

Patterns of internal syllable structuring in Childhood Apraxia of Speech

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INTRODUCTION

Childhood Apraxia of Speech (CAS) is a speech sound production disorder, which occurs in absence of dysarthria or any other apparent muscle malfunctioning, and is considered to be neurologically related (Bernthal and Bankson, 2004, p.173). The impairment in CAS causes a difficulty in enacting a planned sequence of articulatory movements, affecting the intentional implementation of a movement pattern; the praxis of speech is affected, i.e. "the ability to select, plan, organize and initiate the motor patterns" (Ayres, 1985). A definition of 'Apraxia' which considers the above-mentioned factors is given by Cray, (1984): "a group of phonological disorders resulting from disruption of central sensorimotor processes that interfere with motor learning of speech... Paralysis or weakness might be present, but is not sufficient to account for the nature and severity of the observed speech disorder".

The etiology, diagnosis and treatment for Childhood Apraxia of Speech are object of high debate, as CAS appears to be related to a wide variety of symptoms: unintelligibility, vowels misarticulations, reduced production of consonants, difficulty in sequencing phonemes in syllables, difficulty in volitional implementation of movements, inconsistent control over timing of articulatory gestures (e.g. over nasality, inconsistent voicing control), inappropriate use of intonation and stress. These characteristics are accompanied by little awareness of the errors... and very slow progress in therapy; symptoms have great variability across children, and also may change during maturation (Lewis et al., 2004; Shriberg, Campbell, et al., 2003). CAS symptoms emerge in volitional realizations of speech movements, that are otherwise correctly realized at an automatic level. All symptoms are associated with little or no weakness, paralysis or poor coordination in speech muscles, therefore, an impairment in speech motor programming is generally attributed to CAS.

Common symptoms across the apraxias are: (a) difficulties with timing and sequencing, including more difficulties with transitions between postures or states than within postures or states; (b) difficulties in combining smaller units (including units of movement) into larger wholes (c) decreased ability to accommodate to context; coarticulation rate, complexity (Velleman, 2006). The inconsistency of the errors and the impossibility to associate systematically a set of symptoms to the disorder, have generated a debate about the appropriateness to consider CAS as a diagnostic category. However, CAS is still widely considered as a useful independent category for differential diagnosis of 'developmental phonological disorders', to distinguish children which show articulation impairments but for which a neurogenic etiology is more likely than a learned one (Bernthal and Bankson, 2004).

Most acoustic studies have focused so far on AOS, showing slow speaking rate with elongations of transitions, of steady states, and of inter-syllabic pauses, at the suprasegmental level (Kent and Rosenbek, 1982; Code & Ball, 1982; Kent & Rosenbek, 1983; Ryalls, 1986; Ziegler & von Cramon, 1986; Weismer et al., 1995; Strand & McNeil, 1996; Seddoh, et al., 1998). In terms of segmental errors, the analyses have mostly concentrated on the observation of traditional phonemic units (vowels and consonants) and on consonant-vowel coarticulation.

GOAL OF THE STUDY

The present study aims at investigating processes of structuring of vocalic gestures within syllable nuclei, in Childhood Apraxia of Speech (CAS), based on acoustic analysis of speech samples obtained from 6 children out of observations on 15 CAS and 15 normal children, measured at two time points, childhood (3-7) and pre-school/ school age (8-11 years). Vowels observed were contained in lists from Goldman-Fristoe tests, and from the Multisyllabic Word Repetition tasks (Catts, 1986).

CAS children	Age in years	Normal children	Age in years	
T1	GK	3.83	DV	4
T1	MB	3.41	HS	4
T1	DS	7.11	ES	8.25
T2	GK	5.50	SB	5.58
T2	MB	7.67	BW	7.08
T2	DS	7.83	DV	8.83

Table 1 CAS and normal subjects

METHOD

Subjects and speech samples

Speech samples from six children (3 diagnosed with CAS and 3 age-matching normals) were observed at two time points, childhood (3-7) and pre-school/school age period (8-11 years). The audio material was kindly provided by Prof. Lewis. The children recruited from the previous study (Lewis et al., 2004) were diagnosed with CAS based on multiple criteria (Shriberg, Arama and Kwiatkowski, 1997a, 1997b; Stoohs, 1972; Hall et al., 1993; Ozanne, 1995); children were first diagnosed as suspected CAS by the child's speech-language pathologist, then they were tested for motor programming deficits, based on demonstration of at least four generally recognized characteristics of CAS (e.g. difficulties in sequencing phonemes and syllables, consonant deletion, inconsistency in articulation with unusual errors; Hall et al., 1973; Velleman and Strand, 1994). Low diadochokinetic rates (Total Function Score at least 2SD below the norm with respect to the mean for age proposed in the Oral and Speech Motor Control Protocol (Robbins and Klee, 1987) determined eligibility. Presence of nondevelopmental processes, as determined on the basis of the Khan-Lewis Phonological Processes analysis (KLP; Khan-Lewis, 1986) also was a criterion for selection. Finally, the diagnosis for CAS required presence of sequencing errors in the Oral and Speech Motor Control Protocol (Robbins and Klee, 1987) and in the Multisyllabic Word Repetition and Nonsense Word Repetition tasks (Catts, 1986). Also, receptive language abilities were assessed by the Test of Language Development-Primary, 2nd Edition (TOLD P-2; Newcomer and Hammill, 1988).

The normal group consists in normal siblings of the children with disorders, recruited within the genetic study (Lewis et al., 2004). Normal children were administered the same assessment battery as the CAS and the SSD children. These subjects were selected to match the CAS children by age within a 6-12 months range.

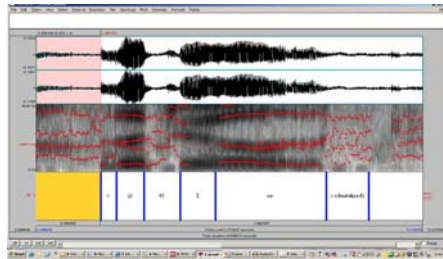


Fig. 2 Spectrogram for non word [v@:sIUs]: MB (CAS, 3:41ys) pronunciation

Analyses

The present study is based on a unique speech corpus including productions by children with childhood apraxia of speech, recorded at different time periods: childhood (3-7ys) and preschool/school age period (8-11ys); the corpus includes also productions by age-matching children in normal development. This corpus is unique, as it provides a developmental perspective on childhood apraxia of speech, allowing at the same time, a comparison with normal speech. On the other hand, the word lists recorded for the study were designed to match two different goals at the same time: to provide an accurate assessment of CAS (therefore including articulation lists, like Goldman-Fristoe, and different multisyllabic words lists), and to provide data for phonological analysis, indicating the stage of development of the child (TOLD language test, conversational speech samples). The present study intended to observe the speech corpus from a phonetic point of view; given the variety of lists administered at different time periods, and the different recording conditions, it was not possible to obtain from the speech corpus a uniform and systematic representative sample for every vowel production. Vowels have been measured, as produced in the different words available, under different stress conditions; also, not in every repetition the sample was clear enough to obtain measurable spectrograms. Therefore, only audio signals that were suitable for a spectrographic analysis have been selected for measurement. The limited number of analyzable data and the individual age-matching of the children did not allow to obtain generalizable data to compare by statistical analysis. Despite these methodological limitations, the study provides a unique perspective on development of intrasyllabic structuring of vocalic nuclei.

The original tapes were digitized at a sampling rate of 22kHz. The Praat package was used for display, playback and acoustic measurements. Wideband spectrograms were created using a black on white spectrographic display with a frequency range of 0-5kHz and a 3.5-second window. First and second formant measurements were obtained from three sources: a) from cursor frequency readouts (via mouse positioning), on the wideband spectrogram display; b) linear predictive coding (LPC) spectra; c) automatic formant tracking Praat algorithm (see Figs. 1 and 2). F1 and F2 measurements and F2/F1 ratio values were calculated for the vowels [E I O ae], for all children at different time points (see Tables 2 and 3).

RESULTS

F2/F1 ratio analysis

Children F2/F1 ratio data have been compared within time periods and between CAS and normal age-matching pairs; the results are reported in Tables 2 and 3, showing, at T1, similar patterns within CAS children for vowels [E] and [I]; [E] and [O] patterns are similar between CAS and normal children, whereas F2/F1 ratio values generally differ between CAS and normal children for [I] and [ae]. At T2 there is more intersubject variability among the CAS children, and also a greater difference between CAS and normal patterns. Similar tendencies are found in the F2/F1 plots for vowels by CAS vs. normal children at T1 and at T2 (Fig. 3). A preliminary comparison between available data for one CAS and one age-matching normal child, in pronunciation of nonwords, provides introductory evidence for consistency between CAS and normal articulation at age 7ys (Table 4).

T1	CAS1-GK	normal1-DV	CAS2-MB	normal2-DS	CAS3-DS	normal3-ES
E	4.6	3.5	3.4	2.5	3.5	3.8
I	3.8	3.2	4.5	3.8	4.6	4.3
O	2.4	2.4	2	2	1.8	1.8
ae	2.8	2.2	2.6	3.6	2.3	2.8

T2	CAS1-GK	normal1-BB	CAS2-MB	normal2-BW	CAS3-DS	normal3-DV
E	4.7	3	2.7	2.6	3.6	3.2
I	2.6	5.2	3.6	3.6	3.1	4
O	2.1	1.7	1.6	2.2	1.8	2.3
ae	3.4	2.8	2.7	2.4	3	3.8

Tables 2 and 3. Average F2/F1 ratios for CAS vs. age-matching normal children at two time points, childhood (3-7ys) and preschool-school age period (8-11ys)

Vowel/ F2/F1 ratio	MB (CAS) - T2	BW (normal) - T2
D	1.7	1.6
ae	2.5	2.4

Table 4. Average F2/F1 ratios for a CAS vs. an age-matching normal child at T2 from non-word repetitions

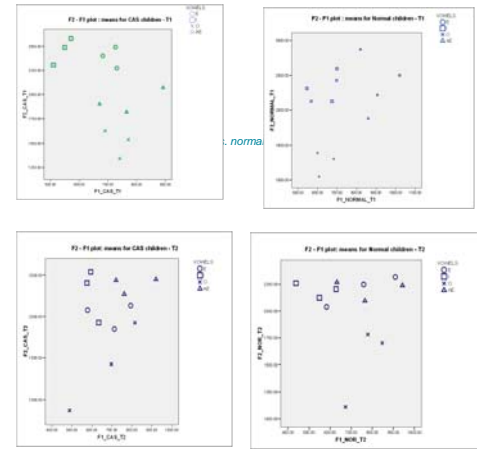


Fig. 3 Vowels space for CAS vs. normal children at T2 (8-11ys)

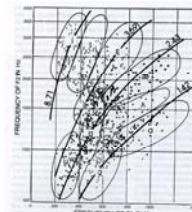


Fig. 4 F1-F2 plot for American vowels produced by 76 speakers (33 men, 28 women and 15 children) (from Peterson and Barney, 1952)

A comparison between vowel spaces at T1, based on F2/F1 plots (Fig. 3), reveals a trend in CAS children, who show consistent patterns, similar to target normal spaces (as compared with the reference formant chart for American vowels in Fig. 4, from Peterson and Barney, 1952) for all vowels. On the contrary, normal children, at the same age, show an overlapping space for vowels [E I ae] and a more consistent and accurate production of [O], with respect to target normal spaces and to CAS. At T2, however, for CAS children, the [E I ae] spaces show complete overlapping with no apparent concentration, indicating an indistinct use of the three different tongue configurations, to achieve the target [E I ae] vowels. The T2 formant space for normal children, on the other hand, shows a rearrangement in the sense of separation of vowels [E I ae] towards the target pattern.

CONCLUSIONS

The preliminary results from this study indicate that intrasyllabic vocalic gestures structuring may emerge in CAS children at childhood (3-7ys of age) following a normal development pattern, but that, at the following age stage, maybe in connection with acquisition of more complex intersegmental coordination patterns, involving different vowels and consonants, the vocalic tongue movements do not appear to be clearly distinct and to overlap. In normal children, an opposite pattern was observed, with a generic front vowel space emerging at childhood, that separates towards more specialized articulatory target areas for front and more central phones later, at the preschool/school age period. Preliminary data on nonwords production show similar trends between CAS and normal children at age 7ys, possibly indicating that development of speech production proceeds by different steps from acquisition of nonspeech movements.

A more systematic analysis of different vowels in controlled phonotactic and stress contexts, would be necessary to clarify whether the patterns described in the present study can be generalized across CAS children at different age stages. Also, kinematic studies on CAS would contribute to provide decisive evidence about gestures coordination within syllable nuclei.

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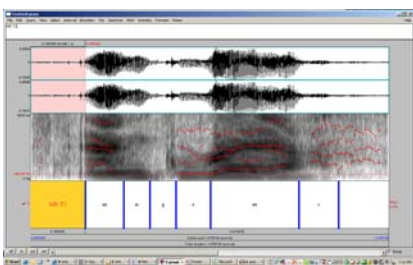


Fig. 1 Spectrogram for phrase 'and grass': MB (CAS, 7:67ys) pronunciation