Curve-to-curve distances to assess lingual articulations in the speech of Italian children who stutter and control peers

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Stuttering is a speech motor disorder that may arise from an innate limitation in the speech motor control system, which fails to prepare and organize the movements required for speech (van Lieshout et al. 2004). In this view, Stuttering-Like Disfluencies (i.e., part-word repetitions, sound prolongations and broken words; Yairi & Ambrose, 2005), the hallmark characteristics of the disorder, reflect errors in the motor control system and they ultimately represent breakdowns in the precisely timed and coordinated articulatory movements required for fluent speech. Anticipatory coarticulation and stability of speech are two critical indexes of speech motor control maturity and the purpose of the study presented here is to assess if, even during fluent speech production, stuttering children use abnormal lingual articulations compared to control peers. A number of acoustic studies, in fact, revealed atypical coarticulatory patterns in the speech of children and adults who stutter compared to non-pathological population, but with quite equivocal results (Subramanian et al., 2003; Chang et al., 2002; Robb & Blomgren 1993; Sussman et al. 2010). A close understanding of the tongue movements during speech is provided by Ultrasound Tongue Imaging (henceforth, UTI) and so far, only few studies have been realized with stuttering children. In Lenoci & Ricci (2018) for example anticipatory coarticulation was investigated through the Locus Equations metric (henceforth, LE) while, for a subset of stimuli, stability of speech movements was estimated with the Nearest Neighbor Distances (henceforth, NND; Zharkova & Hewlett, 2009). Results show different articulatory patterns for the stuttering children, for both measures under investigation.

The purpose of the study presented here is twofold: a) to extent the analyses to a larger set of stimuli and b) to assess anticipatory coarticulation in the stuttering speech by using another method, the NND, which has been proposed as a good index of contextual coarticulatory variability (Rodríguez & Recasens, 2017).

UTI and acoustic data were collected at the SMART lab of Scuola Normale Superiore, from the speech of 4 school-aged (age range: 8-12 years) CWS (2 males and 2 females) and 4 age-matched CWNS (2 males and 2 females). In a child-friendly set up, participants were involved in a sentence repetition-after-listening task in which they produced 12 repetitions of a dysillabic pseudo-word, embedded in a carrier phrase of the type: ‘La stellina C1V1ba salirà’.

Within the stressed first syllable (C1V1), C1 is /b/, /d/ or /g/ and V1 one of the three cardinal vowels, /a/, /i/ or /u/. Recordings were realized with an ultrasound system (Mindray UTI system-30 Hz) with a microconvex probe (Mindary probe 65EC10EA); the UTI images were synchronized with the audio through a synchronisation unit (Synch Bright-up unit).

A semi-automatic tongue contour splining was performed in the acoustic interval spanning from the beginning of the consonantal closure to the end of the following vowel. Each spline was then defined in terms of x,y coordinates, which were then used for comparing tongue curves. For the purposes of the study presented here, one frame within each target syllables was selected for measuring coarticulation and stability of speech: the midpoint of the consonantal closure.

Within each place of articulation, the goal of the analysis was to discover if the shape and location of the tongue curves was affected by the categories to which they belonged, for example /ba/ or /bi/ or /bu/. NND were used to estimate the degree of separation between all the curves in one category and those of the other by calculating the mean of all the Euclidean distances between each point on one curve and its nearest neighbor on the other.

The stability of speech movements is examined from the analysis of variability of multiple repetitions of the same C within the same vowel context (ex. /ba/); by contrast variability in the production across different vowel contexts (ex. /ba/ vs /bi/ vs /bu/) is taken as an index of anticipatory coarticulation (Zharkova & Hewlett, 2009).

All distances were extracted by R scripts and Nearest Neighbor Distances were determined within each individual and then used in statistical analyses of differences according to the speaking groups. A preliminary analysis shows that CWS reach fluency in their speech with different lingual patterns (i.e., higher token-to-token variability and different coarticulatory patterns) compared to controls, corroborating the hypothesis of an impaired speech motor control system for the former group. Results, in fact, suggest that CWS show tongue contours that differ in shape and location compared to controls.

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