Inappropriate Resonance: Possible Marker of Childhood Apraxia of Speech

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INTRODUCTION

- Classic and contemporary studies of suspected developmental apraxia of speech (sAOS) [also termed Childhood Apraxia of Speech (CAS)] suggest that inconsistent resonance or oral-nasal gestures perceived as *nasopharyngeal resonance* (Shriberg, Kwiatkowski, & Rasmussen, 1990) may be a descriptive feature of at least some expressions of this putative disorder.
- In a descriptive-explanatory study, Odell and Shriberg (2001) compared prosody-voice characteristics in adults with acquired AOS to prosody-voice characteristics of children with sAOS. Among other prosody-voice findings, adults with AOS did not have the resonance difference observed in sAOS participants.
- Assessment of nasal resonance may be optimally sensitive and reliable when accomplished with acoustic rather than perceptual methods. In an acoustic analysis of participants with hearing impairment versus typical-hearing controls, Chen (1995) reported that the prominence of an extra peak in the vicinity of 1000 Hz and widening of the first formant bandwidth were significant acoustic cues for the nasalization of vowels. Additionally, the amplitude difference between A1 (amplitude of the first formant) and P1 (normalized amplitude of the extra peak) was found to be relevant because it is equivalent to the amount of separation between the nasal pole and zero. Chen's findings suggested that A1 – P1 values below 10 dB are sensitive to perceived nasality, provided a speaker's vowel has an F1 sufficiently lower than the extra peak introduced by oral-nasal coupling.

Questions

- The goal of the present study is to assess the potential diagnostic value of Chen's metric as an acoustic correlate of perceived inappropriate nasal resonance. Two questions are posed:
  1. Is Chen's metric sensitive to assimilative nasality in speakers with typical and atypical speech acquisition?
  2. If the answer to Question 1 is in the affirmative, how well do the values from Chen's metric agree with perceptual classifications of inappropriate resonance in two groups of atypical speakers?

METHODS

Participants

- Audiocassette recordings of conversational speech samples and accompanying case records for 47 children were selected from a database (The Phonology Project, Waisman Center, Madison, WI).
- The 21 children with sAOS (Groups 3 and 4), are a subset of the 24 reported in Shriberg, Campbell, Karlsson, Brown, McSweeny, & Nadler (2003) and Shriberg, Green, Campbell, McSweeny, & Scheer (2003). Three participants with equivocal classification status or who were older than 9 years were not studied. Speech Delay (SD) was classified using procedures described in Shriberg, Austin, Lewis, McSweeny, & Wilson (1997b).
- **Table 1** includes descriptive information for the 47 children divided into five subgroups. As shown, the five groups differed on speaker status and resonance status as evaluated perceptually.

Table 1. *Summary of descriptive data for children in five participant groups.*

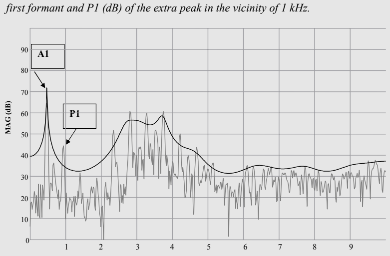
No.	Group	*n*	Age (months) *M*	Age (months) *SD*	Age (months) *Range*	Sex % Male	Sex % Female
1	Speech Delay (SD) and perceptually appropriate resonance (SD_R-)[a]	10	71.6	26.0	37 - 114	50%	50%
2	Speech Delay (SD) and perceptually inappropriate resonance (SD_R+)[b]	6	61.5	24.6	39 - 106	50%	50%
3	Suspected Apraxia of Speech (sAOS) and perceptually appropriate resonance (sAOS_R-)[a]	11	71.6	24.5	39 - 119	91%	9%
4	Suspected Apraxia of Speech (sAOS) and perceptually inappropriate resonance (sAOS_R+)[b]	10	79.3	21.3	44 - 116	100%	0%
5	Normal Speech Acquisition and perceptually normal resonance (NSA_R-)[a]	10	71.6	18.5	39 - 106	50%	50%
Total		47	72.0	22.6	37 - 119	70%	30%

[a] Speakers whose resonance was classified as appropriate or unaffected (R-) had appropriate resonance on at least 80% of their utterances.
[b] Speakers whose resonance was classified as inappropriate or affected (R+) had appropriate resonance on fewer than 80% of their utterances.

Acoustic Measures

- A Kay Elemetrics CSL 4300B system fed by a Tascam 112MKH tape deck was used to digitize participants' conversation at a sampling rate of 20K and to provide spectrographic displays of the conversational speech samples.
- TF32 (Milenkovic, 2001) was used to display Fast Fourier Transform (FFT) and Linear Predictive Coding (LPC) spectra for a 30 msec window centered at the temporal middle of each vowel. The amplitude of F1 was taken from the LPC spectrum and the amplitude of the extra peak, in the vicinity of 1 kHz, from the FFT spectrum. Chen's metric is the difference between the two amplitudes (see Figure 1).

Figure 1. *Example of Chen's method for vowel /i/. Note the A1 (dB) of the first formant and P1 (dB) of the extra peak in the vicinity of 1 kHz.*



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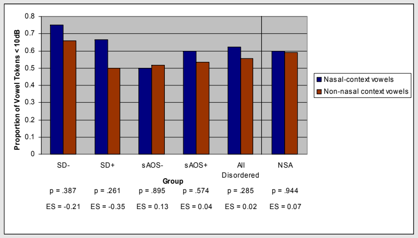
RESULTS AND DISCUSSION

Question 1: Is Chen's metric sensitive to assimilative nasality in speakers with typical and atypical speech acquisition?
Answer: In this study, it does not appear to be.

Findings

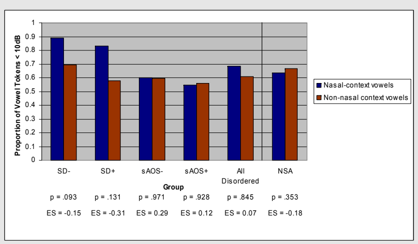
- **Figure 2** is a summary of the proportions of nasal context vowels and non-nasal context vowels in the five participant groups quantified as less than 10 dB on Chen's metric of nasality.
- As shown, none of the between-context comparisons of tokens meeting Chen's criteria for nasality (A1 – P1 < 10 dB) were statistically significant; moreover, effect sizes for each comparison ranged from negligible to small (Cohen, 1988). For each between-context comparison, approximately one-half of the nasal-context vowels met Chen's criteria for nasality; however, one-half of the non-nasal context vowels also met this criteria.

Figure 2. *The proportion of nasal context versus non-nasal context vowels in the five participant groups meeting Chen's metric of nasality.*



- Methodological features of Chen's study may have limited the findings in Figure 2 (high vowels were not included in Chen's study). Analysis of the present data yielded a significant (p = 0.012) difference on the Chen metric for high vowel /ɪ/ compared to the low vowel /ɑ/. Therefore, an extended analysis of the present vowel data was completed.
- **Figure 3** provides a summary of the data analyzed similarly to Figure 2, but limited to mid and low vowels. As shown, none of the within-group comparisons of tokens meeting Chen's criteria for nasality (A1 – P1 < 10 dB) were statistically significant. None of the comparisons differed statistically; excepting the small effect sizes for two within-group comparisons, effect sizes were negligible.

Figure 3. *The proportion of nasal context versus non-nasal context vowels (mid and low vowels only) in the five participant groups meeting Chen's metric of nasality.*



- A GLM ANOVA was completed on all non-nasal context vowels (there were insufficient numbers of nasal context vowels) treating Chen's metric as a continuous variable. Neither the Group nor the Group x Vowel Type interaction was significant. However, a series of 2-sample t-tests to assess nasal context vs. non-nasal context vowels within and between all groups yielded two significant comparisons for the non-nasal context vowel analyses: the SD+ group had a higher proportion of all non-nasal context vowels meeting Chen's < 10 dB criteria than the SD- group (p = .025) and the SD- group had a higher proportion of all non-nasal vowels than the NSA group (p = .041). These findings may have been influenced by an imbalance in the types of specific vowel tokens available in each group.

RESULTS AND DISCUSSION (continued)

Discussion/Implications:

- Chen's (1995) primary finding was that utterances judged to be highly nasal (average judgment of 6 – 8 on a 9-point scale) have an A1 – P1 value of less than 10 dB. As shown in Figures 2 and 3 above, this metric did not differentiate assimilative nasality as assessed in the present study. It is useful to consider methodological aspects of both studies towards the goal of finding an acoustic correlate of resonance that may eventually be used in studies of sAOS.
  - ➢ Nasality: the first order correlation between the acoustic parameter of A1 – P1 and the average nasality judgment in Chen (1995) was –0.82. According to Chen (1995), such a high coefficient may have been ". . . due to the fact that the listeners were trained in perceiving nasality and that they were allowed to repeat stimuli and discuss their discrepancies" (pg. 2453). The present study explored whether the Chen metric would be sensitive to assimilative nasality in typical and atypical speakers. Findings did not support an affirmative answer. Note that in English, nasal-context vowels are apparently produced with a smaller velopharyngeal opening (compared to a language such as French in which vowels are often heavily nasalized), and may be influenced by individual differences (Stevens, 1999).
  - ➢ Resonance: a second methodological issue addresses the need for an acoustic correlate of the nasopharyngeal resonance described for some children with sAOS in Shriberg et al. (1997b, 1997c). This construct is not sufficiently reliable perceptually, but it is possible that it can be captured using acoustic measures of nasality, such as the Chen metric studied in the present paper. Within the methodological constraints of the present study as described here, the Chen metric did not discriminate either assimilative nasality or the resonance of children in the two disorder groups classified as having frequent nasopharyngeal resonance on vowels.
  - ➢ Participant age: Chen's study included both children and adults. Participants ranged in age from 11 to 17 years for the four hearing-impaired children, 13 to 15 years for the three normal-hearing children, and 25 to 45 years for the four normal-hearing adult speakers. The current study included participants ranging in age from three to ten years. Often for women and children's voices, the filter bandwidth corresponds with the harmonic interval resulting in harmonic-formant interaction (Kent and Read, 1992). In the current study, this interaction was resolved by increasing the analyzing bandwidth during acoustic analysis.
  - ➢ Number of participants and tokens: in Chen's study, a total of 20 tokens for the four hearing impaired participants and 18 vowels for the three normal-hearing children were analyzed, in addition to 24 nasal context vowels for the four normal-hearing adult speakers. In the present study 564 non-nasal context vowels and 94 nasal context vowels were analyzed across 47 participants in five participant groups.

Question 2: If the answer for Question 1 is in the affirmative, how well does Chen's measure agree with perceptual classifications of inappropriate resonance in atypical speakers?

- Although the answer to Question 1 is not in the affirmative, contemporary studies of sAOS cited previously continue to find some type of inappropriate resonance in speakers with sAOS as reported in earlier studies (e.g., Bowman, Parsons, & Morris, 1984; Dabul, 1971; Parsons, 1984; Trost-Cardamone, 1986; Yoss & Darley, 1974a). Among other needs, future research to address this question more broadly should:
  - ➢ Continue to attempt to refine the type of aberrant resonance (e.g. hypernasality, hyponasality, nasopharyngeal resonance) observed in children with mild, moderate, and severe expressions of sAOS.
  - ➢ Continue to attempt to identify alternative acoustic metrics of relevant subtypes of inappropriate nasal resonance.
  - ➢ Develop methods whereby perceptual procedures to identify inappropriate resonance can be aided by acoustic procedures (i.e., acoustic-aided prosody-voice analyses).
  - ➢ Combine acoustic-aided identification of inappropriate nasal resonance in sAOS with visualization procedures to describe possible structural and/or functional aspects of velopharyngeal port movements and their possible neurodevelopmental correlates.

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