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Phonetically governed voicing onset and offset in preschool children who stutter☆

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ABSTRACT

Phonetically governed changes in the fundamental frequency (F_0) of vowels that immediately precede and follow voiceless stop plosives have been found to follow consistent patterns in adults and children as young as four years of age. In the present study, F_0 onset and offset patterns in 14 children who stutter (CWS) and 14 children who do not stutter (CWNS) were investigated to evaluate differences in speech production. Participants produced utterances containing two VCV sequences. F_0 patterns in the last ten vocal cycles in the preceding vowel (voicing offset) and the first ten vocal cycles in the subsequent vowel (voicing onset) were analyzed. A repeated measures ANOVA revealed no group differences between the CWS and CWNS in either voicing onset or offset gestures. Both groups showed patterns of F_0 onset and offset that were consistent with the mature patterns seen in children and adults in previous studies. These findings suggest that in both CWS and CWNS, a mature pattern of voicing onset and offset is present by age 3;6. This study suggests that there is no difference between CWS and CWNS in the coordination of respiratory and laryngeal systems during voicing onset or offset.

Educational objectives: The reader will be able to: (a) discuss the importance of investigating children who stutter close to the onset of stuttering; (b) describe the typical change in F_0 during voicing onset; (c) discuss the potential implications of these results with regard to future research.

1. Introduction

Developmental stuttering is a disorder that begins in early childhood. As such, the extent to which specific speech production behaviors are associated with either the onset or moment of stuttering needs to be determined from speech samples that are collected relatively close to the onset of the stuttering problem. The main argument for this criterion is that compared to adults who stutter (AWS), the fluent and disfluent speech of children who stutter (CWS) is less likely to be influenced by years of learned reactive and compensatory behaviors (e.g. Caruso, Conture, & Colton, 1988; Conture, Colton, & Gleason, 1988; Zebrowski, Conture, & Cudahy, 1985).

Beginning in the late 1970s, a relatively large body of literature describing the acoustic characteristics of the speech production behaviors of CWS has emerged. To a large extent, these studies have focused on acoustic measures that reflect laryngeal coordination through measures of voice initiation or laryngeal reaction time (e.g. Cross & Luper, 1979; McKnight & Cullinan, 1987; Till, Reich, Dickey, & Sieber, 1983), as well as laryngeal–supralaryngeal coordination through measures

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of F_0 and temporal and spatial measures that include, among other things, F_0 jitter and shimmer, voice onset time (VOT), vowel duration, and formant transition duration and rate (e.g. Adams, 1987; Chang, Ohde, & Conture, 2002; Hall & Yairi, 1992; Subramanian, Yairi, & Amir, 2003; Yaruss & Conture, 1993; Zebrowski et al., 1985). Findings from this work have been equivocal, but in general the data suggest that there is a subgroup (or multiple subgroups) of children who stutter who exhibit difficulty with the rapid, precise laryngeal and laryngeal–supralaryngeal coordination required for fluent speech production.

There are several reasons for these inconsistent results, with the most likely related to the fact that the measures used were obtained from speech samples that by their very nature are subject to both linguistic influence (e.g. utterance length and syntactic complexity, prosodic variation) (Stepp, Hillman, & Heaton, 2010) and the idiosyncratic dialectical pattern and articulation rate of the speaker. Taken together, these variables contribute to the frequent observation of large within- and between-group variability seen in the acoustic representations of speech production for children, and to a lesser extent, adults.

Recently, several researchers have proposed that measuring short-term phonatory changes associated with the offset (devoicing) and onset (voicing) of phonation in vowels surrounding a voiceless stop obstruent provides a measure of laryngeal function. The change and variability of change in F_0 (referred to as relative fundamental frequency or RFF) in so-called phonetically governed devoicing and voicing gestures is thought to reflect the coordination of laryngeal and aerodynamic adjustments necessary for the production of voiceless obstruents or "true consonants" (i.e. stops, fricatives and affricates; Edwards & Shriberg, 1983) with vocal fold morphology (e.g. stiffness) and vocal tract anatomy. That is, changes in phonetically governed devoicing and voicing F_0 are the direct consequence of the laryngeal and respiratory coordination required for specific articulatory gestures (e.g. lip closing and opening associated with bilabial stop consonants), and as such are not under overt or deliberate speaker control or the influence of language and related suprasegmental variation (Baken & Orlikoff, 1988; Goberman & Blomgren, 2008; Robb & Smith, 2002; Stepp et al., 2010).

Recently, Robb and Smith (2002), Goberman and Blomgren (2008), Stepp et al. (2010), and Stepp, Merchant, Heaton, and Hillman (2011) adopted a method developed by Watson (1998) and based on work by House and Fairbanks (1953) and Baken and Orlikoff (1988), to examine short-term RFF or phonetically governed voicing changes in both typical and atypical children and adults. For typical speakers, this work has shown consistent, age-related patterns of vowel F_0 change and variability immediately before and after the production of voiceless stop consonants (Peterson, 2001; Robb & Smith, 2002; Watson, 1998); specifically, there is a reduction in F_0 across vocal cycles in the vowel preceding the consonant, and a relatively high F_0 at voicing onset in the subsequent vowel followed by a decline across vocal cycles. Further, there is relatively high inter-subject F_0 variability for both the devoicing and voicing gestures, and this variability decreases with age. In studies of atypical speakers, researchers have observed these same patterns (i.e. F_0 reduction across cycles preceding a voiceless obstruent, and a relatively high F_0 at voicing onset, followed by a steep decline) in individuals with Parkinson's disease (PD) and vocal hyperfunction, although qualitative differences between these populations and typical speakers have emerged. Specifically, individuals with PD show smaller relative fundamental frequency changes in phonetically governed voicing onset and offset compared to typical speakers, and those who exhibit vocal hyperfunction show lower short-term RFF overall than their typical peers (Goberman & Blomgren, 2008; Stepp et al., 2010). Stepp et al. concluded that the differences between typical and atypical speakers (i.e. PD and vocal hyperfunction) is likely due to increased laryngeal tension and/or reduced airflow secondary to rigidity of the respiratory system in the latter.

Based on their study of short-term RFF in normally speaking children and adults, Robb and Smith (2002) suggested that comparing F_0 change and variability associated with voicing offset and onset in children with and without speech disorders would help to uncover specific laryngeal/respiratory adjustments surrounding disrupted articulatory events (including speech disfluencies). The consistent pattern of F_0 change across short devoicing and voicing onset intervals seen for even the youngest children (four years; Robb and Smith), with associated variability decreasing with age, suggests that these measures may be particularly sensitive to subtle differences in laryngeal muscle tension and coordination that have long been suspected in CWS. As previously discussed, of special benefit is that this method offers a simple, noninvasive and nonintrusive method for observing the subtle and difficult to observe changes in laryngeal articulation (specifically, laryngeal/aerodynamic coupling necessary to facilitate consonant production) that occur in young children during normal speech development. Further, the nature of the analyzed sample should reduce the high degree of within- and between-child variability in speech production that characterizes children's speech.

With this in mind, the purpose of this study was to compare both mean F_0 change and variability (i.e. standard deviation) associated with voicing offset and onset, in V-(voiceless) C-V syllables produced by preschool children who do and do not stutter (CWNS). As discussed at the beginning of this paper, we used young children relatively close to the onset of stuttering as participants because of our assumption that any speech production anomalies that have been suspected to be associated with the onset and early development of stuttering need to be determined from speech samples that are collected relatively close to the onset of the stuttering problem.

Specifically, we hypothesized that consistent with other between-group studies of speech physiology, there would be no difference in the trajectory or patterns of RFF associated with the devoicing–voicing gestures, but that compared to CWNS, CWS would show higher within- and between-group variability, reflecting a more heterogeneous population in general, and less stable patterns of laryngeal strategies for voicing and devoicing. Further, with reference to the developmental data