Conflicting demands of complex timing patterns in Essential Tremor patients: When the realisation of a phonological constituent breaks down

Chronic deep brain stimulation (DBS) of the nucleus ventralis intermedius (VIM) is an effective treatment for patients with medication-resistant Essential Tremor (ET). However, these patients report that the stimulation has a deleterious effect on their speech (cf. Flora et al. 2010, Mücke et al. 2014, Pützer et al. 2007). The present study investigates the articulatory timing in ET patients with and without stimulation as well as for healthy control speakers.

We recorded 12 ET patients treated with deep brain stimulation in stimulation-ON and stimulation-OFF as well as 12 age-matched healthy controls (German speakers) with a 3-D Electromagnetic Articulograph. Sensors were placed on upper and lower lips, tongue tip and tongue dorsum. We used a sentence production task and included target words varying from low to high complexity, such as <Lima> /lima/ (capital of Peru) and <Pina> /pina/ (proper name) with simple onset (CV) and <Klima> /klima/ ('climate') and <Plina> /plina/ (nonce) with complex onsets (CCV) embedded in carrier sentences such as "Er hat wieder ___ gesagt" (*'He said ___ again'*). We labelled gestural landmarks of C and V gestures, i.e. onset, peak velocity and maximum target. We analysed gestural coordination patterns within the coupling hypothesis of syllable structure (Browman & Goldstein 2000; Nam et al. 2009) and calculated the temporal intervals between the gestural onsets and targets of C and V gestures, i.e. CV lag and CC lag as well as Rightward and Leftward Shift. It is assumed that in a CV syllable C and V are coupled in-phase, leading to a simultaneous initiation of the C and the V gesture, resulting in a CV lag which is zero. In CCV syllables, where a more complex competitive coupling structure is assumed, both Cs are coupled in-phase with V and at the same time in anti-phase with each other, leading to a sequential activation of the consonantal gestures (measured in CC lag) and shift of the leftmost C away from the V and a shift of the rightmost C towards the vowel.

Results reveal that ET patients show a timing deficit in the phonetic realisation of syllables with a high level of complexity such as /kli/ and /pli/, indicating a lack of complex coupling relations (non-innate, learnt) between movements of the tongue tip, tongue dorsum and lips. Fig. 1 exemplifies the coordination pattern in /li/ (CV) versus /kli/ (CCV) for one ET patient with stimulation-ON. The figure shows the averaged trajectories (incl. repetitions) for CV and CCV; the trajectories in the display the tongue tip closure, and the trajectories below show the movement of the tongue dorsum. In /li/, the C and the V gestures show a synchronous pattern of activation, i.e. initiated at the same time (Fig. 1, left: CV lag around zero). This pattern reflects the underlying coupling structure: in CV syllables, C and V are coupled in-phase. Thus, there are no deficits in the realisation of syllables with a low level of complexity, indicating that the simple, innate pattern is still available. However, /kli/ fails to show the expected timing pattern. Due to a competitive coupling structure in CCV, there should be an activation delay between the two consonants. This is not the case, the CC lags are also around zero, i.e. the Cs are activated at the same time and thus not sequentially. This indicates that ET patients show timing deficits in realizing complex coordination structures (Fig. 1, right). In order to compensate for these deficits, the gestural activation interval for /l/ is considerably stretched (see Fig. 1: /l/ in /kli/).

The overall results reveal stimulation-induced effects on the regulation in speech motor control in ET patients. We found timing deficits in the phonetic realization of competing coupling relations for complex onsets in the ET patients. While for syllables with high complexity, a delay would have been expected between the activation of both initial C gestures in the speech of ET patients. However, both C gestures are activated at the same time. We discuss how much timing variability is tolerated in a phonological system before the system becomes instable and patterns of syllable organisation break down.

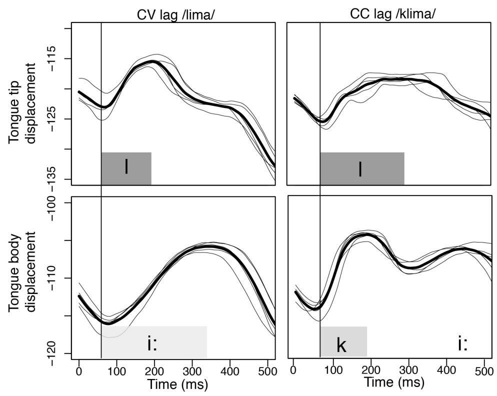

Fig. 1: Articulatory coordination patterns in /li/ (left) and /kli/ (right). Boxes display gestural activation interval.

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