ACOUSTIC MEASURES IN THE SPEECH OF CHILDREN WITH STUTTERING AND NORMAL NON-FLUENCY: A KEY TO DIFFERENTIAL DIAGNOSIS

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ABSTRACT
Stuttering is a disorder of fluency, characterized by repetitions, hesitations, prolongations and audible pauses. Stuttering usually develops in the early years of childhood, and it tends to undergo many changes in the course of time. Many children stutter transiently before developing normal fluent speech. There is no clear agreement to regard transient period of dis-fluency as stuttering. It is difficult to group the speech dis-fluencies of young children as either normal or stuttered. Various guidelines, perceptual protocols and acoustic measures have been formulated in the past for assessing stuttering in children which have led to more confusions than solutions. In this context, the present paper aimed at differentially diagnosing normal non-fluency from stuttering based on perceptual and acoustic parameters. This is a part of a project funded by Indian council of medical research (ICMR). Ten normal and ten stuttering children speaking Kannada and in the age range of 3 - 12 years served as participants. Subjects were seated comfortably and were tested individually. Speech was elicited using pictures, picture depicting stories and repetitions of words. All these were audio-recorded and transferred to multi-channel software. Using wide-band spectogram, transition duration of F2, extent and speed of F2; transition, onset and offset of F2 and pattern of F2 were extracted. These parameters between groups were compared and results indicated shorter TD, higher offset of F2 and higher SFT in children with stuttering compared to normal children. Absent and discrepant transitions were more in children with stuttering compared to normal children.

INTRODUCTION
Van Riper (1982) defines stuttering as a temporal disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound. This disruption is characterized by repetitions, hesitations, prolongations and audible pauses. Many children stutter transiently before developing normal fluent speech. Onslow, Garden, Bryant, Stickings and Knight (1992) in their study showed that listeners frequently disagreed on deciding whether speech dis-fluencies of young children were either normal or stuttered. Further, there is no clear agreement to regard transient periods of dis-fluency as stuttering (Yairi, 1997). Despite divergent opinions, it is universally agreed that the dys-fluencies should be identified early and treated. It is widely accepted that it is better to treat stuttering in its early stages than to wait until adolescence or adulthood. Not only is early intervention more time and cost effective, but it also liberates children from a lifetime of frustration and embarrassment about speech (Onslow, 1996). Clinicians do not find it difficult to decide that a child is “normally fluent” if he or she exhibits extremely fluent speech; likewise it is not hard to decide that a child is “stutterer” if he prominently dysfluent. It is, however, difficult for a clinician to decide about a child whose behavior falls between these youngstes who can be classified as stutterers. Unfortunately these in-between youngsters represent a sizable portion of all children who stutter. Part of this difficulty arises from lack of “objective measures of stuttering” and “norms” to clearly separate “fluent” from “dysfluent” speaker. Howell & Vause (1986, among others) have set a few indicators that show that the fluent and disfluent speech of stutterers and non-stutterers, though perceptually identical, differ acoustically. However, the results of acoustic analysis of the speech of normally non-fluent and stuttering children are equivocal. F2, F2 transition, Voice onset time, duration of vowels and consonants, FO perturbation have been investigated as possible differential diagnostic indicators. The second formant transitions in dysfluent speech of normal children and children with stuttering indicate a variable pattern. The F2 transitions are sometimes absent or atypical (Howell & Vause, 1986; among others) and when they are appropriate they tend to
be shorter in duration (Yaruss & Couture, 1993). Klich & May (1982) found that stuttersers' F₁ and F₂ values were more centralized compared to non-stuttersers, which were interpreted to reflect restricted articulatory adjustments. This was contradicted by Prosek, Montgomery, Walden, & Hawkins (1987) who failed to find any such centralization. In spite of several findings, it has not been possible to differentiate stuttering and normal non-fluency. In this context, a project has been undertaken to differentially diagnose stuttering from normal non-fluency. The present study is a part of the project and it investigated the efficacy of acoustic parameters as indicators of differential diagnosis of stuttering and normal non-fluency.

**METHOD**

**Subjects:** Two group of subjects participated in the study. Group I consisted of 10 children diagnosed as stuttering and group II consisted of 10 subjects diagnosed as normal non-fluency in the age range of 3-12 years. Children above 25% disfluency were diagnosed to have stuttering. None of the subjects had any complaint of hearing impairment, mental retardation, neurological problem or language delay. All of them had normal oro-facial structure and function.

**Material:** Ten C₁V₁C₂V₂ Kannada meaningful words with the unvoiced consonants [k,c,t,t,p] and their cognates [g,j,d,d,b] in the initial position followed by a long mid vowel /a/ a trill and vowel /u/ or vowel /i/ in the final position formed the material. Conversation and picture description were also recorded.

**Method:** Children were tested individually. They were instructed to repeat the words after the experimenter in a microphone kept at a distance of 10 cms from the mouth and these utterances, conversations and picture description were audio recorded on to a high quality audio cassette [Meltrack D 90] using a Sony stereo professional cassette deck. Conversation and picture description were transcribed verbatim and sound syllable repetitions (SSR) were identified and analyzed.

**Acoustic analyses:** Acoustic analysis was performed using multi speech software, which permitted to store the tokens. The tokens was fed from the cassette deck in to the computer digitized at 8 kHz sampling rate using a 12-bit quantization and stored on to the memory of the computer. Each token was analyzed using 'spectrogram' and 'formant frequency' program and following parameters were extracted.

1. **F₃ Transition duration (TD):** The duration of the formant transition was measured as the time difference in ms between the onset of F₃ transition at the beginning of the vowel till the steady state. The beginning of the steady state portion of the following vowel was defined as the time when the formant, paralleled the time axis. This measure of F₃ transition duration is believed to approximate the amount of time the articulators spend moving from one position to other (Yaruss & Couture, 1993).
2. **Extent of F₃ transition (EFT):** The extent of the F₃ transition was estimated by calculating the difference between the onset and offset frequency of F₃. This is believed to represent the overall movement of the articulators during the transition.
3. **Speed of F₃ transition (SFT):** The speed with which the second formant frequency changes during the transition was measured by using the following formula. This is believed to approximate the speed with which the speech articulation moves from one location to the next.
4. **Onset and Offset of F₃:** the onset and offset of F₃ in Hz was estimated from the visually apparent center of the F₃ energy bands on the spectrogram display at the onset and offset of F₃ transition.
5. **Pattern of F₃ transition:** Pattern of F₃ transition was noted as discrepant, non-discrepant or absent.

**Statistical analysis:** The mean and standard deviation of these parameters were computed. Independent t-test was used to find out the significant difference between the groups.

**RESULTS AND DISCUSSION**

Results indicated significantly shorter TD, higher offset of F₃ and higher SFT (P<0.05) in children with stuttering compared to normal children. Absent and discrepant transitions were more in children.
with stuttering compared to normal children. Table 1 shows the mean and SD of all acoustic parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Stuttering</th>
<th>Normal non-fluency</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
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<tr>
<td>TD</td>
<td>33.82</td>
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<td>Onset of F2</td>
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<tr>
<td>SFT</td>
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<td>15.33</td>
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<td>EFT</td>
<td>431.52</td>
<td>398.37</td>
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<td>Pattern of F2</td>
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<td></td>
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<tr>
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<td></td>
<td>D</td>
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<td></td>
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</table>

Table 1: Mean, SD. Degree of freedom and P-levels of the acoustic measures.
(* indicates statistically significant difference)

The results revealed several points of interest. First of all, shorter transition duration was found in children with stuttering compared to children with normal non-fluency and the difference was statistically significant at 0.05 level. This supports the results of Prakash, Saji and Savithri (1998). Shorter transition duration implies faster articulatory movements.

Second, speed of F2 transition was significantly higher in children with stuttering compared to children with normal non-fluency. This again indicates faster articulatory movements in stutterers.

Third, offset frequency of F2 transition significantly higher in children with stuttering compared to children with normal non-fluency. This is in agreement with the results of Klich and May (1982) and suggests production of more central vowel in children with stuttering.

Out of the array of acoustic parameters, offset frequency of F2 transition, transition duration and speed of F2 transition were significantly different among the groups. It appears that these acoustic parameters can be used for the differential diagnosis of stuttering and normal non-fluency. Further continuation of the project should prove the effectiveness of these acoustic parameters in differentiating stuttering from normal non-fluency.

ACKNOWLEDGEMENTS
The authors wish to acknowledge Dr. Vijayalaxshmi Basavaraj, Director, All India Institute of Speech and Hearing, Mysore, for having given permission to prepare and present the paper in Frontiers of Research in Speech and Music.

REFERENCES

