VOWEL DEVELOPMENT OF /i/ AND /u/ IN 15-36 MONTH OLD CHILDREN AT RISK AND NOT AT RISK TO STUTTER

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ABSTRACT

A study was designed to compare the high front /i/ and high back /u/ vowel in children at risk and not at risk to stutter. Recordings were made of children playing with parents for 10 minutes between 15 and 36 months of age. Anatomical and linguistic influences did not differ across subjects with the exception of the 24 month period. At risk children were slightly taller at 24 months. Spontaneous utterances from each child were digitized into a CSL, Model 4300. The F1 and F2 of the steady-state portion of each /i/ and /u/ vowel was measured. Not-at-risk children demonstrated values typical of normally-developing children. Repeated measure ANOVAs showed that children who were at risk to stutter had significantly higher formant values for F1 for both /i/ and /u/ vowels. These results suggest that the tongue height is lower than it should be for the high vowels. Formant frequencies for F2 for both /i/ and /u/ were significantly higher also reflecting a more forward tongue position for the front and the back vowels in at-risk children.

1. INTRODUCTION

Stuttering is a prosodic disorder observed in most languages in which the speaker knows precisely what to say but for a brief period of time cannot express the thought. Researchers posit that stuttering occurs when there is a mistiming between phonation, articulation, and respiration. Repetitions, cessations, or prolongations of sound result. Stuttering develops in the preschool years and if it remains untreated or undiagnosed develops into a lifetime disorder.

There have been no comparisons between children at risk and not at risk to stutter in terms of analyzing behaviors known to characterize stuttering. By following a normal developmental model that has characterized vowel acquisition, investigators can determine whether or not at-risk infants show normal prosodic development.

Normal vocal development has been well-documented [1]. There is a gradual and consistent advancement in vowel development as early as the babbling stage through three years of age in normal children. Researchers [2] reported that vocalization pursues an orderly developmental progression in normal 18 month-old infants. Most notably, vowels produced early during the babbling stage of development appear centralized, and later move frontward to the lower left quandrant of the vowel space ([3], [4], [5], [6], [7], [8]).

A different pattern of vowel preference surfaces in early words. The high front and high back vowels are produced more accurately than other vowels [9]. A child between 14 and 20 months of age accurately produced the /i/ vowel in early words 80 percent of the time and /u/ 89 percent of the time. Vowel acquisition can be measured and norms are available for formant frequencies ([1], [10]).

The focus of the present study was to record vocal development in a defined population of young children potentially at risk to stutter and compare them to a group of children who have a limited risk to stutter. Longitudinal recordings were made to observe if children at risk to stutter produce the later learned high front /i/ and high back /u/ vowels more anterior or lower than children at risk. It was of importance in this study to focus on vowel production of later-learned vowels to determine whether or not children can be differentiated at risk based on formant frequencies.

2. METHOD

2.1. Subjects

Three at-risk and 4 not-at-risk subjects were selected to participate in this study. All subjects came from middle class backgrounds mainly from the Southern California area of the United States.

The at-risk subjects had a familial predisposition for a fluency disorder and the not-at-risk subjects had no immediate or extended family members who had a history of a speech or language disorder. All of the at-risk subjects began to stutter and received treatment after the time under consideration in this study. Currently, all of the at-risk children have remained fluent for at least two years after treatment.

Height, weight, morphemic, and standardized speech and language measures were collected for each of the subjects. With the exception of the at-risk children being slightly taller ($p < .05$) than the not-at-risk children at the 24 month milestone, no other significant differences between the groups were found.

2.2. Procedure

Parent-child observations were videotaped at regular intervals (at 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36 months). Each parent-child dyad was instructed to go into a toy-filled room and play together. No guidelines were given regarding how to speak to the child or what verbalizations would be measured.

After a 3 minute warm-up period, videotaping began (using a Camcorder Model #A-C20) for a 10 min. interval. A Micronta digitized stopwatch (Model #40/6391) was used to time the sessions. A Pressure Zone Microphone (PZM) was situated in the middle of the room to enhance a potentially less than optimal acoustic environment and improving the signal-to-noise ratio above that of a build-in camcorder microphone.

2.3. Coding of Transcripts

The tool selected for encoding data was the Child Language Data Exchange System (CHILDES). It was developed by MacWhinney and Snow [11] to systematize more uniform and reliable ways to collect, transcribe, and analyze naturalistic data so cross-investigator reliability could be established. For purposes of the study, the main speaker tier was used to identify utterances selected for the acoustic analysis. Any utterance of a recognized word with the /i/ or /u/ vowel was included in the analysis. The comment line or the parent's utterance frequently verified what the child had said.

The samples were perused by the coder for words that contained /i/ or /u/ vowels. All words containing the high front /i/ or high back /u/ vowel were highlighted. The transcript was followed to assist in locating the audiotaped portion containing the /i/ or /u/ vowels.

2.4. Acoustic Analysis

Once the utterance was identified, the analog recordings were digitized into a Kay Elemetrics Computerized Speech Lab [12] at 16 bits. Spectrographic analysis used wideband spectrograms covering a fixed frequency range (0 to 5000 Hz). A 500 ms interval was displayed for analysis (waveform and spectrogram). The filter bandwidth used for the spectrograms was 146 Hz. A 20 ms interval of the /i/ or /u/ vowel was selected for a Linear Predictive Coding (LPC) spectrum analysis. A power spectrum using the Fast Fourier Transform (FFT) algorithm was applied to the filter coefficients generated by the LPC, shaped to 512 points. The resulting frequency response spectrum was 256 spectral coefficients.

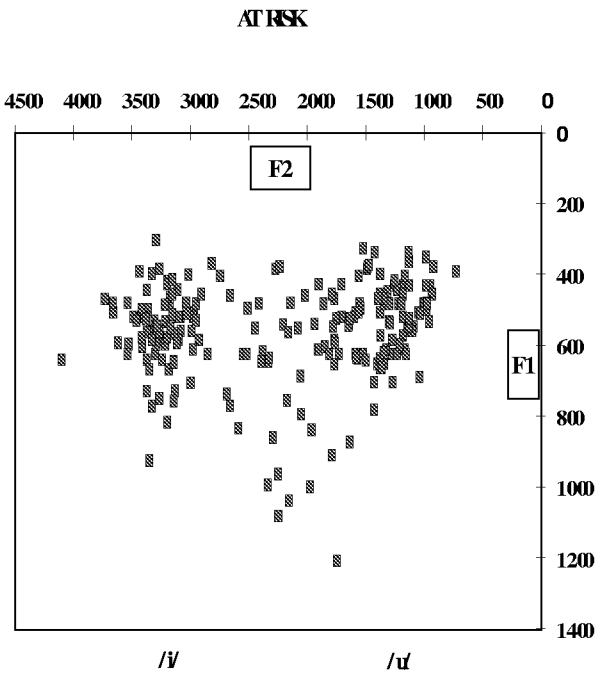
The steady-state portion of each /i/ and /u/ vowel token in the 10 min sample was measured. Most of the tokens selected for measurement occurred in CV, CVC, V, or VC syllables. Few two-syllable words occurred but they were included in the study.

3. RESULTS

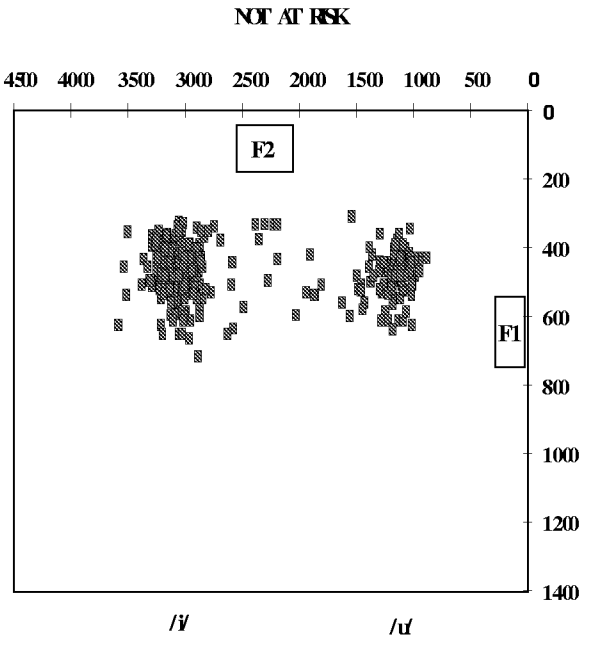
An ANOVA comparing the children at risk and not at risk to stutter revealed a significant group difference in terms of formant frequencies for F1 [$F(1,307) = 74.34$; $p < .001$] and F2 [$F(1,307) = 13.28$; $p < .001$] for the /i/ vowel. Also, there were significant differences between the groups for F1 [$F(1, 224) = 32.70$, $p < .001$] and F2 [$F(1,224) = 52.16$, $p < .001$] on the /u/ vowel. Children who were at risk to stutter had higher formant values for F1 for both /i/ and /u/ vowels suggesting that the tongue height or possibly the jaw is lower for the high vowels. Formant frequencies for F2 for both /i/ and /u/ were significantly higher also reflecting a more forward tongue position for the front and the back vowels in at-risk children.

Figure 1 illustrates the variability in the at-risk group for the high front and back vowel. There is not a clear distinction between the front and back vowels for the at-risk children. Not-at-risk children demonstrated values typical of normally-developing children as shown in Figure 2.

A repeated measures ANOVA was done to determine if any changes in F1 and F2 occurred over time for the /i/ and /u/ vowels. There were no significant differences observed for /i/ or /u/ between Observation 1 (15 and 18 months), 2 (21 to 24 months), 3 (27 to 30 months), and 4 (33 to 36 months). The formants did not change over time because the children may make those changes earlier than 15 months of age as reported in other studies ([13], [14]).



3.1. Figure 1 illustrates vowel formants for the /i/ and /u/ vowel spoken by children at risk to stutter.



3.2. Figure 2 depicts the vowel formants for the /i/ and /u/ vowel for children not at risk to stutter.

Factorial ANOVAs were completed to determine if there were any significant differences as a result of word order of the tokens, syllable type, struggled versus fluent vowels spoken, and place and manner of the adjacent consonant. There were no significant differences for word order or type of syllable spoken for the /i/ vowel. There were no group differences in terms of struggled versus fluent vowels spoken; however, the at-risk group had a slightly higher F1 for struggled /i/ vowels. Place and manner distinctions also influenced formants significantly for the /i/ vowels as has been noted by previous researchers.

There were no word order, place, or manner effects for the /u/ vowel. Syllables did not differ for F1 but tremendous differences were noted in F2. Children at risk to stutter had higher formant values when producing CV, CVC, and VC combinations with the /u/ vowel suggesting a more forward tongue position when coarticulating /u/ than observed in not-at-risk children.

4. CONCLUSION

Not-at-risk children in this study were very consistent in their productions of the /i/ and /u/ vowels as Davis and MacNeilage [9] previously reported. The children at-risk to stutter showed more variability, higher F1 and F2 formants, lower jaw and tongue positions, and more fronting of back vowels than the not-at-risk subjects. In a preliminary study, Fosnot [15] found that a not-at-risk child demonstrated a period of fronting vocalization, centralization, and finally developed a fuller vowel space faster than an at-risk child. The same developmental pattern was emerging in the vocalizations of the at-risk child, but the milestones for acquisition occurred at a slower pace. The current study shows a delayed pattern in producing the high front and back vowels for three children who were at risk to stutter.

Recall that the height and weight measurements were taken at all the developmental milestones with the exception of the 30 month period. Interestingly, the at-risk children were slightly bigger than the not-at-risk child throughout the course of the study and were significantly taller at 24 months. Therefore, the variability in the formants of at-risk children is most likely not related to the anatomical development of the child.

Other variables (place and manner, type of syllable, and struggled vowels) influenced the formants suggesting that lowering tongue position or fronting of the vowels may not attribute to the variability observed in the at-risk subjects. Future study will observe the relationship between the consonant and vowel within the utterance to determine if the speech of at-risk children can identify children who potentially could develop stuttering behaviors prior to the diagnosis of a fluency disorder.

5. ACKNOWLEDGMENTS

This work was supported by the UCLA Phonetics Lab. Special thanks to the NIH Training Grant (T32 DC0029-06). Extended thanks to the families who participated in this longitudinal study. ***Special thanks*** to Mr. & Mrs. Bernstein, Benefactors.

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