Velum gestures and nasalization phenomena in Guarani

Guarani, a Tupi-Guarani language spoken in Paraguay, shows many interesting phenomena related to nasalization. The phonological complexity of nasal harmony has been described in various papers. However, very little has been done to understand the phonetics of nasal harmony and the consequences of nasal spreading on various classes of segments such as voiced and voiceless fricatives. This paper discusses results of aerodynamic and acoustic measurements obtained from native speakers of Paraguayan Guarani. The first part of the paper focuses on the phonetic description of acoustic and aerodynamic parameters (nasal and oral airflow and intra-oral pressure) involved in the production of nasal harmonies and nasalized segments. The second part of the paper discusses the phonological interpretation of velum gestures observed in the phonetic data. Patterns emerging from Guarani nasal phenomena and their consequences for phonological theory are then discussed. The final part of the presentation is devoted to the discussion of perceptual experiments designed to check the validity of some hypotheses made from data obtained in speech production.

In order to describe velum movements and various parameters involved in the production of nasal phenomena in Guarani, a set of words and sentences was chosen from Suarez & Suarez (1961). Six speakers (2 women and 4 men) participated to the experiments. They were asked to pronounce and repeat 5 times each of the words both in isolation and in carrying sentences. A simultaneous recording of the oral and nasal airflows was synchronized with a recording of the acoustic signal. For some speakers intraoral pressure (Po) was also recorded. Recordings were made according to the rules of the ethical committee of the Université Libre de Bruxelles concerning the participation of human subjects. Po was measured by a small plastic tube (ID 2mm) that was inserted through the nasal cavity into the oropharynx. The tube was connected to an EVA2 portable workstation consisting in a PC computer and an acquisition system equipped with various transducers and the signal editing and processing software phonedit. Oral airflow (Oaf) was measured with a rubber mask connected to the acquisition device of the workstation; nasal airflow (Naf) by two plastic tubes connected to each nostril by a small silicon olive. The acoustic signal was recorded with a directional microphone connected to the EVA 2 portable workstation. The microphone was at a constant distance from the rubber mask. The signal was sampled at 16000 kHz and processed with the software *phonedit* and *signal explorer*. In order to obtain a smooth line, plots were low pass filtered at 70 Hz.

The interest of the synchronized acoustic and aerodynamic measures is that they allow making some inferences about the coordination between the velum and the other articulator's movements. This also allows observing the opening and closure gestures of the velum in time and to some extent the degree of nasalization of the segments.

Results show a number of striking phenomena. The first is that the velum is much more active than expected in fully nasalized words or sentences. Data suggest that the velum does not remain open during whole words but that there are opening and closing gestures marking the separation between nasalized vowels and consonants. In fully nasalized words the only segments that are not nasalized are the voiceless stops. When a nasal precedes a voiceless stop there is a substantial amount of nasal airflow remaining during the first part of the stop, sometimes with a weak voicing. There is also a sharp peak of nasal airflow at the end of the preceding vowel but the closing gesture only happens after the vowel during the consonant that remains voiceless in any case. This peak of nasal airflow at the end of the vowel suggests that

there is a complete closure of the oral tract at the end of the vowel, leaving all the airflow going through the nasal cavities. The observation of the nasal airflow patterns seem to confirm claims made by Suarez & Suarez (1961) who state that the amount of nasalization is not the same everywhere even in fully nasalized sequences. The consequence of this being that next to a 2-way phonemic contrast in nasalization, there are at least three degrees of nasalization phonetically. This has still to be established quantitatively but this is under way. The Guarani data also show that Ohala & Ohala (1993) and Shosted's (2006) claims about nasalized fricatives are not as opposed as might seem at first sight. Some of the incompatibilities predicted by Ohala & Ohala are observed and some predictions made by Shosted too. When nasalized [x] also assimilates in voicing to become [ɦ̃]. Therefore as claimed by Shosted (2006), the spectrum is affected, changing from high frequency energy to more flat. This makes the voiceless velar fricative become a laryngeal fricative but also voiced. The latter point goes along claims made by Ohala & Ohala (1993) who say that the nasalization of fricatives is more likely for voiced fricatives when it happens. Data presented on the Figure (presenting nasal airflow in hPa and audio waveform), show that the velum is very active during long nasalized sequences in sentences. These sequences are often described as the consequence of a nasal harmony process. Nasal airflow data from Guarani suggest that rather than having a single [+ nasal] feature, there is a complex pattern of closing and opening velum gestures that account for such sequences.

References

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