Speech Movement Characteristics in Children with Speech Delay

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Introduction

Background

Investigations of articulatory coordination of speech have quantified developmental changes in the coordinative organization of the lips and jaw in typically developing children (Green et al., 2002). Oral kinematic analyses have provided some evidence of disruptions in the organization of lips and jaw in children with motor speech disorders such as dysarthria and developmental apraxia of speech (Connaghan et al., 2000; Nijland et al., 2004).

The current investigation was designed to describe in children with speech delay the speech movement characteristics of the lips and jaw during tasks involving rapid repetitive productions of syllables (diadochokinesis). Inherent task requirements of timing and sequencing of movement reversals in repetitive production of syllables provide a unique opportunity to observe physiologic adjustments by articulators and may reveal motor constraints in speech production in young children, including both typically developing children and those with speech delay.

Experimental Questions

- Are there subgroups among children with speech delay and typically developing children on measures of cycle-to-cycle variability of lip and jaw movement during repetitive speech production ?

Method

Participants

- Children with Typical Speech development (TS; n=19; F=11, M=8)
- Children with Speech Delay (SD; n=26; F=7, M=19)

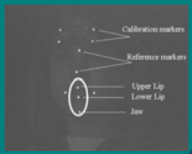
All children were between the ages of 3 and 5 years. The children were classified according to the Speech Disorders Classification System (Shriberg et al.,1997).

Stimulus – Speech Sample

Two trials of continuously repetitive productions of the syllable /pa/ were prompted using a repeated adult model presented by computer prior to each trial.

Data Acquisition

Positions of movement markers on the upper lip (UL), lower lip (LL), and the jaw were extracted automatically from video recordings of each participant using an infrared–sensitive camera coupled to a vide recorder and a computer based movement tracking system (Peak, Motus). LL displacement signal was derived by subtracting LL signal from jaw signal. Microphone was placed on the child's forehead to capture the acoustic signal.



Data Analysis

For each participant, the trial with the greater number of syllables produced and judged to be perceptually accurate was included in the analysis.

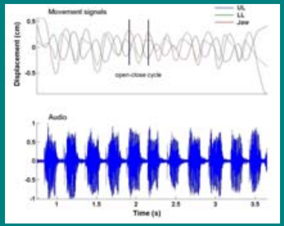


Figure 1: The movement signals for UL, LL and jaw (top panel) and the respective acoustic signal (bottom panel) during repetitive production of syllable /pa/ by a typically developing child. The kinematic signals were parsed into open-close cycles based on the zero crossings in the derived jaw velocity signal.

The cyclic Spatio-Temporal Index (cSTI) was used to quantify the stability of repeated individual movement cycles for each of the articulators (van Lieshout & Moussa, 2000). This measure has been modified from the STI measure developed by Smith and colleagues (Smith et al., 1995). To calculate cSTI, individual movement cycles, defined by the peaks in the signal, were amplitude- and time-normalized and aligned with each other. The standard deviations across the overlapping segments (number of cycles in the given trial) at 2% intervals in the relative time scale (i.e., 50 values, one at every 20th point for a 1000 point normalized time scale) were calculated and summed to yield the ***cSTI*** .

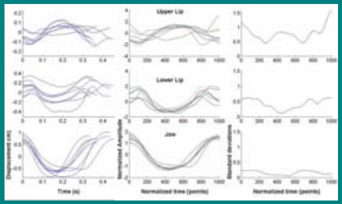


Figure 2: The parsed displacement signals (first panel), the amplitude and time normalized signals (second panel) and the computed standard deviations across cycles (third panel) for UL, LL and jaw.

In addition, cSTI was also calculated for the Inter-Lip Distance (ILD) signal The Inter-Lip Distance signal was derived by subtracting the UL signal from the LL signal.

Cluster analysis (ClustanGraphics,v8.02) was used to identify the distribution of features of movement characteristics of articulators in a heterogeneous sample of children with speech disorders and typically developing children without apriori assignment to predefined subgroups.

Results & Discussion

The cSTIs for UL, LL and jaw signals were standardized to z-scores across all participants and served as input variables for the cluster analysis.

Cluster Analysis: Hierarchical Agglomerative Clustering
Proximity Measure : Squared Euclidean Distance
Linkage Function: Increase in Sum of Squares

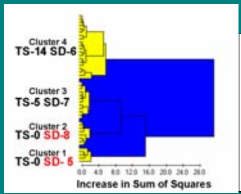


Figure 3: Dendogram highlighting the four cluster solution with cSTI for UL, LL and jaw as variables.

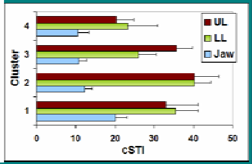


Figure 4: Cluster means and standard deviations of cSTI for UL, LL and Jaw

The upper tail rule (Mojena & Wishart, 1980) was used as stopping rule for hierarchical clustering and to determine the number of significant clusters in the dataset. The four cluster solution was found to be significant in the above analysis (t= 1.39; realized deviate = 9.19, df = 43).

Preliminary evaluation of this dataset revealed subgroups of children (clusters 1 and 2 in figure 3 and 4) comprising of only children with speech delay with higher cSTIs for UL, LL and/or jaw movement signals.

Further, a cluster analysis was performed with the standardized cSTIs for ILD and jaw signals. The four cluster solution was found to be significant (t= 1.08; realized deviate = 7.12, df = 43). Subgroups of children with speech delay (cluster 1 and 2 in figure 5 and 6) with higher cycle-to-cycle variability in the jaw and/or ILD signals emerged separately from a large group of typically developing children and children with speech delay as evidenced from the fusion values in figure 5. The presence of subgroups are representative of differential speaker categories in terms of articulator performance during repetitive production of syllable /pa/.

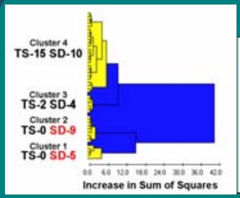


Figure 5: Dendogram highlighting the four cluster solution with cSTIs for ILD and Jaw as variables

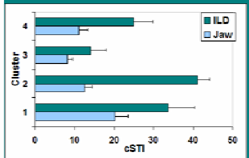


Figure 6: Cluster means and standard deviations of cSTI for ILD and jaw.

The coordinative organization of the lips and the jaw appear to provide a distinctive indication of speech delay in the context of typical development of speech motor control. The observation of lower cSTI for jaw in comparison to UL and LL is consistent with earlier findings of developmental changes in the coordinative organization of jaw and lips in children in terms of the motor control for jaw maturing earlier than the upper and lower lip (Green et al., 2002).

The decreased movement stability of articulators across repetitive production of syllables observed in the typical-sounding speech of children with speech delay appears to exist at a subclinical level (i.e., below the perceptual threshold for disorder) and is consistent with the the role of motor capacities underlying the deficits associated with speech sound delay of unknown origin.

Future investigations would attempt to correlate the cycle-to-cycle variability in the articulator movement with additional descriptors of articulator performance such as amplitude and velocity of movement.

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