

# Children's vocal behaviour in a pre-school environment and resulting vocal function

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## Abstract

*This study aims to shed some light onto the relationship between the degree of hoarseness in children's voices observed at different times during a day in pre-school and different aspects of their speech behaviour. Behavioural aspects include speech activity, phonation time, F0 variation, speech intensity and the relationship between speech intensity and background noise intensity. The results show that children behave differently and that the same type of behaviour has a varied effect on the different children. It can be seen from two children with otherwise very similar speech behaviour, that the fact that one of them produces speech at a higher intensity level also brings about an increase of hoarseness by the end of the day in pre-school. The speech behaviour of the child with highest degree of hoarseness on the other hand cannot be observed to be putting an extreme load on the vocal system.*

## Introduction

Speaking with a loud voice in noisy environments in order to making oneself heard demands some vocal effort and has been shown to harm the voice in the long run.

In several studies on vocal demands for different professions it has been shown that pre-school teachers are rather highly affected and that voice problems are common (Fritzell, 1996; Sala, Airo, Olkinuora, Simberg, Ström, Laine, Pentti, & Suonpää 2002; Södersten, Granqvist, Hammarberg & Szabo, 2002). This problem is to a large extent based on the need of the members of this professional group to make themselves heard over the surrounding noise, mainly produced by the children present.

It is reasonable to assume that children's voices are equally affected by background noise as adult voices. As children most of the time contribute to the noise in a pre-school setting themselves – rather than other environmental factors as traffic etc. – they are exposed to the noise source even more potently as they are closer to the noise source. Another factor point-

ing in the same direction is their shorter body length compared to pre-school teachers.

In an earlier study by McAllister et al., (2008, in press), the perceptual evaluation of pre-school children showed that the girls' voices revealed higher values on breathiness, hyperfunction and roughness by the end of the day, which for the boys was only the case for hyperfunction.

In the present study the interest is directed to speech behaviour of children in relation to the background noise and the affect on the vocal function. Diverse acoustic measurements were carried out for this purpose.

The investigation of *speech activity* is chosen to show the individuals' liveliness in the pre-school context and includes voiced and voiceless speech segments, even non speech voiced segments such as laughter, throat clearing, crying etc. In addition, measurements on *phonation time* were chosen, reflecting the vocal load. It should be noted that in some parts of speech intended voicing could fail due to the irregularity of the vocal fold vibrations – the hoarseness of the speaker's voice. Therefore, both measurements, *speech activity* and *phonation time* were considered important. In a study on phonation time for different professions, Masuda et al. (1993) showed that the proportion for pre-school teachers corresponded to 20% during working time, which is considered a high level compared to e.g. nurses with a corresponding level of 5.3% (Ohlsson, 1988). Having these findings in mind, the degree of children's speech activity and phonation time and the consequences for perceived voice quality is an interesting issue.

Other factors for the analysis of vocal load consist of *F0* including F0-variation and *speech intensity* including intensity variation. A vocal trauma can be based on using high fundamental frequency and high vocal loudness (and hyperfunction, which this study is not focusing on in particular), as Södersten et al. point out.

One further aspect that may increase the risk for voice problems is the need of a speaker to be heard over background noise. Therefore,

the relationship *speech intensity/background noise intensity* is investigated. According to the results of Södersten et al. the subjects speech was 9.1dB louder than the environmental noise, in an already noisy environment.

## Material and Method

The material investigated in the present study is part of the data gathered for the project *Barn och buller* (Children and noise). The project is a cooperation between the University of Linköping and KTH, Stockholm, within the larger BUG project (*Barnröstens utveckling och genuskillnader*; Child Voice Development and Gender Differences; <http://www.speech.kth.se/music/projects/BUG/abstract.html>). It consists of the data of selected recordings from four five-year-old children, attending different pre-schools in Linköping. These children were recorded using a binaural technique (Granqvist, 2001) three times during one day at the pre-school: at arriving in the morning (**m**) and gathering, during lunch (**l**) and in the afternoon during play time (**a**). The binaural recording technique makes it possible to extract one audio file containing the child's speech activity (**1**) and one file containing the surrounding sound (**2**). Each recording consisted of two parts. First a recording with a controlled condition was made, where the children were asked to repeat the following phrases three times: "En blå bil. En gul bil. En röd bil". Furthermore spontaneous speech produced during the following activities at the pre-school were recorded for approximately one hour.

The recordings of the controlled condition, comprising the phrase repetitions, were used in an earlier study (McAllister et al., in press) to perceptually assess the degree of hoarseness, breathiness, hyperfunction and roughness by three professional speech pathologists. Assessment was carried out by marking the degree of each of the four voice qualities plus an optional parameter on a Visual Analog Scale (VAS).

The averaged VAS-ratings by the speech pathologists for the four children regarding the comprehensive voice quality *hoarseness* were used as a selection criterion in the present investigation. The selected children showed different tendencies regarding the *hoarseness* variation over the day at pre-school (see e.g. Table 1).

- child **A** showed a marked increase of hoarseness,
- child **B** showed some increase of hoarseness,

- child **C** showed no increase of hoarseness,
- child **D** showed a clear decrease of hoarseness.

The development of the children's voices over the day was compared to the development of several acoustic measures of the recordings of spontaneous speech, shedding light on the children's speech behaviour and activity and the use of the voice

The *speech activity* of each child during each recording session was calculated by setting the number of obtained intensity counts in relation to the potential counts of the whole recording according to an analysis in PRAAT with a sampling rate of 100Hz (in %).

Furthermore *phonation time* was calculated by setting the number of obtained F0-measures in relation to the potential counts of the whole recording according to an analysis in PRAAT with a sampling rate of 100Hz (in %).

An analysis of the *fundamental frequency* and the *intensity* was carried out in PRAAT with a sampling rate of 100Hz for file (**1**), which contains the child's speech. Intensity measures were also normalised in comparison to a calibration tone and with regard to microphone distance from the mouth to 15 cm.

For both F0- and intensity measurements, the mean value, standard deviation and median (in Hz and dB) was calculated. For the sake of interpretation of the results regarding the measurements of fundamental frequency, additional F0-measurements of controlled speech obtained from the BUG-material for each child is given in the results.

Concerning the *background noise* investigation, the *intensity* was calculated in PRAAT with a sampling rate of 100Hz for file (**2**). Intensity measurements for this channel were normalised in comparison to a calibration tone.

Descriptive statistics for the interpretation of the measurements was used. The degree of hoarseness is not a direct consequence of the speech behaviour reflected by the acoustic measurements presented in the same rows in the tables below, because the recordings of the controlled condition were made before the recordings of spontaneous speech.

## Results

In this section the results of the diverse measurements are presented. In the tables, the perceptual ratings of degree of hoarseness obtained from an earlier study are shown, too. They are, however, not considered any further here but

are relevant for the next section, for the discussion.

### Speech activity and phonation time

Speech activity increases for the children A, B and D between morning and afternoon and is highest for the children B and C (Table 1). Child C has a higher activity in the morning and during lunch, but decreases activity in the afternoon.

Phonation time is in general highest for child B, who also shows the strongest increase over the day. The children A and D show lowest phonation time, however child A shows a clearly higher level in the afternoon. Child C has a degree of phonation time in between with the highest measure at lunchtime.

Table 1. Degree of hoarseness, speech activity and phonation time.

| CHILD | Re-cording | Hoarse-ness in mm VAS | Speech activity in (%) | phonation time in (%) |
|-------|------------|-----------------------|------------------------|-----------------------|
| A     | m          | 53                    | 20.6                   | 9.5                   |
| A     | l          | 81                    | 19.4                   | 9.9                   |
| A     | a          | 72.5                  | 30.5                   | 13                    |
| B     | m          | 16.5                  | 26.5                   | 14.5                  |
| B     | l          | 21                    | 33.3                   | 17.7                  |
| B     | a          | 25.5                  | 39.7                   | 25.2                  |
| C     | m          | 29.5                  | 34.1                   | 11.9                  |
| C     | l          | 26                    | 34.2                   | 14.2                  |
| C     | a          | 28.5                  | 24.9                   | 12.3                  |
| D     | m          | 20.5                  | 16.9                   | 8.1                   |
| D     | l          | 18.5                  | 21.2                   | 9.9                   |
| D     | a          | 10                    | 28.8                   | 9.7                   |

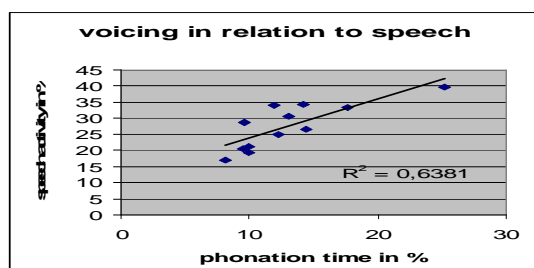


Figure 1. Correlation between speech activity and phonation time.

There is generally a good correlation between speech activity and phonation time as can be seen in Figure 1. This means that both measures

point in the same direction giving an outline to whether a child is an active speaker or not.

### Fundamental frequency (F0)

Table 2 shows not only the results from spontaneous speech but even measures of the mean fundamental frequency obtained from the BUG-recording with controlled speech.

Child B produces speech on a relatively high mean F0 with a large F0-range in the morning and decreases mean F0 and range over the rest of the day. Furthermore, child B is producing speech on a clearly higher mean F0 in spontaneous speech compared to controlled speech.

Child C presents a relatively strong increase of mean F0 over the day, however the range is broad in the morning and at lunch but less broad in the afternoon. Mean F0 is relatively high for spontaneous speech compared to the controlled condition in the afternoon but rather moderately higher for the other times of the day.

Child D shows a moderate increase of F0 and maintains a fairly stable F0-range over the day. F0-mean is higher in the morning and at lunch for spontaneous speech compared to controlled speech, however for the afternoon recording F0 is much higher for the controlled condition.

Table 2. Degree of hoarseness, mean fundamental frequency, F0-standard deviation, F0-median and mean F0 for controlled speech.

| CHILD and re-cording | Hoarse-ness in mm VAS | F0              |            |                   |                            |
|----------------------|-----------------------|-----------------|------------|-------------------|----------------------------|
|                      |                       | F0 mean in [Hz] | sd in [Hz] | F0 median in [Hz] | F0 mean controlled in [Hz] |
| A, m                 | 53                    | 322             | 77         | 308               | 354                        |
| A, l                 | 81                    | 331             | 79         | 325               | 307                        |
| A, a                 | 72.5                  | 328             | 74         | 315               | 275                        |
| B, m                 | 16.5                  | 369             | 100        | 358               | 266                        |
| B, l                 | 21                    | 308             | 88         | 295               | 236                        |
| B, a                 | 25.5                  | 305             | 85         | 296               | 236                        |
| C, m                 | 29.5                  | 290             | 108        | 292               | 284                        |
| C, l                 | 26                    | 302             | 110        | 306               | 285                        |
| C, a                 | 28.5                  | 335             | 92         | 328               | 279                        |
| D, m                 | 20.5                  | 312             | 91         | 298               | 270                        |
| D, l                 | 18.5                  | 321             | 88         | 311               | 279                        |
| D, a                 | 10                    | 332             | 90         | 318               | 354                        |

No clear tendency over the day can be observed for Child A; possibly a moderate F0-increase for lunch and a slight F0-decrease in the after-

noon. Range varies little between morning and lunch and decreases somewhat in the afternoon. Even the relationship between the F0-measurements of the different conditions shows quite a discrepancy: higher F0 occurs for the controlled recording in the morning, but at the other two instances F0 is higher for the spontaneous recordings, where the difference is largest in the afternoon.

Child A uses in general a narrow F0-range, whereas child C shows the broadest F0-range.

### Speech intensity

Child B produces speech with highest intensity in general and child C with lowest intensity (Table 3). Child B presents little variation in intensity at lunch and in the afternoon, which is equally high for both times of the day. Also the median of intensity is clearly higher for lunch and in the afternoon compared to the other children and for all recordings higher than the mean. This means that child B is producing speech at high vocal loudness most of the time.

Table 3. Degree of hoarseness, mean intensity, standard deviation and median of intensity.

| CHILD and re-cording | Hoarse -ness in mm VAS | Intensity mean in [dB] | Intensity, sd in [dB] | Intensity, median in [dB] |
|----------------------|------------------------|------------------------|-----------------------|---------------------------|
| A, m                 | 53                     | 71                     | 18                    | 72                        |
| A, l                 | 81                     | 72                     | 18                    | 75                        |
| A, a                 | 72.5                   | 71                     | 19                    | 72                        |
| B, m                 | 16.5                   | 76                     | 23                    | 80                        |
| B, l                 | 21                     | 73                     | 17                    | 76                        |
| B, a                 | 25.5                   | 78                     | 17                    | 83                        |
| C, m                 | 29.5                   | 64                     | 16                    | 65                        |
| C, l                 | 26                     | 65                     | 17                    | 67                        |
| C, a                 | 28.5                   | 70                     | 17                    | 72                        |
| D, m                 | 20.5                   | 72                     | 17                    | 77                        |
| D, l                 | 18.5                   | 71                     | 17                    | 75                        |
| D, a                 | 10                     | 70                     | 17                    | 72                        |

### Speech intensity and background noise

It can be seen in Table 4 that the speech intensity of the children's speech is lower than the intensity of the background noise in most cases. However, child C, who is exposed to the highest level of background noise, produces speech with the lowest intensity level. Child B, who also is exposed to a fairly high level of background noise on the other hand, also produces speech at a relatively high intensity level, which in the afternoon is even higher than the level of background noise. In the case of the lowest

measured level of background noise (70dB and 71dB) the children exposed to that level produce speech either slightly stronger (child D) or at the same intensity level (child A).

Table 4. Degree of hoarseness, mean background noise intensity, mean speech intensity and the difference between the intensity levels.

| CHILD and re-cording | Hoarse -ness in mm VAS | Background intensity mean in [dB] | Child's speech intensity, mean in [dB] | difference |
|----------------------|------------------------|-----------------------------------|--|------------|
| A, m                 | 53                     | 75                                | 71                                     | -4         |
| A, l                 | 81                     | 79                                | 72                                     | -7         |
| A, a                 | 72.5                   | 71                                | 71                                     | 0          |
| B, m                 | 16.5                   | 82                                | 76                                     | -6         |
| B, l                 | 21                     | 76                                | 73                                     | -3         |
| B, a                 | 25.5                   | 73                                | 78                                     | 5          |
| C, m                 | 29.5                   | 81                                | 64                                     | -17        |
| C, l                 | 26                     | 81                                | 66                                     | -15        |
| C, a                 | 28.5                   | 78                                | 70                                     | -8         |
| D, m                 | 20.5                   | 70                                | 72                                     | 2          |
| D, l                 | 18.5                   | 75                                | 71                                     | -4         |
| D, a                 | 10                     | 73                                | 71                                     | -2         |

### Discussion

In this section the relationship between the children's speech behaviour presented in the results and the degree of hoarseness obtained from an earlier study (McAllister et al.) are discussed. As there is a good correlation between speech activity and phonation time (see Figure 1), these parameters will be discussed together.

#### Hoarseness vs. speech activity and phonation time

The child with highest increase of speech activity and phonation time over the day – child B – also shows a clear increase of hoarseness. Child B, however is not the child with the highest degree of hoarseness. The child with the highest degree and increase of hoarseness – child A – does not show the highest degree of speech activity and phonation time. Child A reveals most speech activity and highest phonation time in the afternoon, but highest degree of hoarseness around lunchtime. Child C is an active child, but does not present us with a change for the worse in terms of hoarseness. However, this child exhibits a slightly higher degree of hoarseness than child B. Child D shows a fairly low level and an increase of speech activity over the day, but a decrease in hoarseness.

The parameters speech activity and phonation time solely do therefore not give a clear explanation to vocal fatigue. However, child B, who suffers from vocal fatigue by the end of the day presents us with an amount of phonation time comparable to what has been found for pre-school teachers (Masuda et al. 1993).

### **Hoarseness vs. fundamental frequency**

Child B presents us with particularly high mean F0 - much higher than F0 under controlled condition - and a broad F0-range in the morning, followed by an increase of hoarseness later in the day. However, Child C with fairly high F0-increase over the day and a high F0-range is not affected by a change of hoarseness for the worse. Child A with fairly stable mean F0 and F0-range over the day presents us with higher degree of hoarseness after the morning recordings. Child D with comparably stable mean F0 and F0-range on the other hand improved the voice condition over the day.

The use of high F0, a high F0-range solely does not seem to account for voice deterioration.

### **Hoarseness vs. speech intensity**

The child (B) producing speech at highest loudness level is the one that suffers most from increased voice problems later in the day. Strenuous speech production with high intensity therefore seems to be an important parameter to take into consideration when accounting for voice problems in children.

### **Hoarseness vs. speech intensity and background noise**

The children react in a different way to the level of background noise. Being exposed to a high level of background noise, one of the active children (B) seems to be triggered for a loud voice use, whereas one other speech active child (C) does not behave in the same way, but produces a much softer voice. The child reacting with a stronger voice (B) also responds with increased hoarseness later in the day.

As has been presented in the results, the children never produce speech at a loudness of 9.1dB above background noise, the level that had been found by Södersten et al. to occur for pre-school teachers. However, normalization with regard to microphone distance for the children's speech might be a question to be considered, since no comparable normalisation

has been carried out for the recordings of the background noise.

### **General discussion**

It can be found that child B refers to a typical child in a risk zone who suffers from voice problems by the end of the day due to hazardous voice use: being a lively child in a very noisy environment leads to making use of a loud, strong voice with a relatively high fundamental frequency and a high fundamental frequency range, resulting in vocal fatigue at the end of the day, reflected by an increase of hoarseness. The results for this child agree with Södersten et al. that producing high fundamental frequency at high vocal loudness can lead to vocal trauma.

Child A on the other hand does not show any particularly unusual voice use. However the degree of hoarseness was already very high in the first recording made in the morning and increases further in during the day. The high degree of hoarseness could have had influence on the calculation of different acoustic measurements, e.g. phonation time is fairly low, because the algorithm is not able to pick periodical parts of speech. Even the low measure of intensity might have been affected, since voiced sounds show stronger intensity, which might be lacking due to the child's high degree of hoarseness. It should however be noted that child A does not present us with high number of measurements on speech activity, so that a low degree of phonation time is unlikely to be based on period picking problems. This child might have a predisposition for a hoarse voice, or an already obtained voice problem.

Child C seems to be typical for a lively child with high speech activity (Table 1) and a broad F0-range (Table 2). On the other hand, this child shows lowest speech intensity (Table 3) which seems to be a good prerequisite to prevent voice problems. This child presents us with a somewhat higher degree of hoarseness than child B, but there is no change for worse over the day. When taking a look at how child C uses her voice, one can find out that she is humming a lot by herself.

Child D is most lively in the afternoon, where the degree of hoarseness is lowest (Table 1). Obviously, this child seems to need to warm up the voice during the day, which results in highest activity later in the day combined with best voice condition.

In summary, the children behave in a different way. Being an active child in a noisy environment can lead to a high level of speech activity and phonation time, and high F<sub>0</sub> and F<sub>0</sub> range. However, increase of hoarseness rather seems to occur if speech is produced with high intensity on top of high level measures of the other parameters. The child reacting with a louder voice also responds with increased hoarseness later in the day. As has been shown above, another speech active child's voice has not been affected in the same direction as it produces speech at a much weaker intensity.

## Conclusions

A lively child with high speech activity in a noisy environment feeling the need to compete with the background noise by producing loud speech is at risk to suffer from vocal fatigue. An equally lively child without the need to make her/himself heard in an equally noisy environment prevents a child from a similar outcome. Putting a high vocal load on the voice by producing speech at a high intensity level is therefore likely to be the key-parameter leading to a raised level of hoarseness. A child with a predisposition for hoarseness seems to be at risk to suffer from even stronger hoarseness later in the day even if there are no signs for extreme use of the voice.

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