Development of temporal and spectral characteristics in the speech of hearing impaired preschoolers

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Conclusions

1. Vowel duration and articulation space are independently controlled in speech production. Early-identified children performed more like normal hearing children than did their later-identified peers on both measures.

2. Shorter vowel durations and smaller vowel production areas in early-identified HI children and NH children are consistent with previous reports. With respect to vowel area, three of four subjects were cochlear implant users (S22 was a hearing aid user), and it is possible that cochlear implant use correlates with improved production space characteristics (i.e., a smaller vowel area). This possibility is supported by the single-subject report of a CI user by ErTmer (2001). Early-ID and cochlear implantation are interacting factors determining auditory experience, though the nature and degree of this interaction is as yet unclear.

3. Early-identified/CI children performed more like normal hearing children than their later-identified peers, despite having greater degrees of hearing loss (early-ID children had profound hearing loss, late-ID children had mild-to-moderate hearing loss). Early-identified/CI children were also provided with early intervention—three of four received cochlear implants—which could help explain this effect.

4. Extended vowel duration in certain populations could impact aspects of speech production (e.g., coarticulation and intelligibility). A better understanding of outcomes could lead to improved clinical intervention in late-identified hearing impaired populations, especially with vowels (not typically a focus in clinical speech-language pathology). Future work could profitably contribute to this understudied area.

Main Point

The development of temporal and spectral speech properties of hearing impaired (HI) children is not fully understood, particularly in children with early- versus late-identified hearing impairment. Results from this longitudinal study (a) document development of vowel production and (b) indicate a speech production advantage for children with early-identified hearing loss. We offer a few possible directions to improve understanding and linguistic outcomes in 4- and 5-year olds with hearing impairment.

Background

Vowels are central to speech production and speech intelligibility (Peterson & Barney 1952, Fant 1960, H finsbrand et al 1995, Neal 2008). Sensitivity to the durational and spectral features of vowels has been shown in newborns (Elmas et al 1971, Aldridge et al 2001), and continues to develop until puberty or later (Lee et al 1999). Development of vowel production in children is generally toward shorter durations and low- extreme formant valuses (Lee et al 1999, Vorpian & Kent 2007).

Hearing impaired children’s linguistic development is influenced by:

a) auditory (Stelmachowicz et al 2004; Donahue 2007)

b) age at which hearing loss (HL) is identified (Moeller 2007)

c) Intervention strategy (Uchanski & Geers 2003)

Developmental studies comparing children with normal (NH) and impaired hearing (HI) show:

a) vowel durations in hearing impaired talkers are longer (Mosenson 1974, McGarr & Harris 1983, Osberger 1987, Uchanski & Geers 2003)

b) vowel formants in hearing impaired talkers are more extreme (McGarr & Harris 1983, Uchanski & Geers 2003, Pratt & Tyge-Murray 2008).

Public Policy

About 3 per 1000 children born in the US have hearing loss. Early detection procedures are inexpensive (~$500/child), non-invasive, and effectively reliable. Myriad benefits are reported in the literature (Aguuzzo & Yosinago- tano 1999, Donahue 2007, Moepler 2007, Durieus&Smith et al 2008).

In July 2008, the U.S. Department of Health and Human Services, Preventive Services Task Force released an A-grade recommendation concerning newborn hearing screening concluding “that the net benefit of screening all newborn infants for hearing loss is moderate” (USPSTF 2008).

Early access to auditory experience may play an important role in language development for infants with hearing loss; empirical study of the benefits will continue to guide public policy.

Research Questions

1. Do HI children develop vowel space and duration in a manner similar with NH children?

2. Do children with early- versus late-identified hearing impairment differ in the development of their vowel productions?

Methods

Materials

Vowels are a subset of the 14 vowels (able, eye, ah, ee, ay, ee, ee, oo, ow, ah, ay, ee, oo, ow) for the purposes of this study. Each vowel was synthesized using a PureSpeech synthesizer (Isenberg & Fant 1968, Fant 1969).

Vowel Area (kHz²)

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\text{Vowel Area} = 0.5 \times \left( \frac{\text{F1}^2 + \text{F2}^2}{\text{F1} + \text{F2}} \right) \times \left( \frac{\text{F2}^2 + \text{F3}^2}{\text{F2} + \text{F3}} \right)
\]

Task

Listen-and-repeat game of isolated, monosyllabic CSVT target words (Kert et al 1994). Experimenter fed a plastic chip to a participant upon completion of each repetition.

Total corpus

31 target words (> 1-2 repetitions) ± 2 ages (48- and 60-months) ± 24 speakers

2200 total target vowels

Talkers

12 normal hearing children

3 late-ID hearing impaired children

4 early-ID hearing impaired children

All children were grouped based on chronological age and hearing status.

Measurements

Segment boundaries were marked using Praat (Boersma & Weenink 2006). Durations and formant values were collected using an automated script customized for children.

Early-ID hearing impaired children show a smaller degree of relative change, but do not achieve the same absolute levels.

Reference