

Instability of speech production as a marker of Childhood Apraxia of Speech (CAS): segmental and acoustic evidence

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INTRODUCTION: Childhood Apraxia of Speech (CAS) is a neurogenic Speech Sound Disorder (SSD; DSM-V, APA 2013) whose etiology and neurobiological correlates are still unclear. According to ASHA (2007), CAS is “a neurological childhood disorder in which the precision and consistency of movements underlying speech are impaired in the absence of neuromuscular deficits”, a speech motor disorder whose core deficit involves the planning and/or programming of the spatiotemporal parameters of movement sequences (Terband & Maassen, 2010). From a segmental point of view, CAS subjects often produce a reduced phonetic inventory than expected for their chronological age, and the production is often characterized by inaccuracy in the realization of speech sequences, resulting in phonemes omissions, additions, substitutions and distortions that frequently make the speech unintelligible. The speed of articulation, measured in number of syllables per second is significantly slower than their peers (Chilosi et al., 2015). CAS subjects may also present several markers of morphological and syntactic disorders. Syntactic structures suffer from the limitations of the vocabulary so that CAS children tend to produce sentences of less than average length and with a simpler grammatical structure compared to their peers (Chilosi et al., 2015). It has been hypothesized that the small vocabularies of children with CAS have an upstream impact on the cognitive-linguistic aspects of phonology (Velleman, 2011). Acoustic analysis of CAS speech production revealed reduced distinctiveness in intra-syllabic (CV) coarticulatory extent across stop place categories, as indexed by Locus Equation method and less adultlike LE form (Sussman et al., 2000).

METHOD: Three subjects (11 and 10.4 yrs, female; 8.3 yrs, male) were reported by clinicians as affected by CAS. The first one (GE) presented a lexicon comprehension level slightly under the chronological age (PPVT, Stella et al., 2000), while the verbal production showed a serious deficit. Morphosyntax was seriously under the standard scores both for comprehension (TCGB, Chilosi e Cipriani, 1995) and production (Rustioni et al., 2007). The scores of the oral- facial movement`s test showed that also this area was seriously affected, with more difficulty on performing praxias in imitating than doing them on request (Bearzotti e Fabbro, 2003). The Phonological Working Memory (PWM) couldn't go over the two elements (VAUMeLF test, Bertelli e Bilancia, 2008). The second subject (RoA) presented a lexicon comprehension level under the standard scores (PPVT), while the production showed a serious deficit. Morphosyntax was seriously below the standard scores both for comprehension (TCGB) and production (Rustioni et al., 2007). The scores at the oral- facial praxias test (Bearzotti e Fabbro, 2003) revealed this area to be seriously affected, with more difficulty on performing praxias on imitation than on request. The PWM scored 1 (very low). Articulatory diadochokinesis was also severely impaired (Williams & Stackhouse, 1998). The third subject (DO) presented lexicon and morphosyntax comprehension levels under the standard scores (PPVT, TROG-2). The scores of the oral-facial movement's test showed a difficulty in performing praxias, particularly on request than on imitation (Bearzotti e Fabbro, 2003). Articulatory diadochokinesis was also severely affected. The PWM was limited to two elements (VAUMeLF test). The aim of the present study is to verify whether the extreme variability in the production of the very same linguistic unit (word or syllable) be a marker of CAS.. Consequently, we devised to engage the subjects in multiple productions of the same linguistic units, and then we analyzed the recorded signals by different metrics (both segmental and acoustic), chosen among the most sensitive to track variability, in order to assess the consistency and stability of the CAS subjects.

The subjects were administered the Italian version of CDI (Caselli et al., 2007), which allowed us to calculate the lexical age, based on total words produced according to their parents, the socio-linguistic questionnaire, which reported basic information about psycho-physiological and linguistic development of the subject etc., and the TPF1, a new phonetic test not yet published (see Zmarich et al., 2012). The TPF1 form appropriate for subjects aged 25-47 months was chosen, which includes 78 figures to be named by subjects, which performed the TPF1 three times in the same day. According to CDI, subjects resulted to have a relatively restricted lexicon (GE: 623 words; RoA: 464; DO: 617). Control subjects were recruited according to different criteria. A first group of typical developing children, scoring the same number of words at CDI, were recruited ("lexical age" peers). Adding to these, in order to make the comparison more complete, 3 typical developing children having the same chronological ages of the CAS subjects ("chronological age" peers), and 3 adult subjects (considered as the reference model for the developing children) were chosen. Finally, after phonetic transcription and digital coding (by means of PRAAT and PHON), the data were analysed.

RESULTS. The results we present come from Rancan (2015), which compared the segmental productions of two CAS subjects (GE and RoA) with those of the "lexical age" peers, on a number of phonetic-phonological measures (phonetic inventory, error analysis) and from Raccanelli (2016), which added another CAS subject (DO) and analyzed the productions on a number of acoustic measures (VOT and degrees of intra-syllabic coarticulation, calculated by means of LE equation method, see Sussman et al., 2000). In the last work, CAS subjects were compared also to adults "chronological age" peers and "lexical age" peers. According to segmental analysis, the speech production of GE and RoA sounds scarcely fluent and is affected by a wide range of error processes. In line with the literature findings, multiple productions of the same speech target are phonologically inconsistent and the subjects present a difficulty in combining phones in syllables and syllables in words. Percentage of errors increase together with length and complexity of words. Speech is characterized by widespread abnormalities on different levels, in rhythm as well as in stress allocation, and reveals a tendency towards omission of weak syllables. The subjects have an incomplete and atypical phonetic inventory, since they have not yet acquired consonants normally mastered since 24-32 months of age. Results relative to the acoustic analysis of VOT show a difficulty in producing voice for CAS subject and the "lexical age" peers. RoA is not able to produce voicing contrast at all. As to the analysis of intra-syllabic CV coarticulation, CAS subjects and "lexical age" peers have similar coefficients of coarticulation and they are significantly different from the "chronological age" peers and adults, suggesting that CAS children could have an immature speech motor control (like that of 2- or 3-years-old children). Anyway, we didn't find CAS children to be significantly different from controls, as to intra-individual variability among multiple productions, as initially hypothesized.

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