Temporal and spatial adjustments to conflicting demands for consonantal targets

Background

The notion of an articulatory phonetic target is implicit to most definitions of segments and phonological features. However, it has been challenged by the fact that articulatory configurations show a high amount of variability due to e.g. prosodic, contextual and speaker-dependent factors. Finding invariance in variability has been a major issue in phonetic research for the last two decades. One of the most often applied methods is to introduce some sort of natural perturbation or conflicting demands on specific target requirements and investigate stable patterns in the spatial or temporal domain of articulatory movements. In the current study the role of the jaw for different manners of articulation for coronal consonants will be studied by varying vocal effort. Besides an increase in subglottal pressure a higher amount of vocal effort is associated with lower jaw positions for vowels (see Schulman 1989, Geumann 2001). The jaw also contributes to different manners of articulation: sibilants and the voiceless stop /t/ require a high and almost invariant jaw position whereas for the voiced consonants /d, n, l/ the jaw position is lower and varies to a greater degree due to vowel context (e.g. Keating et al. 1994, Geumann 2001). Furthermore the temporal coordination between apical and mandibular movements differs for different manners of articulation: /s, S, n, l/ are produced with a symmetrical pattern, i.e. the tongue tip reaches the target configuration before the jaw and starts the opening movement later, which can be attributed to the sluggishness of the jaw which causes a later target achievement and necessitates an earlier onset of the opening movement. For the two stops a different timing pattern emerged: here jaw reached its target much later than the tongue tip and started the opening movement at the same time or even somewhat after the tongue tip. The onset of the mandibular opening movement was coordinated with the burst (see Mooshammer et al. 2003).
The aim of this study is (a) to find stable patterns for the jaw contribution to the production of coronal consonants across two levels of vocal effort (normal vs. loud) and (b) to analyse which strategies speakers use to adapt to both demands, a lower jaw position for vowels produced in loud speech and a high jaw position for the obstruents.

Method

The speech material consisted of /ˈVCV/ embedded in the carrier phrase "Hab das Verb ___ mit dem Verb___ verwechselt" with the target consonants consisting of the coronal phonemes of German differing in manner of articulation /s,ʃ,t,d,l,n/ and the symmetrical long vowel context /aː/ with the first vowel stressed and the second one unstressed. The sequences were produced 12 times in randomised order at normal and loud volume by five speakers. Articulatory data were obtained by means of Electromagnetic Midsagittal Articulography (Carstens Medizinelektronik AG100) at a sampling rate of 250 Hz. Four sensors were placed on the tongue and three on the jaw (inner and outer surface of the gums, angle of the chin). Only the sensor on the tongue tip and on the lower incisors will be considered here. The intrinsic tongue was estimated by the method proposed by Edwards (for details see Geumann 2001).
Closing and opening movements of the intrinsic tongue tip and jaw were labeled by means of the tangential velocity signal and by using a 20% threshold criterion. The intervals between the offset of the closing movement and the onset of the opening movement were defined as target intervals. Latencies were computed by subtracting specific time landmarks of the jaw movement from the time landmarks of the tongue tip movement.

Results

The following patterns could be found for loud speech compared to comfortable vocal effort:

- Initial and final /a/ were produced with lower jaw positions.
- Significantly lower positions during the consonants were found for /n/ (four speakers), /l/ (two speakers) and the alveolar oral stops (one speaker).
- All speakers increased closing and opening jaw displacements, durations and velocity peaks for all consonants.
- The consonantal target durations were not affected.
- The timing between tongue tip and jaw was not affected by volume increase during the target interval, i.e. tongue-tip jaw latencies for onset and offset of the consonantal target were stable for normal and loud speech.
- Latencies between peak velocities of the tongue tip and the jaw were reduced for the closing movement towards /s/ with the jaw reaching its velocity peak earlier than the tongue tip for three speakers. This speaks for an adjustment to the necessity of an early achievement of the jaw target for this sound.
- Latencies between peak velocities of the opening movement after /t/ increased significantly for three speakers, i.e. the jaw reached the peak velocity later relative to the peak velocity of the tongue. This readjustment of the timing of velocity peaks can be attributed to the necessary late jaw target for the stop.

Discussion

The results from this study suggest that spatial changes due to vocal effort increase only occur for the vowel /a/ and the nasal /n/, which both show in general a larger variability in their spatial targets, i.e. if the phonetic identity is not at risk. Temporal changes such as tongue-jaw latencies and durations were restricted to the movement phases whereas the consonantal target intervals were not affected by vocal effort. Closing and opening phases seem to be the domains for adapting to conflicting demands by speeding up the movement and if necessary also changing the timing between velocity peaks of the jaw and the tongue tip.