sequence started with the complex or the simple syllable can only be interpreted on the basis of rather complex articulatory programming.

REFERENCES

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