Ejectives are produced with a glottal closure at the larynx and another at various places of the vocal tract. The temporal timing and coordination of the gestures made at the glottis and in the vocal are crucial to understand how these sounds are produced and how they differ from pulmonic stops. Ejectives are produced by an elevation of the larynx that makes the space between the glottal and oral closures smaller. This volume reduction triggers and elevation of the pressure in the cavity sealed between the glottis and the oral closure. When the oral closure is released a sharp and intense burst is produced.

Amharic has a set of ejective consonants \([p', t', k', tʃ', s']\) that can be short and long. There are several interesting questions related to their production mechanism and to their difference with pulmonic stops: (1) is the glottal closure released separately or simultaneously with the oral closure? (2) How are ejectives fricatives and affricates produced? (3) Is the production of geminated alveolar ejectives fricatives really possible? If so what makes the difference with singleton ejectives fricatives? This study presents results of experiments made by using aerodynamic (oral airflow, sub-glottal \((Ps)\) and intraoral \((Po)\) pressures) and acoustic parameters on Amharic ejectives. These data allow making inferences on the dynamics of articulatory movements that produce ejectives consonants.

Aerodynamic recordings were made using the Physiologia workstation (Teston and Galindo 1990). Oral airflow measurements were taken with a small flexible silicon mask placed against the mouth. Intraoral pressure was recorded with a small flexible plastic tube (ID 2 mm) inserted through the nasal cavity into the oro-pharynx. Subglottal pressure \((Ps)\) was measured with a needle (ID 2 mm) inserted in the trachea. The needle was placed after local anesthesia with 2% Xylocaine, including the subglottal mucosa. The tip of the needle was inserted, right under the cricoid cartilage. Acoustic recordings were made via a High Fidelity microphone set on the hardware equipment connecting the transducers to the computer. Aerodynamic data were recorded with one speaker and acoustic data with 6 speakers. Those were used to evaluate observations made from the aerodynamic recordings.

Results show that when compared to pulmonic stops ejectives have a VOT with no noise after the burst release. This suggests that the oral closure release is made before the glottal. This can be seen on data presented at Figures 1 & 2. \(Ps\) shows a drop between the burst and the beginning of voicing accounting for the following vowel for pulmonic stops while it is not the case for ejectives (Figures 1 & 2). This shows that the glottis is still open during this interval of time for pulmonic stops.

Ejectives fricatives are produced by making a glottal closure after the initial glottal opening at the beginning of this consonant. Then the volume of air between the glottis and the alveolar constriction is evacuated from the vocal tract when the larynx is raised. Figure 1 shows that the oral airflow is interrupted after an initial increase. Then the air volume that is in front of the glottis is expelled from the vocal tract. The frication noise is reaching a peak towards the end of the larynx’s elevation. The short lag after the constriction release accounts for the still closed glottis. The latter opens shortly after for the following vowel.

Geminated alveolar ejectives fricatives (that have greater duration compared to singleton, i.e. 197.7 ms on average \((n=25)\) for the geminated vs 123.5 ms on average \((n=25)\) in the recorded data) show that the frication noise increases gradually as a consequence of the slower elevation of the larynx (Figure 1). This is different to pulmonic fricatives where the frication is rather constant. Another strategy that has been observed in the data is a delay in the larynx
elevation allowing the lengthening of the consonant’s duration. In this case the frication noise is comparable to a pulmonic fricative during about 2/3rd of the duration. The larynx elevation occurs in the last part and generates a strong intensity frication noise. These observations suggest that speakers have some control on the timing between the larynx elevation and the oral constriction.

For affricate ejectives [tfʰ] an oral closure interrupting the oral airflow is made during the larynx elevation. This precedes the frication noise produced by expelling the air comprised between the closed glottis and the palatal constriction.

A last point that is important to note is that pulmonic stops and ejectives show no big difference in Ps. This is likely because the closed glottis and the larynx elevation trigger a greater tension of the respiratory system. Therefore the expected Ps lowering due to a greater subglottal volume is not observed. What is observed is a Ps elevation due to a stress in the subglottal system. This hypothesis about the Ps elevation accompanying the larynx’s vertical movements for ejectives consonants needs further investigations to be established.

Results of this experiment suggest that the timing and dynamics of oral and glottal closure/opening gestures is a crucial feature making the difference between plain and ejective stops. This is in addition to the required larynx elevation. The comparison between singleton and geminated alveolar ejective fricatives suggest that speakers have some control on the timing of the larynx’s raising movements.

Reference

Figures

**Figure 1.** Audio waveform, oral airflow and Ps plots for the word [kˈisˈi:l] ‘adjective’. The VOT without noise for [k′] is shown in the rectangular box; the single arrow on the oral airflow plot shows the moment of the glottal opening, double arrows show the interruption of the oral airflow at the time of the glottal closure and the short lag at the end of the alveolar constriction. The arrow on Ps shows a constant Ps.
Figure 2. Audio waveform, oral airflow and Ps plots for the word [kəʊsəl] ‘charcoal’. The VOT with a weak burst for [k] is shown in the rectangular box; double arrows show the correspondence between Ps and oral airflow. When Ps diminishes because of a glottal opening there is an increase in oral airflow.