

Speech production in Italian vs. English children with Childhood Apraxia of Speech: an acoustic longitudinal study

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RESEARCH QUESTIONS

The study aims at investigating speech production characteristics in children affected by Childhood Apraxia of Speech (CAS).

I QUESTION: Does the disruption of speech production mechanisms in CAS affect the structuring of a general speech motor control plan or does it affect transmission of the general speech motor plan to the articulators?

It was hypothesized that an impairment at the level of the general speech motor control plan would generate similar errors across languages (Schmitz, 1995); on the other hand, different errors between languages were hypothesized to indicate disruption of language-dependent parameters, possibly implemented during transmission of the general speech motor plan to the articulators (Klapp, 2002).

✦ In order to test the hypothesis that impairment in CAS occurs at the level of the general speech motor plan, vowels produced by CAS children speaking English vs. Italian was compared, to assess whether similar error patterns would be found across the two languages.

METHOD

In particular, the similarities between the two languages have been tested on three dimensions of description of speech production in CAS: a) CAS errors in speech vs. non-speech productions or errors typical of CAS with respect to other speech sound disorders b) CAS errors at different age stages. Each of these three dimensions is described by open questions and hypotheses, that were tested in the present study, in the Italian and English children samples. The questions are described in the following:

II QUESTION: Are the errors by CAS children typical of speech productions, or do CAS children show similar errors in words vs. nonwords?

✦ In order to test whether speech-specific errors occur in pronunciations by CAS children, vowels produced in words vs. nonwords by English and Italian children with CAS were compared, to assess whether similar error patterns in speech vs. non-speech would be found across the two languages. If similar error patterns were found in words and non-words, the results would indicate that the impairment in word production in CAS was possibly not typical of speech motor control.

III QUESTION: Are errors by CAS children similar to errors by children affected by other speech disorders, or are they typical of CAS?

✦ In order to determine whether the errors by the CAS children were typical of this disorder, productions by children with CAS were compared with productions by children with Speech Sound Disorders (SSD) and by normal children (N).

IV QUESTION: Is it possible to identify errors typical of different stages of development of CAS?

✦ In order to determine whether it is possible to identify time stamps in development of CAS, errors in vowel production by CAS children were compared at two age stages: childhood (4-6y) and school-age (7-12y).

Acquisition of vowel production was considered as indicative of progress in internal structuring of motor patterns within syllables, and in acquisition of correct syllable sequencing. Difficulties with timing and sequencing of phonetic units, as well as difficulties in combination of smaller units (e.g. syllables) within large utterances and decreased ability to adapt to context and to master coarticulation (Velleman, 2003) are common symptoms of Childhood Apraxia of Speech; the present study aimed at shedding some light on the process of internal structuring of "units of movements", or syllables, considered as a typical stage in acquisition of the motor programming skills (Klapp, 2002), across languages.

ENGLISH		ITALIAN	
Language tests	TOLD-3 Up to 12 yrs	Expressive language: D) Multiple-answers: TAI, 30 to 71 months (20x to 60x Italian standard) E) Boston Naming Test (50x to 110x)	
		Receptive language: 1) RUSTIDE (Morphological-lexical awareness) test: normalized, from 3.0 to 6y 2) Peabody Vocabulary Test (3.0 to 12y)	
Oral-motor test	Oral-motor-Test 2	Exame Prassie	
Articulatory tests	Goldman-Fristoe 2 FUSI (for adults, but applied to children) (includes dis. Test)	FUSI (see above, includes diadochokinetic Test)	
Diadochokinetic test	Fluency	Exame Prassie2 FUSI (see above, includes diadochokinetic Test)	

Table 1. Comparison of assessment tests administered to Italian and to English children for initial diagnosis

English children

English children had been recruited within a previous study (Lewis et al., 2004), and they were diagnosed with CAS based on multiple criteria (Sriberg, Arama and Kwakowski, 1997a, 1997b). The normal group consisted in siblings of the children with disorders, also previously recruited (Lewis et al., 2004). Normal children were administered same assessment battery as the CAS and the SSD children.

12 English children: 4 diagnosed with CAS, 4 diagnosed with SSD, and 4 age-matching normals. The CAS and SSD children were recorded at two age stages, childhood (4-6y) and school age period (7-12 years), and normal children (4) samples were selected to match each of the CAS and SSD children's ages (see Table 2).

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 (Sriberg, Arama and Kwakowski, 1997a, 1997b, Zachackow, 1972, Hall et al., 1993, Ozanne, 1995) (see Table 1 for test battery).

Italian children

4 subjects diagnosed with CAS, 4 diagnosed with SSD, and 4 age-matching normals, were selected. Different children were recorded at the two age stages, childhood (4-6y) and school age period (7-12 years), and normal children were not related by family connections to the children with disorders. This selection criterion was adopted because the aim of the present study was to identify properties in speech production typical of those administered to study genetic factors related to the emergence of CAS (main focus of the English study).

Italian children were diagnosed with CAS and SSD, based on a battery of tests comparable with those administered to diagnose the English children (see Table 1): for language assessment, the Peabody receptive language test for syntactic and lexical components, as well as the Rustion screening test, the Boston naming test, and the TAI, morpho-phonetic expressive language test were administered; also, the children were evaluated by an articulatory test (Fusi-Cantagalli) and an oro-motor test (Exame prassie), both including a diadochokinetic test.

ITALIAN CHILDREN		ENGLISH CHILDREN	
CAS	4	4	4
SSD	4	4	4
Normal	4	4	4
Childhood	4	4	4
School age	4	4	4

Table 2. Italian and English children

Speech corpus and recordings

Speech samples used to evaluate speech production for the English children included mono- and multisyllabic words, obtained by elicitation in a Goldman-Fristoe test, and multisyllabic non-words, elicited during the same recording session (Lewis et al., 2004). For Italian children, the speech samples included both words and non-words, elicited within different carrier phrases, from a corpus created ad hoc for the experiment. Samples were not recorded from the assessment tests, also for the English children. Also, for Italian children, assessment tests were administered to all children in a separate session, while the recordings of the words for the present experiments were obtained during normal therapy sessions.

The observed words had different syllable structures in English (mostly CV), with complex onsets and codas) and in Italian (mostly CV(C)VC), reflecting frequency of occurrence of syllables types in the different languages.

Also words and non-words in the Italian corpus were selected ad hoc, to contain the following vowels: [e, o, a, u] in first and second syllable. The consonants in the Italian corpus were the following: [h, d, r, v, k, g, l, b, p]. English samples were selected from the Goldman-Fristoe articulatory test and from the multisyllabic words and nonwords repetitions test used for assessment (Katz, 1986).

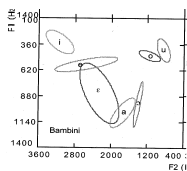


Fig. 1 F1-F2 spaces for Italian vowels produced by children B-12yr (from Zmarich and Bonficio, 2003) and American vowels produced by 76 speakers, including children (33 men, 28 women and 15 children) (from Peterson and Barney, 1992)

WORDID	Vowels	e	eh	a	oh	o	NONWORD S	Vowels	e	eh	a	oh	o
Disorder	Disorder						Disorder	Disorder					
CAS	TD/Childhood	3.9	3.9	1.5	1.9	2.01	CAS	TD/Childhood	3.9	3.5	1.8	1.9	2.1
	FS/Childhood	4.7	2.9	2.03	1.9	2.5		FS/Childhood	4.2	2.5	2.1	1.9	2.4
	GI/School age	3.9	3.5	1.5	2.1	2.1		GI/School age	4.3	3.9	1.9	1.9	2.2
	LMF/School age	4.6	-	3.4	2.6	2.6		LMF/School age	4.4	4.03	1.8	2.3	2.5
SSD	SA/Childhood	4	2.4	2.1	2	2.4	SSD	SA/Childhood	3.9	2.9	2.2	1.7	2.1
	PF/Childhood	4.5	2.4	2.1	1.9	2.4		PF/Childhood	3.8	2.4	1.8	1.5	2.3
	IE/School age	3.9	3.5	1.5	2.1	2.1		IE/School age	3.9	3.3	2	2.2	2.1
	MC/School age	4.9	3.4	2.5	2.3	2.6		MC/School age	4.8	4.9	1.8	2	2.2
	LMF/School age	4.6	-	3.4	2.6	2.6		LMF/School age	4.4	4.03	1.8	2.3	2.5
Normal	SA/Childhood	3.9	3.4	2.03	1.6	1.9	Normal	SA/Childhood	3.9	2.8	2.2	1.9	2.1
	PF/Childhood	4.2	2.3	1.8	1.3	2.6		PF/Childhood	3.9	2.8	2.2	1.9	2.1
	IE/School age	3.2	2.9	1.6	2.1	2.5		IE/School age	3.9	4.6	3.4	1.8	2.3
	BS/School age	3.9	3.9	2.1	2.1	2.5		BS/School age	3.9	3.7	1.7	1.6	2.4

Table 3 F2/F1 ratio values for Italian children with CAS, SSD and in typical development, in Words and Nonwords pronunciations

Fig 1 F1-F2 chart for children with CAS, SSD and no disorder

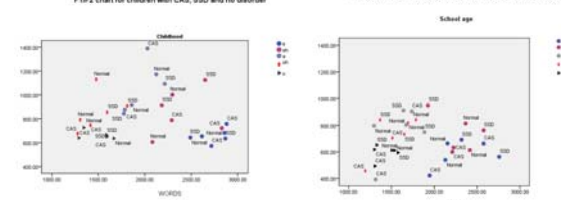


Fig. 2 Formant charts for Italian children with CAS, SSD and in typical development, at Childhood and School Age, obtained from Words pronunciations

Fig 2 F1-F2 chart for Italian children with CAS, SSD and no disorder

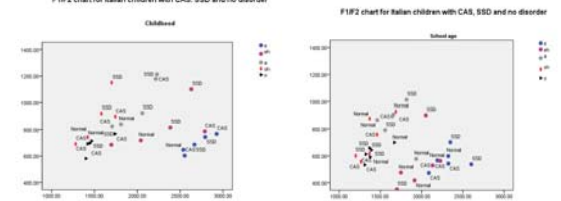


Fig. 3 Formant charts for Italian children with CAS, SSD and in typical development, at Childhood and School Age, obtained from Non-Words pronunciations

Data analysis

For the present study F1 and F2 values were calculated for the vowels [e, o, a, u] in Italian CAS, SSD and normal children speech. The measurement of the center of the formants was performed based on wideband spectrograms, by Praat software. The filter bandwidth for the wideband spectrograms, was expressed in Praat by the duration in time constant of the filter instead of Hz: the time constant selected was 3ms, a value which seemed to be revealing of all characteristics of the children's formants. 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.

Reference values for Italian vowels produced by Italian children of age 8-12yr (Zmarich and Bonficio, 2003), are reported in reference 2, as well as reference formants for American English vowels (Peterson and Barney, 1992).

RESULTS

I QUESTION: Does the disruption of speech production mechanisms in CAS affect the structuring of a general speech motor control plan or does it affect transmission of the general speech motor plan to the articulators?

For word production, CAS pronunciations by English children were matching the normal productions of age-matching children at T1, whereas at T2, the central front timbers (E, I, A) would overlap.

In Italian children a somehow similar trend was found, where in realizations at T1, all qualities seemed to correspond to normal targets, except for [O], however, at T2, F2 in [E] would be off, as well as F1 of [a] and the whole [O]. [a] and [E] showed overlap, as found for the English children at same age. In particular, it seems that the problem affects F1 of low-mid vowels, seeming to indicate an incorrect control of placement of the tongue in the height dimension. This trend is confirmed by pronunciation of [E] in non-words, where an incorrect F1 occurred. However, the realizations of non-words are generally much more accurate than the words pronunciations, but intermediate timbers [E] and [O] seem to overlap on more extreme vowels [a] and [o] respectively.

II QUESTION: Are the errors by CAS children typical of speech productions, or do CAS children show similar errors in words vs. nonwords?

Italian children showed both from the formant ratio analysis and from the vowel spaces, a more stable behavior in pronunciation of non-words with respect to words. This was also data in CAS children showed stability across speakers and across ages similar to SSD and Normal children, in production of non-words. On the other hand, children with CAS showed variability across speakers and ages in word tasks; a similar but less evident variability was found in SSD children, whereas more stable patterns were found for normal children, especially at School Age.

Similar results were found for CAS English children, who matched the normal F2/F1 ratio for production of vowels in non-words, in production of words, on the other hand, the CAS differed consistently from Normal across subjects and ages. Vowel spaces for non-words in Italian children, also show clustering of vowels by Normal, SSD and CAS speakers, but scattering in CAS pronunciations, for words productions.

III QUESTION: Are errors by CAS children similar to errors by children affected by other speech disorders, or are they typical of CAS?

Both in English and in Italian, the SSD children did not show marked differences from CAS, although CAS pronunciations seemed to deviate more from the normal productions, both in terms of F2/F1 ratio, and in terms of dispersion of the vowel spaces.

IV QUESTION: Is it possible to identify errors typical of different stages of development of CAS?

The overall pattern of distribution of the vowels in the formant space did not seem to change across ages for the CAS Italian children. The normal children, characterized especially the central-front vowels [a] and [E], which did not appear to be realized consistently across ages, in word productions. The same trend appears in the normal children's distributions were found across ages (for discussion about different patterns in words vs. non-words, see Question II).

DISCUSSION

The general trend observed in the comparison of vowels production between English and Italian children with CAS, seems to show that similar patterns of distortion of target pronunciations exist, both in the structuring of the vowel space through the age periods, and in the placement of the tongue for the single vowels, represented by the F2/F1 ratio. Such trends seem to provide some evidence to support the hypothesis that disruption involved in CAS might affect the structuring of a general speech motor control plan.

Also, more adequate pronunciations patterns found in production of non-words with respect to vowels spaces for words, across subjects and ages, might lead to hypothesize that disruption in CAS is connected in some way with speech-specific motor control mechanisms.

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