Pitch range and vowel duration in the speech of children with Williams syndrome

PITCH RANGE AND VOWEL DURATION IN THE SPEECH OF CHILDREN WITH WILLIAMS SYNDROME

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ABSTRACT

This paper reports the pitch range and vowel duration data from a group of children with Williams syndrome (WS) in comparison with a group of typically developing children matched for chronological age (CA) and a group matched for receptive language abilities (LA). It is found that the speech of the WS group has a greater pitch range and that vowels tend to be longer in duration than in the speech of the typically developing children. These findings are in line with the impressionistic results reported by Reilly, Klima and Bellugi [17].

Keywords: Williams syndrome, prosody, pitch range, vowel duration, atypical populations.

1. INTRODUCTION

WS is a rare genetic disorder with a prevalence of about 1 in 25,000 live births ([10], [6]) which occurs due to a microdeletion on chromosome 7. This deletion results in a number of physical abnormalities, such as elevated blood calcium levels, sensitive hearing and high blood pressure, failure to thrive in infancy, abnormal sensitivity to certain classes of sounds (hypersacusis), and moderate to severe learning difficulties. It has been argued that linguistic abilities are relatively strong, compared to general cognitive functioning and non-verbal abilities ([1], [2], [4], [5]). However, recent research has begun to question the claim that linguistic abilities are strong in WS ([8], [9], [10], [21]). It seems that, for many individuals with WS, linguistic abilities are on a par with their general cognitive functioning. It has recently been shown that pragmatic abilities in the WS population may also be impaired ([11], [19]). In comparison to a rich body of research into morpho-syntactic and semantic abilities in WS, relatively little attention has been paid to phonological abilities in this population, including prosodic features.

To our knowledge, there has only been one published study which has investigated prosodic ability in WS. Reilly, Klima and Bellugi [17] evaluated the use of affective vocal prosody (pitch changes, vocalic lengthening and modifications in volume) in a story telling task. The study found that adolescents with WS used significantly more affective expressive prosody in comparison with adolescents with Down's syndrome matched on mental age, and two groups of typically developing children (a group 3 & 4 yr olds and a group of 7 & 8 yr olds). The affective prosody scores for the WS group were similar to CA matched group (ages 10-11), which was interpreted as a relative strength in the WS cognitive profile, although it is acknowledged that the high use of affective expressive prosody by the adolescents with WS was abnormal. The findings are reflected in a later related study by Losh, Bellugi, Reilly and Anderson [12], which did not specifically look at prosody; children with WS were shown to use more evaluative and social engagement devices than a group of age- and gender-matched peers.

Reilly *et al* [17] used only impressionistic measures of the data in their study. We aim to test their findings by submitting speech data collected from participants with WS to acoustic tests, and comparing them to typically developing children, matched for language age and chronological age. Our research questions in this paper are:

- Does the pitch range of children with WS differ from typically developing children (experiment one)?
- Do vowel durations differ across those groups (experiment two)?

2. PARTICIPANTS

Data were collected from 14 children with WS aged between 6;04 and 13;11 with a mean age of 9;06, 14 LA controls aged between 4;03 and 7;04 (mean age 5;07) which were matched to the WS group on the Test for the Reception of Grammar (TROG 2) ([3]), and 15 CA matches aged between 8;00 and 12;04 (mean age 9;09). Raven's Coloured

Matrices (RCM) ([15]) was also administered as a measure of general non-verbal cognitive abilities.

The children were recorded on to digital audio tape generating a story from the wordless picture book *Frog, Where Are You?* [12], which is also the text used in the study by Reilly *et al*.

3. EXPERIMENT 1: PITCH RANGE

3.1. Method

The recorded stories were analysed using Laryngograph hardware and associated software. The F0, mode, mean, minimum and maximum pitch and the pitch range were extracted.

Laryngograph generates two types of measurements: DFx1 and DFx2. We used the DFx2 value, which is derived by including pitch points only when two successive vocal fold vibrations have the same frequency. To control for further error, such as that which might arise from pitch halving or doubling, we looked at the 90% range rather than the whole range for the minimum, maximum pitch and pitch range.

Semitone conversion was used to normalize the pitch range data, as [14] suggests that a logarithmic scale best models speaker intuitions about pitch range. This allowed us to compare the pitch ranges of the subjects, even though they had different modal F0 and their pitch values were obtained from different ranges on the physical scale. The pitch range in semitones (ST) for each child was obtained using the following formula, in which f_{max} is the maximum pitch in Hz and f_{min} is the minimum pitch in Hz for a particular child:

$$(1) \quad st = 12\left(\frac{LN(f_{max}/f_{min})}{LN2}\right)$$

We then performed ANOVA to investigate whether there were significant differences in pitch range between the 3 groups. Our significance level is set at $p \leq 0.05$.

3.2. Results and discussion

The mean pitch ranges for each of the three groups is given in Table 1. It is clear from these findings that the WS group has a much larger average pitch range than either of the two typically developing groups. This is reported in [17], but is now confirmed by our instrumental study. There is also greater variation across participants in the WS group, as can be seen by the standard deviation values.

Group	Pitch range in ST	St. Dev
LA	5.11	1.9
CA	6.02	2.15
WS	9.64	3.38

Table 1: Mean pitch range across the three groups.

The results from the ANOVA show that there was no significant difference between the LA and CA group. There was, however, a statistically significant difference between the participants with WS and their CA-matched peers of p=0.002, and also a significant difference between the LA-matched group and the WS group of p=0.000. These results are shown visually in Fig. 1.

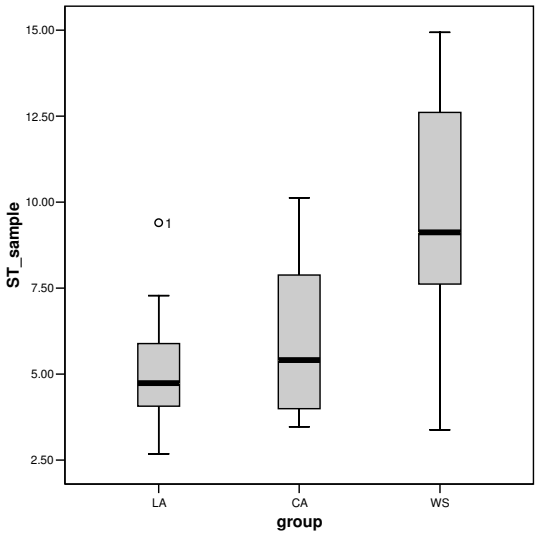

Figure 1: Graph showing the pitch range data, measured in semitones for the three groups of participants.

These findings suggest that the individuals with WS demonstrate an atypical profile concerning pitch range. This is in line with claim of [17] that individuals with WS's use of affective prosody may be aberrant.

4. EXPERIMENT 2: VOWEL DURATION

4.1. Method

In the second study, the software Speech Filing System [18] was used to conduct spectrographic analysis of vowel durations in the data mentioned in the previous study. 60 seconds of the speech data for each subject was recorded onto a computer

in the point at which the child gave the first qualifying vowel sound. In this way, there would be a minimum of just over 59 seconds of speech and an absolute maximum of 60 seconds. Each sound file was then subjected to spectrographic analysis using SFS, marking the start and end point of each qualifying vowel using the SAMPA transcription key.

In order to qualify, each vowel had to fulfil four criteria:

- It must not be part of an unintelligible sequence;
- It must not be the final sound before a restart or self-interruption;
- It must not be part of a filled pause;
- The boundaries must be identifiable (through auditory, spectrographic and/or waveform measures) without ambiguity considerably greater than 30ms.

Vowels generally had one boundary identifiable to within 20ms (often within 10ms) and the other with an ambiguity of 20-40ms, depending on whether the vowel was the first sound after or before a pause, with the most clearly identifiable being those occurring between consonants. The permitted ambiguity was largely due to the quality of the recordings, which were not generally made in what might be thought of as a consistent laboratory recording environment. The majority of vowel durations were therefore identified to within an overall ambiguity of around ±25-30ms.

The five main categories of vowel were identified as those in utterance-initial or utterance-medial syllables, those in utterance *and* sentence-final syllables, those only in utterance-final syllables, those that were produced with a 'calling' intonation, and those in syllables preceding a call. Some vowels clearly fell into more than one category. There was an additional category for vowels whose sentence final status was ambiguous; these were included in the sentence-final group. In this experiment we have limited the categories to two: all vowels, and vowels minus the utterance-finals and calls.

Once all recordings had been analysed and labelled, the boundaries were exported from SFS in the form of .txt files. The vowel durations were then determined using a spreadsheet, and subsequent statistical analysis using SPSS was carried out. The significance level is $p \leq 0.05$.

4.2. Results and discussion

Table 2 and Fig. 2 show the average durations and standard deviations in ms across the groups for all vowels (in black, Fig. 2), and vowels minus utterance-finals and calls (in grey, Fig. 2).

	WS	LA	CA
All vowels (ms)	135 (sd 23)	134.3 (sd 19)	108.7 (sd 29)
Minus utterance-final and calls (ms)	117.1 (sd 23)	118.6 (sd 14)	92.7 (sd 27)

Table 2: Mean vowel duration and standard deviations across the three groups.

Statistical analysis indicates that there is no significant difference between the WS group and the CA group for all vowels or vowels excluding utterance-finals and calls. However, there are significant differences between the WS and CA groups on the one hand and the WS and the LA group on the other, in both conditions. For all vowels, Bonferroni post-hoc tests show a difference between the WS children and the CA matches of p=0.015, and the LA group and the CA matches of p=0.019. When utterance-finals and calls are removed, a difference of p=0.012 is shown between the WS group and the CA children, and of p=0.008 between the CA group and the LA group.

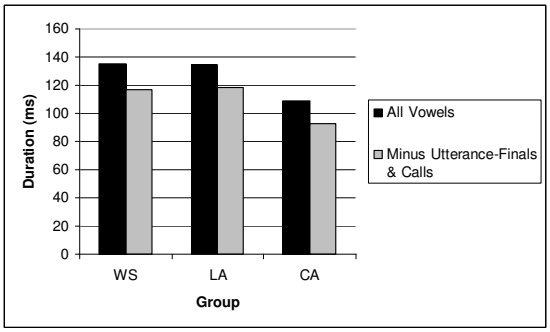

Figure 2: Graph showing a comparison of the mean vowel duration data.

The children with WS seem to use similar vowel durations as their LA matched peers which suggests that they are delayed in comparison to typically developing children of their own age. It is clear to see from Table 2 and Fig. 2 that they hardly differ at all from the LA group, even when calls and utterance-finals, known to be subject to lengthening, are removed from the analysis.

5. CONCLUSIONS

The aim of the current study was to investigate the pitch range and vowel durations of a group of children with WS in comparison to children matched for chronological age, and a group matched for receptive language skills in a spontaneous speech task. We found that children with WS have a significantly wider pitch range than children of the same chronological age or receptive language abilities. This suggests that there is something different about their use of pitch, or that they lack the ability to control pitch range effectively, which may contribute to these children sounding 'odd' or using a lot of emotional prosody. Research has shown that fundamental frequency and pitch are related to expressing emotions in speech (see [14] for a detailed review). This is in line with the findings of [17], that children with WS sound more emotionally involved. The vowel durations in children with WS in the present study were found to be similar to those of children matched on receptive language age. This suggests a delay and may contribute why these children may sound more like younger typically developing children. The extremely wide pitch range found in the WS group and their similarity in vowel duration to younger children may be one of the explanations why these children's prosody is often anecdotally described as 'odd'.

Although we have found this difference in the *production* when measuring pitch range with electronic equipment, it would be interesting to find out whether naïve listeners actually *perceive* a difference in the emotional involvement between the children with WS and their CA and LA peers. WS children clearly show a profile which suggests something atypical about their pitch, and needs further investigation.

In conclusion, it could be said that children with WS do not make use of or are unable to use prosody in spoken language in the same way, or to the same extent, as typically developing children.

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