ON GESTURES TIMING IN EUROPEAN PORTUGUESE NASALS

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ABSTRACT

In this paper a first study of gestures timing in European Portuguese nasals is presented. Velum, lips and tongue tip gestures were automatically annotated in an existent EMMA corpus. Analyses concentrated on the characterization of the different gesture landmarks in terms of average duration values, investigation of factors influencing such durations, and characterization of inter-gestural coordination.

Keywords: Gestures, timing, nasals, Portuguese, EMMA.

1. INTRODUCTION

Articulatory Phonology basic units are gestures [1]. They are defined along both spatial and temporal dimensions. The spatial dimension includes variables that refer to both location and degree of constriction. Individual gestures combine with each other to form larger combinations, called constellations of gestures.

Concerning the temporal dimension, gestural landmarks represent the dynamic of the gesture over time. Gafos [4] proposed a particular notation - onset, target, center, release, and release offset - to indicate the coordination relationships between gestures. In CV sequences, for example, the center of the consonantal gesture is phased with the onset of the vocalic gesture. The information regarding phasing relationships between gestures is represented in a gestural score. The "study of temporal relations among gestures is in its infancy" [4, p. 279].

1.1. Articulatory Phonology and Nasals

The majority of past work within Articulatory Phonology has addressed the allophony related to syllable. Results suggest that syllable-initial and syllable-final consonants tend to exhibit different patterns of gestural organization. These syllable position effects have been observed for many consonant classes, including laterals, nasals and stops (see [6] for a review).

Articulatory evidence concerning nasal consonants is provided by [5, 6]. Concerning effects on the timing of the lowering gesture relative to the gestures for oral tract closure, Krakow found that in the production of the syllable-final [m] the lip closure occurred later than the velum lowering.

Wang [16] investigated the inter-articulator timing patterns for syllable-initial and final nasals in Cantonese. The results showed no significant timing lag in syllable-initial or syllable-final nasals, suggesting that these patterns are not universal, but language-specific. Krakow [6] suggests that the difference in results across the two studies may have been due to differences in speaking style.

Tobin [15] is now extending Krakow's finding, that syllable structure affects inter-articulatory timing, to the nasal consonant [n], using MRI data.

According to Oliveira and Marin [8], the patterns of velum coordination are similar in Brazilian Portuguese and English: oral gesture in coda position is sequential to the velum gesture (gestures are anti-phase) and in the onset position velum gesture is coupled synchronously with the oral gesture (gestures are in phase). However, it was been observed that at fast rates, there is a shift from sequential coordination to synchronous coordination.

1.2. Nasal sounds of Portuguese as dynamic sounds

Nasal vowels are one of the distinctive characteristics of Portuguese because of their number and their particular properties. Traditionally, the emergence of nasal vowels in EP is explained through a process of regressive propagation of nasality from a nasal consonant [11]. A limited number of forms with nasal vowels appeared in Portuguese as a result of progressive assimilation.

The phonemic or allophonic status of Portuguese nasal vowels has long been debated [9]. Structuralists identified nasal vowels as sequences of oral vowel plus nasal archiphoneme. Generative phonologists, based in morphophonemic alternations, postulate that nasal vowels derive from underlying VN sequences. For Parkinson [9], nasal vowels function as diphtongs (VV˜). Some authors argue for the inclusion of nasal vowels in the EP phoneme set. However, there is no doubt that surface oppositions exist between oral and nasal vowels (*sim* "yes" vs. *si* "oneself" [11].

One of the most important things as far as nasal

Portuguese vowels are concerned is the manifestation of nasality in the temporal dimension. Lacerda [7] shows that nasal vowels start in an oral configuration and make a transition to a nasal configuration. Nasal vowels may be followed by a consonantal off-glide, whose quality is determined by the nature of the next consonant. The off-glide is particularly evident before plosives [11]. In word-final position, the existence of such nasal consonantal segments is not so common. However, certain dialects of Brazilian Portuguese are reported to show signs of *nasal coda restoration*[12]. Clumeck [3, p.351] was the first investigator to notice the important role of dynamics in the perception of Portuguese nasal vowels. Teixeira's [13] results also point to the influence of velum variation in time in the perception of synthesized nasal vowels.

We consider the best way to deal with this dynamic dimension of Portuguese nasal vowels is within the Articulatory Phonology Framework. In European Portuguese (EP), the inter-articulator timing between the component gestures of nasals remains almost unstudied. In that sense, the goal of this study is 1) to contribute to an appropriate characterization of Portuguese nasal segments; and 2) to analyse the relative timing of gestures in Portuguese nasals. In more general terms, this study is a necessary and important step towards our ongoing effort on the automatic derivation of gestural scores for Portuguese and its integration with an articulatory synthesizer.

The paper was structured as follows: section 2 is devoted to corpus and its annotation. The results for duration of nasal and oral gestures and for inter-gestural timing are given separately in section 3. The paper concludes with discussion of the main results and some directions for future work.

2. CORPUS

The corpus was not specifically designed for this experiment. Data were collected as a part of an exploratory study motivated by the need to improve quality of synthesized nasal sounds [14]. Stimuli included words containing nasal sounds in different contexts. We report here the results for a subset of the corpus: words with $C_1V_nC_2$ sequences, C_1 and C_2 being stops (8 repetitions available for most words); word-final nasal vowels (only a few samples available); words with nasal consonants in an intervocalic position (a small number of examples).

The recording session took place in Ludwigs Maximillians Universität, in Munich. Data were collected using Carstens AG100 EMMA system. The subject was the first author, a male speaker of standard Portuguese. Receivers were placed on the tongue (back, tongue dorsum and tongue tip); lower lip; velum (glued to a strip of overhead transparency fixed to an artificial palate); upper teeth and nose bridge (for reference).

2.1. Automatic Annotation

Velocities for three receivers (tongue tip, velum and lips) were automatically calculated in order to determine temporal articulatory landmarks: movement onset (O), target achievement (T), target release (R) and release offset (Roff). For velum and lips, vertical displacement velocity was employed; for tongue tip, tangential velocity minima was used [2]. Onsets and offsets were located at points where velocity enters or leaves a noise band around zero [2]. A noise band of 15% of maximum velocity was used for tongue tip; 20% was used for the other sensors. A post-processing step was added to deal with inflexions/ complex movements removing some landmarks (e.g. contiguous sequences of Onset-Target with Target very close to the next Onset).

Gestural duration and inter-gestural timing was obtained based on these landmarks by algorithmically searching the annotations using broad phonetic transcription as a guide to the time intervals to focus search. The less reliable annotation results were obtained for tongue tip, particularly in contexts involving high vowels. This problem can be, at least in part, attributed to the sensor placement (aprox. 1 cm from the tongue tip).

Whenever the number of samples was sufficient, the results were further subject to statistical tests.

3. RESULTS

First we will address timing information for velum and oral gestures, separately. After this, inter-gestural timing coordination will be considered. The spatial dimension has already been presented elsewhere [10].

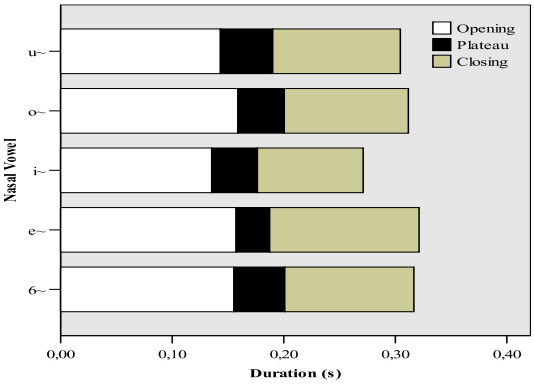
3.1. Velum Gestures

Nasal vowels - Results for the opening, plateau and closing durations of nasal vowels in $C_1V_nC_2$ context are presented in Fig. 1.

Overall average durations were: $152(std = 31)$ ms for opening; $41(std = 26)$ ms for plateau; and $114(std = 33)$ ms for closing.

The 3 parameters were separately evaluated with 3-factor ANOVA. Factors considered were: vowel quality, consonant before (C_1)and consonant after (C_2). ANOVA for opening and closing show vowel quality and C_2 as significant factors: high vowels present smaller opening duration and a following [g] causes a shorter opening; closing duration is shorter

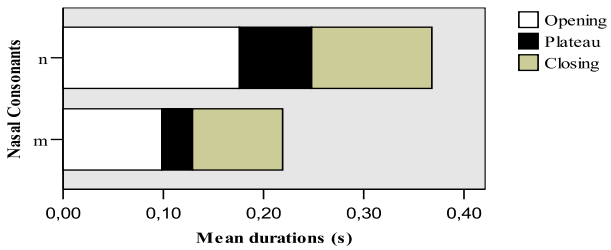
Figure 1: Results for velum gestures timings in CV_nC, presenting, from the left to the right, opening, plateau and closing durations.



for [ĩ] and has higher values when nasal vowels precede velar stops. This can be related to the lower amplitude of velic movement for [ĩ] [10] and the mutual effects of the velum and tongue back raising for the velar stops. For plateau only, C_2 factor was significant: duration is smaller when the nasal vowel is followed by velar stops, with an average duration of around 20 ms.

For word final nasal vowels only the opening velum movement was detected, with an average duration of 169 ms (95 % confidence interval between 135 and 202 ms). The overlap of this confidence interval with that obtained for opening duration in CV_nC shows as non-significant the difference of the opening in the two contexts.

Figure 2: Durations of nasal consonant gestures. Average durations are presented for opening, plateau and closing from left to right



Nasal consonants - We only analysed their occurences in vocalic context. Results are presented separately for the 3 timings in Fig. 2 for two of the three EP nasal consonants, [m] and [n].

The differences in at least opening and plateau durations are clear in the graph. The total duration of the gesture is very different, being shorter for [m].

3.2. Oral Gestures

As a preparatory step for the coordination studies involving velum gestures, we investigated the raising and lowering of lip and tongue tip for EP bilabial and alveolar consonants (both nasal and oral).

For [m], mean durations measured were 88, 21 and 133 ms, for opening, plateau and closing respectively. These durations for [n] are: 203, 21 and 196.

For both consonants the plateau is of reduced duration and has very similar values, reflected in the same average value obtained. For [n] the opening and closing movement present similar durations, the gesture being more symmetrical.

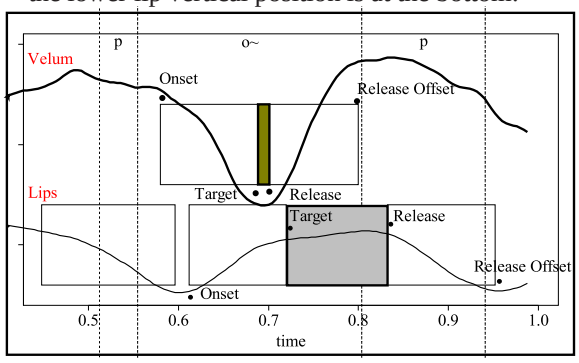
Neverthless, these results and observations should be considered with care due to the reduced number of examples analysed.

3.3. Gesture Coordination

Nasal consonants - Following Oliveira and Marin [8], we investigated Target-to-Target Lag (TTL) - the difference from achievement of velum target to achievement of oral gesture target.

Due to the reduced sample, only average values were included. Mean TTL was -2.9 ms, lower than our time resolution. The t test confirms as non-significant the deviation from 0 ($p = 0.87$). These close to zero values are considered typical of synchronous coordination [8].

Figure 3: Sample of CV_nC, [po˜p], with oral and velum gestures. The velum trajectory is at the top, the lower lip vertical position is at the bottom.



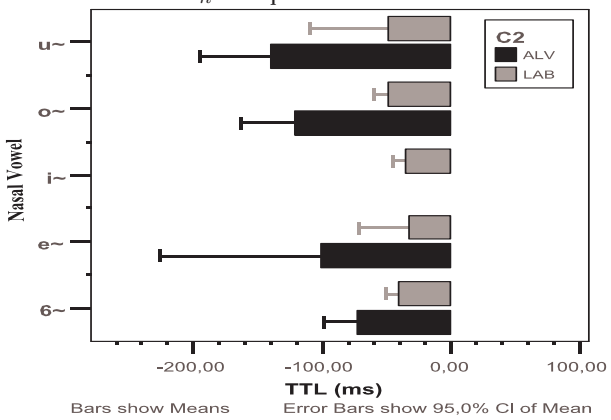
Nasal vowels - For nasal vowels we investigated both synchronization with C_1 and C_2. A sample with the annotated gestures is presented in Fig. 3.

Regarding the coordination of velum opening with C_1 oral gesture we measured two intervals: one between velum opening Onset and oral Release (ORL); the second from velum opening Onset to oral Release Offset (OROL). Only labial oral gestures were considered. An average value of 60 ms was obtained for ORL and -59 ms for OROL. These values indicate a small degree of overlap, that is, the velum gesture starts after the release of the previous oral gesture but before release offset, approximately halfway between the two.

Untill now we have only investigated the TTL parameter for coordination with C_2. As explained, this

parameter refers to the coordination of velum opening target with C_2 oral gesture. The same parameter can be interpreted, in the light of the nasal vowel as V+N theory, as the time between velum opening target and the target for N oral gesture. Considering or not the existence of 2 consonants we have the same unique oral gesture. Our results are presented in Fig. 4.

Figure 4: TTL for velum to C_2 oral gesture coordination in CV_nC sequences.



As seen in the figure the values are all negative, indicating sequencial gesture coordination. Also, it is clear the difference in TTL values for the two types of C_2, alveolar and labial, included in our analyses. When the nasal vowel is followed by a labial consonant TTL is shorter, but still negative.

4. CONCLUSIONS

In this paper we heave presented analyses of gestures duration and inter-gestural timing for EP nasals, for both consonants and vowels. Due to corpus content, analyses concentrated on CV_nC sequences with some complementary information regarding other relevant contexts, such as word final nasal vowels and nasal consonants in vocalic context.

Analyses were based on automatic annotation, making possible, for the first time, the use of the entire corpus. Automatic annotation gave good results.

The results confirm the dynamic nature of Portuguese nasals. The temporal information now obtained is crucial for our ongoing work on automatic generation of gestural scores for EP nasals. Average durations of gestures as well as information about gestures coordination are now available. The influence of the segmental context in the velar movement is also evident. On the contrary, results suggest that word position has no significant effect in velum opening movement.

Assuming nasal vowels as sequences of oral vowel+nasal consonant, our results support the proposals of Krakow [5] for English and of Oliveira and Marin for Brazilian Portuguese [8] that velum gesture in onset position (VNV) is synchronous with the oral gesture, and oral gesture in coda position (CV_nC) is sequential to the velum gesture.

The main problems in this work were the reduced number of examples for contexts other than CV_nC and the difficulties in tongue tip annotation. We are already working on the definition of a new corpus allowing us to complement the present study.

5. REFERENCES

[1] Browman, C. P., Goldstein, L. 1989. Articulatory gestures as phonological units. *Phonology*, 6, 201–251.

[2] Chitoran, I., Goldstein, L., Byrd, D. 2002. Gestural overlap and recoverability: Articulatory evidence from Georgian. In *LabPhon 7*, 419–447.

[3] Clumeck, H. 1975. A cross-linguistic investigation of vowel nasalization: An instrumental study. *Nasálfest - Papers from a Symposium on Nasals and Nasalization*, Stanford University, 133–151.

[4] Gafos, A. 2002. A Grammar of Gestural Coordination. *Natural Language & Linguistic Theory*, 20, 269–337.

[5] Krakow, R. 1989. *The articulatory organization of syllables: a kinematic analysis of labial and velar gestures*. PhD thesis, Yale Univ.

[6] Krakow, R. 1999. Physiological organization of syllables: a review. *J. of Phonetics*, 27, 23–54.

[7] Lacerda, A., Head, B. F. 1966. Análise de sons nasais e sons nasalizados do Português. *Rev. Lab. Fonética Experimental, Coimbra*, VI, 5–70

[8] Oliveira, L., Marin, S. 2005. Patterns of velum coordination in Brazilian Portuguese. In *Phonetics and Phonology in Iberia (PaPi)*, Spain.

[9] Parkinson, S. 1983. Portuguese nasal vowels as phonological diphthongs. *Lingua*, 61, 157–177.

[10] Rossato, S., Ferreira, L, Teixeira, A.. 2006. Les Nasales du Portugais et du Français: une étude comparative sur les données EMMA. In *Actes des XXVIes JEP*, Dinard, France.

[11] Sampson, R. 1999. *Nasal Vowel Evolution in Romance*. Oxford University Press.

[12] Shosted, R. 2003. Nasal coda restoration in Brazilian Portuguese. In *Proc. of the 15th ICPhS*.

[13] Teixeira, A., Vaz, F., Príncipe, J. C. 1999. Influence of dynamics in the perceived naturalness of Portuguese nasal vowels. In *Proc. ICPhS*.

[14] Teixeira, A., Vaz, F., 2001. European Portuguese Nasal Vowels: An EMMA Study. In *Proc. EuroSpeech*, Aalborg, 1843-1846.

[15] Tobin, S., Byrd, D., Bresch, E., Narayanan, S. 2006. Syllable structure effects on velum-oral coordination evaluated with real-time MRI. *J. Acoust. Soc. Am.*, 119(5), 3302.

[16] Wang, Q. E. 1995. *Are Syllables Units of Speech Motor Organization? - A Kinematic Analysis of Labial and Gestures in Cantonese*. PhD thesis, Univ. of Connecticut.