'Koartikulation' and 'Steuerung' as Factors Influencing the Perception of 'Momentary Tempo'

B. Pompino-Marschall, H.G. Piroth, P. Hoole, H.G. Tillmann
Munich, Federal Republic of Germany

1. Introduction

In earlier experiments we were able to replicate the results of Ventsov's (1981) investigations into the influence of open and closed syllables on the perception of 'momentary tempo' but the results of our modified experiments led us to the conclusion that it is rather the sequence of the articulatorily defined point of 'Koartikulation' - in accordance with the results of p-centre experiments (cf. Tuller/Fowler 1980) - than the sequence of closed syllables as proposed by Ventsov, which determines the perception of 'momentary tempo'. The tests described below were designed firstly to examine the effect of the direction of vowel manipulation and secondly to investigate sequences with consonant clusters instead of just one consonant.

2. Procedure

The subjects were asked to decide wheter a [mamamamamam] sequence had the same rhythmic structure as an [a a a a a] sequence (all [a] sounds being separated by pauses), whereby the repetition rate of the open [ma] syllable was different from the repetition rate of the closed [am] syllable. A natural utterance of [mamamamamam] was segmented into single pitch periods normalised with regard to F_0 as described in Pompino-Marschall et al. (1982). In the following the pitch period will be used as the unit of time. For Experiment 1 the periods from this inventory were combined according to (1):

(1) (4m+[26a)+(8m]+[22a)+(12m]+[18a)+(16m]+[14a)+
(20m]+[10a)+24m]

In this way a test sequence was produced in which the [ma] syllable is always 30 periods long, and the [am] syllable always 34 periods long (round brackets vs square brackets).

Five sequences for comparison were constructed, each consisting of five vowels separated by pauses. The vowels were constructed from the above inventory of [a] periods, and were equal in length with those of the test sequence. The pauses were so chosen as to give five different sequences with vowel repetition rates corresponding to a time equal to 28, 30, 32, 34 and 36 periods respectively. The five sequences for comparison with the test sequence are analogously described in (2), where 'nP' stands for a pause of length n periods:

(2.1) (26a + 2P) + (22a + 6P) + (18a + 10P) + (14a + 14P) + 10a
(2.2) (26a + 4p) + (22a + 8P) + (18a + 12P) + (14a + 16P) + 10a
(2.3) (26a + 6P) + (22a + 10P) + (18a + 14P) + (14a + 18P) + 10a
(2.4) (26a + 8P) + (22a + 12P) + (18a + 16P) + (14a + 20P) + 10a
(2.5) (26a + 10P) + (22a + 14P) + (18a + 18P) + (14a + 22P) + 10a

Stimuli for an AX test were formed by combining sequence (1) with each of the sequences (2.1)-(2.5). The five stimuli, which occurred ten times each, were presented to the subjects over loudspeakers. The interval between the end of the first sequence and the beginning of the second sequence within each stimulus was 250 ms. The stimuli were separated by a pause of 3 s. Between each block of 10 stimuli there was a longer pause of 5 s. The subjects were required to decide whether the two sequences in a given stimulus had the same rhythmic structure. 12 students and members of the institute took part in the experiments.

3. Results

The results of Experiment 1 largely confirmed the findings of Ventsov (1981) (see fig. 1). As in his Experiment 2 the stimulus with a vowel repetition rate of 34 periods in the second sequence was the stimulus most often judged to have the same rhythmic structure in both sequences. In contrast to Ventsov however we found an asymmetry between the number of 'same' responses to stimuli (1 - 2.3) and (1 - 2.5). In other words, the sequence with the slowest vowel repetition rate (36 periods) was more sharply discriminated from the test sequence than was the sequence with a vowel repetition rate of 32 periods. To test our hypothesis that this asymmetry is caused by a perception of increasing tempo within the test sequence, for Experiment 2 we constructed a complementary test sequence with lengthening [a] according to (1.1):

(1.1) (24m+[10a)+(20m]+[14a)+ (16m]+[18a)+(12m]+[22a)+(8m]+[26a)+4m].

Analogously to Experiment 1 the vowels of the sequences for comparison were chosen so as to reflect the vowel structure of the test sequence. Procedure and subjects remained the same.

The results (cf. fig. 1) are clearly in agreement with our hypothesis (the closed syllable is here 30 periods long) since there is a similar asymmetry but in the opposite direction.

To test whether these results are interpretable along p-centre lines, for the

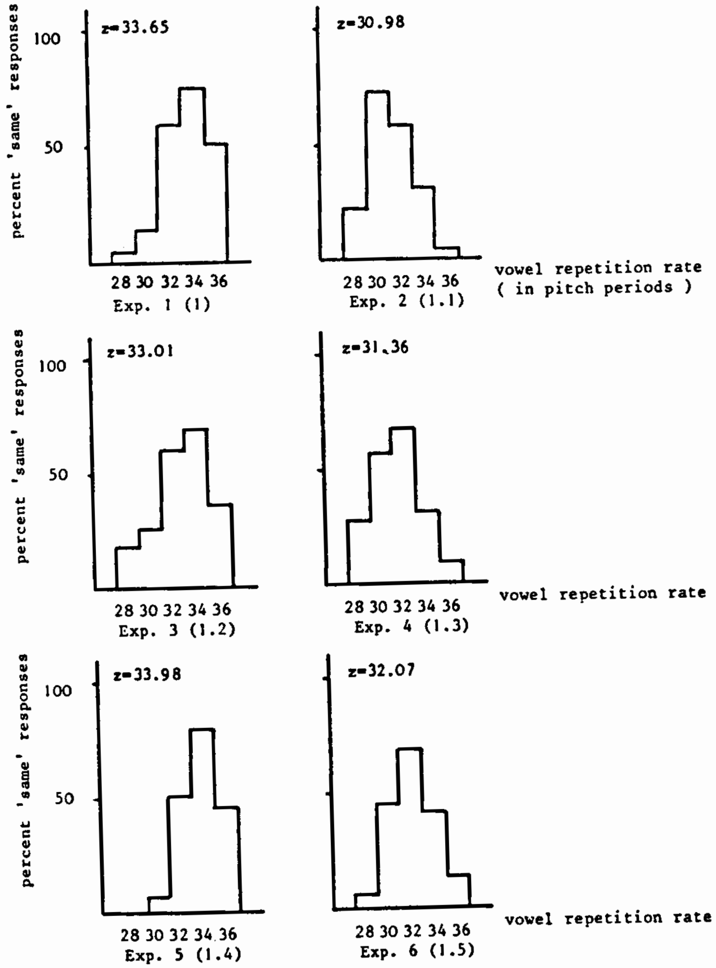

Figure 1. Results of experiments 1-6 (numbers in brackets referring to the formula in the text).

next pair of experiments we complicated the consonantal part of the sequence by introducing the variable-length fricative [ʃ] before the constant [m]:

(1.2) (4ʃ+[4m+22a)+(8ʃ]+ [4m+8a)+(12ʃ]+[4m+14a) +(16ʃ]+[4m+10a)+(20ʃ] +[4m+6a)+24ʃ].

In analogy to Experiment 2 the complementary sequence (cf. 1.3) was tested in Experiment 4:

(1.3) (24ʃ+[4m+6a)+(20ʃ]+ [4m+10a)+(16ʃ]+[4m+14a)+(12ʃ]+[4m+18a)+(8ʃ] +[4m+22a)+4ʃ].

The results of this pair of experiments clearly show the same reversal in the asymmetry of responses (see fig. 1); it is also noticeable that the median for the 'same' responses now lies slightly further away from vowel onset than in the simple [mam] sequences. The results are all in agreement with those of the p-centre experiments: lengthening of prevocalic consonant clusters shifts the point of psychological syllable onset away from vowel onset and the complementary sequence shows the mathematically opposite effect.

In the last pair of experiments we tested our hypothesis that these results as well as the results of the p-centre experiments are interpretable along the lines of the theory on 'Koartikulation' and 'Steuerung' proposed by Menzerath/de Lazerda (1933), i.e. that the psychological moment of syllable onset is the point of 'Koartikulation', defined by the simultaneous production of the prevocalic consonant and the vowel.

Here we kept the vowel constant and varied the relationship of [m] to [ʃ] in a consonant cluster also of constant length, sequence (1.4) starting with long [ʃ], short [m] and sequence (1.5) starting with short [ʃ], long [m]:

(1.4) (24 ʃ+[4m+6a)+(20 ʃ]+ [8m+6a)+(16 ʃ]+[12m+6a)+ (12 ʃ]+[16m+6a)+(8 ʃ]+ [20m+6a)+4 ʃ]

(1.5) (4 ʃ+[20m+6a)+(8 ʃ]+[16m+6a)+(12 ʃ]+[12m+6a) +(16 ʃ]+[8m +6a)+(20 ʃ] +[4m+6a)+24 ʃ]

The experiment with sequence (1.4) could also be easily interpreted along the lines of 'Koartikulation' (see fig. 1). However, the complementary sequence (1.5) was perceived as beginning in [ʃma] and ending in [ma ʃ], and gave results showing that the subjects perceived the tempo as lying half-way between [ʃma] and [ma ʃ]. We would interpret this as indicating that the effect of 'Steuerung' becomes more pronounced in the course of the sequence i.e. as syllable-final [ʃ] becomes longer.

References

Menzerath, P., Lacerda, A. de (1933). Koartikulation, Steuerung und Lautabgrenzung. Eine experimentelle Untersuchung. *Phonetische Studien* **1**. Berlin and Bonn: Dummlers.

Pompino-Marschall, B., Piroth, H.G., Hoole, P., Tilk, K., Tillmann, H.G. (1982). Does the closed syllable determine the perception of 'momentary tempo'? *Phonetica* **39**.

Tuller, B., Fowler, C.A. (1980). Some articulatory correlates of perceptual isochrony. *Perc. and Psychophys.* **27**, 277-283.

Ventsov, A.V. (1981). Temporal information processing in speech perception. *Phonetica* **38**, 193-203.