Articulatory-to-Acoustic relations in Childhood Apraxia of Speech: Vowel production

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Speech production in childhood apraxia of speech (CAS) is characterized by impaired motor control phenomena such as errors in the production of consonants, simplifications of clusters and complex syllables, and higher than normal token-to-token variability in the absence of contextual variation ([1]; [2]; [3]). Token-to-token variability is generally measured according to acoustic parameters (e.g. [4]) or in terms of articulatory variation as determined by EMA (e.g. [5]) or UTI data ([6]; [7]). A close understanding of the acoustic and/or articulatory nature of token-to-token variability is crucial not only for rehabilitative purposes, but also for a deeper knowledge of the relation between acoustic and articulatory dimensions of variation (e.g. [8]; [9]).

The current work is an articulatory (UTI) and acoustic study of vowel production by three 10-year-old Italian CAS children and three control peers. We test the following hypotheses: (i) tongue contours from multiple repetitions of the same V target show higher variability in the speech of CAS children compared to control peers (within-category variability); (ii) tongue contours for different vowels are less distinct from each other in CAS speech (between-category distinctiveness); (iii) increased within-category variability and decreased between-category distinctiveness in tongue contours are reflected in the acoustic output (formant frequencies).

A sentence repetition-after-listening task was used to elicit the production of non-words with /a/, /i/ and /u/ as target vowels in CV syllables with /d/ as onset consonant and lexical stress on the target vowel. Each non-word was repeated eight times non-consecutively by each subject. Audio and tongue profiles were recorded via a Mindray UTI system (sampling frequency: 30 Hz) associated to a 65EC10EA microconvex transducer and a Shure unidirectional microphone. The acoustic midpoint of the vowel was chosen for both formant extraction (F1 and F2 automatic extraction through a PRAAT script followed by LPC-based manual correction, then CLIH speaker normalization, [10]) and tongue contour extraction (through semi-automatic tracker implemented in AAA v.2.16.16 by Articulate Instruments Ltd followed by manual correction). Within-category variability was assessed through Nearest Neighbor Distances (NND; [11]): each spline was converted into a set of x,y coordinates and the mean of all the Euclidean distances between each point of one curve and its nearest neighbor on a comparison curve was calculated, through an R script, for each pair of repetitions of each target vowel produced by each speaker. Between-category distinctiveness was assessed through SSANOVAs ([12]) and Bayesian confidence intervals among the three target vowels produced by each speaker. Acoustic variability was assessed by calculating the standard deviation values of non-normalized formants across the eight repetitions of a given vowel for each speaker; acoustic distinctiveness between vowels was assessed for each group (CAS and control children) by calculating the normalized F1 and F2 Euclidean distances obtained for vowel pairs /i-a/, /a-u/ (F1, Euclidean) and /i-u/ (F2, Euclidean) ([13]).

A preliminary analysis shows that hypotheses (i) and (ii) are confirmed, since CAS children show significantly higher within-phoneme variability values and less distinct tongue contours for the three vowel segments compared to control peers. Changes in lingual movements evoke partly similar changes in the acoustic vowel space (see hypothesis (iii)), particularly in the posterior region (/u/ showing a more fronted tongue profile and a higher F2 in CAS speech); Euclidean distances between pairs of vowels were also smaller for CAS children. The results will be discussed with respect to the effects of the pathophysiology on intraspeaker variability and to the articulatory-acoustic relationship.

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