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KINEMATIC AND ACOUSTIC CORRELATES OF QUANTITY IN SWEDISH AND WOLOF: A CROSS-LANGUAGE STUDY

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RESUME

Peut-on lier le phasage des patterns cinématiques et acoustiques à la nature des structures syllabiques sur lesquelles repose une opposition de quantité vocalique ? Cette étude, qui porte sur deux langues non apparentées, tentera de repondre à cette question et, par là, de mettre à jour les régularités lieés aux contraintes phonotactiques des langues étudiées.

ABSTRACT

The main question addressed here is: does syllable structure affect the robustness of vowel quantity kinematic and acoustic phasing patterns? This investigation is an attempt to answer this question by examining data from two unrelated languages, and also to unveil regularities related to the phonotactics of the languages studied.

INTRODUCTION

Some languages use quantity for lexical and grammatical distinctions. This investigation focusses on the use of vowel quantity for lexical distinctions in two unrelated languages, Swedish and Gambian Wolof. Swedish has a contrast between two lengths, and this contrast occurs only in lexically stressed syllables, where the vowel is either short or long. If the vowel is long, it is either word final or followed by a short consonant, VVC; if the vowel is short, it is followed by a long consonant, VCC (Elert, 1964; Engstrand & Krull, 1994). This linguistic specificity has been reffered to as the complementary distribution of the quantities (i.e. short-long *vs.* long-short). Wolof also has a contrast between two lengths and the contrast occurs only in the first syllable which is the lexically stressed syllable. Here also the vowel is either short or long. However, unlike Swedish, Wolof does not show a complementary distribution of the quantities, as both short and long vowels are followed by a single consonant, i.e. VC *vs.* VVC.

The main question addressed here is: does syllable structure affect the robustness of vowel quantity linguistic distinctions? Thus speech rate is varied to test for this robustness, and the emerging acoustic and kinematic phasing patterns will be analyzed and discussed in terms of linguistic constraints.

METHOD

One male speaker of Wolof and one male speaker of Swedish uttered a series of CVCV words that were chosen to vary vowel quantity and quality in the two languages. Each token was embedded in a carrier sentence:

The speakers were instructed to produce the randomized list of utterances at a normal conversational rate, and at a self-selected fast rate, at least fourteen times in each speech condition. There were 5 conditions in all: 2 speech rates (conversational or normal and fast) X 2 vowel lengths (short and long) X 3 vowel types (i, a u) X 2 voicing contrasts (voiceless and voiced) X 3 places of articulation (p, t, k).

The movement data were recorded using, for Wolof, a three-coil transmitter system, with five transducers, the Electro Magnetic Articulograph (AG 100, *Carstens Medizinelektronik*), and for Swedish, another three-coil transmitter system, the Electro Magnetic Midsagittal Articulometer (EMMA - Haskins), as described by Perkell *et al.* (1992).

Receivers were placed on the vermillion borders of the upper and lower lips, the lower incisors for the jaw, and at a median position on the tongue body (an additional receiver was placed on the tongue tip for the Swedish data). Moreover, a receiver placed on the upper incisors and the nose bridge were used for correction of head movements relative to the helmet. Caution was taken during each receiver placement to ensure that it was positioned at the midline with its long axis perpendicular to the sagittal plane (cf. Löfqvist *et al.*, 1993). A simultaneous audio recording was carried out, using a helmet incorporated microphone.

Based on articulatory events in the velocity signal, two cycles were identified in the movement of each articulator (Delattre et al. (1990). These velocity cycles were determined as the interval between successive negative or positive peaks associated with the lowering or raising movement in the production of a vowel and a consonant. An oral opening phase, associated with the production of the vowel, was defined within the oral opening cycle, and an oral closing phase, associated with the production of the consonant, was defined within the oral closing cycle. Two acoustic cycles were also defined (Abry et al.,1985): one as the recurrence of the onset of a clear formant structure (i.e. in the VC domain) corresponds to the vocalic cycle; the other as the offset of a clear formant structure (i.e. in the CV domain), corresponds to the consonantal cycle. Acoustic phases were specified within the appropriate acoustic cycles, as the interval that presents a clear formant structure for the vocalic phase, and as the obstruent portion for the consonantal phase. It is hypothesized that oral opening and acoustic vocalic phases would reveal quantity contrasts, while oral closing and consonantal phases would highlight probable concomitant consonantal differences.

RESULTS AND DISCUSSION

Data processing is based on the *percentage* of time taken by each phase in its cycle. ANOVAs were performed on measured intervals as dependent variables and grouping factors limited to *Quantity*, *Quality* and *Rate*. However, only typical results will be given here.

Vowel quantity contrasts

In Swedish, vowel quantity contrasts emerge distinctly, in both the acoustic and movement domains, along the vocalic phase ($p<0.01$), while cycle or syllabe durations are comparable for VCCs and VVCs ($p=ns$). Quantity contrasts are maintained significantly with rate increase. Such differences are obtained by the tendency for classes to remain relatively stable at around 35% of the cycle for the short vowels and at around 58% for their longer counterparts regardless of the compression of cycle durations (cf. Figure, top). Relative stability is the strategy used here to obtain and maitain phonological differences.

In Wolof, vowel quantity contrasts also emerge clearly (cf. Figure, bottom) in both the acoustic and movement domains. In normal speech, significant phase differences ($p<0.01$) are coupled with mean cycle differences in both domains. When speaking rate is increased, these differences are still maintained. The strategy adopted to preserve phonological contrasts is as follows: when long vowels reduce both their cycles and the proportion of their phases under increased speaking rate, their shorter counterparts do likewise, thus drifting away from a potential phonological confusion "zone". This is an example of how variability is exploited fruitfully, in speech. However, short vowels in Wolof are limited, for reasons related to vowel identity preservation, in the compressibility of their vocalic phases or of their overall cycle durations. Long vowels ultimately tend to merge with their shorter counterparts as speech rate increases (Sock, 1984). Quantity distinctions do not therefore seem to be as robust in Wolof as in Swedish.

Consonantal durations

In Swedish, in the consonantal cycle corresponding to the CV domain, and at a normal speaking rate, closure differences (especially for the unvoiced category) are clear-cut on the acoustic level: the consonantal phase for the VCC category takes up around 65% of the consonantal cycle, while that of the VVC category occupies, on an average, 45% of the cycle. These differences are maintained in fast speech, despite the reduction of cycle durations. On the movement level, differences are less clear-cut. However, the tendency is quite discernable. Thus concomitant consonantal differences seem to reinforce vowel quantity contrasts in Swedish.

In Wolof, consonantal phases tend to stay relatively stable (between 70% and 75%) of the cycle, while reducing the duration of these cycles with increase in speaking rate, on both the acoustic and movement levels. If such a constrained behaviour does not contribute to distinguishing the vowel categories, it could be attributed to constraints that are tied to the biomechanic and aerodynamic properties of the system.

SUMMARY

The VC domain, indeed seems to be an efficient temporal span where quantity contrasts are exemplified. Such results are in line with data reported by Delattre *et al.* (1990). Vocalic phasing patterns corresponding to the different linguistic entities emerge clearly in this temporal span in normal speech and are more or less maintained in fast speech, thus confirming the relevance of such measurements in speech timing studies and quantity contrasts.

Results confirm our initial hypothesis that the complementary distribution of the quantities in Swedish would serve to reinforce vowel quantity contrasts. However, in Wolof the consonantal phase simply reveals constraints in phase variability.

Strategies adopted to preserve quantity contrasts are closely tied to syllable type. Thus both kinematic and acoustic timing patterns obtained for Swedish are comparable with those obtained for Kuweti Arabic (Delattre et al., 1990) where VCCs contrast with VVCs as in Swedish; while data obtained for Wolof are structurally similar to those observed for Tunisian Arabic (Boussaffa et al., 1991), where VCs contrast with VVCs as in Wolof. It is thus posited, based on a substantial amount of data collected for different quantity languages and from several speakers, that knowing the syllable structures that convey quantity in a given language, one may predict the structuring of kinematic and acoustic phasing patterns and also evaluate their robustness.

Data obtained for Swedish show more clear-cut patterns than those obtained for Wolof, not only in normal speech but also when the linguistic task becomes difficult, i.e. when speaking rate increases. Such results suggest that quantity contrast is more robust in Swedish than in Wolof and also corroborate major timing results obtained for other quantity languages using a similar paradigm (cf. Delattre et al., 1990):

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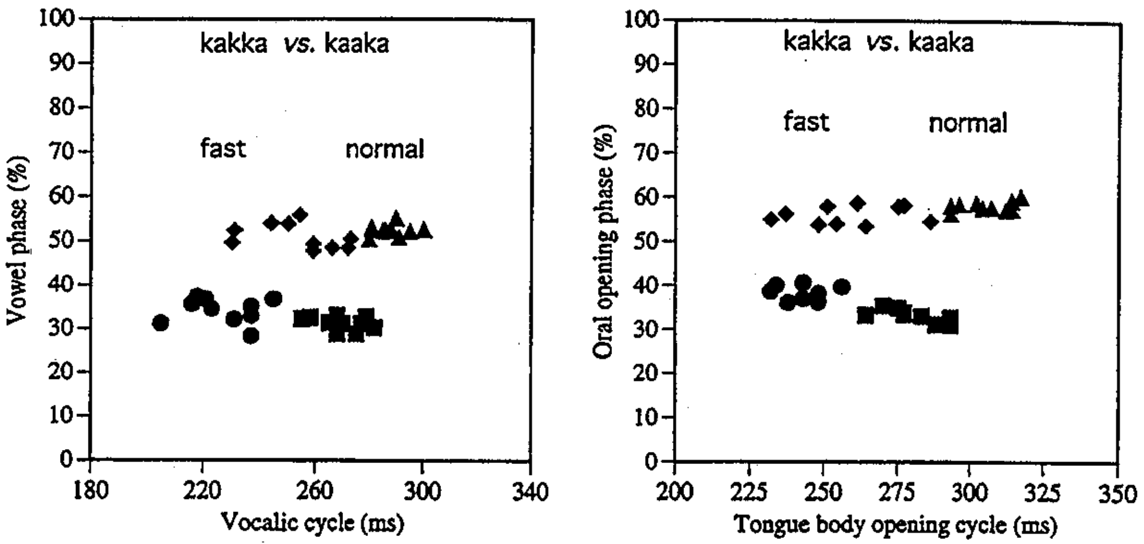
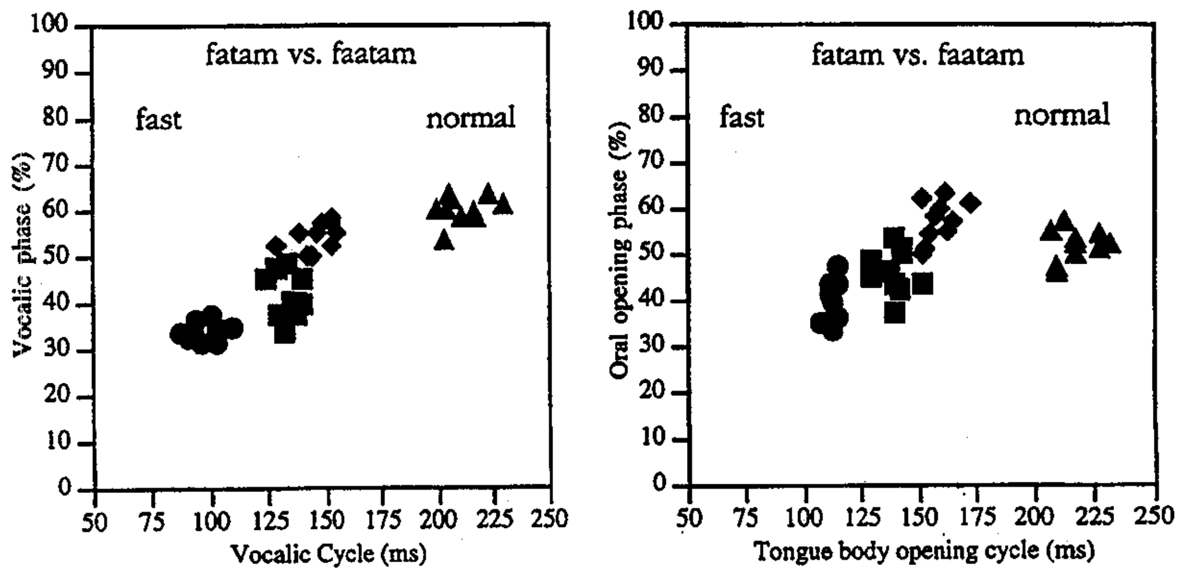


Scatterplots of Swedish vocalic patterns for VCCs in normal (■) and fast (●) speech rates, and for VVCs in normal (▲) and fast (◆) speech rates on the acoustic (left) and movement levels (right). See text for details.



Scatterplots of Wolof vocalic patterns for VCs in normal (■) and fast (●) speech rates, and for VVCs in normal (▲) and fast (◆) speech rates on the acoustic (left) and movement levels (right). See text for details.