

# Linköping University Post Print

## Child Voice and Noise: A Pilot Study of Noise in Day Cares and the Effects on 10 Children's Voice Quality According to Perceptual Evaluation

Anita McAllister, Svante Granqvist, Peta Sjölander and Johan Sundberg

N.B.: When citing this work, cite the original article.

Original Publication:

Anita McAllister, Svante Granqvist, Peta Sjölander and Johan Sundberg, Child Voice and Noise: A Pilot Study of Noise in Day Cares and the Effects on 10 Children's Voice Quality According to Perceptual Evaluation, 2009, Journal of Voice, (23), 5, 587-593.

<http://dx.doi.org/10.1016/j.jvoice.2007.10.017>

Copyright: Elsevier Science B.V. Amsterdam

<http://www.elsevier.com/>

Postprint available at: Linköping University Electronic Press

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-20457>

## **Child Voice and Noise: A Pilot Study of Noise in Day Cares and the Effects on 10 Children's Voice Quality According to Perceptual Evaluation**

Anita M McAllister<sup>1</sup>, Svante Granqvist<sup>2</sup>, Peta Sjölander<sup>2</sup> & Johan Sundberg<sup>2</sup>

### **Summary**

The purpose of this investigation was to study children's exposure to background noise at the ears during a normal day at the day care center and also to relate this to a perceptual evaluation of voice quality. Ten children, from three day care centers, with no history of hearing and speech problems or frequent infections were selected as subjects. A binaural recording technique was used with two microphones placed on both sides of the subject's head, at equal distance from the mouth. A portable digital audio tape (DAT) recorder (Sony TCD-D 100, Stockholm, Sweden) was attached to the subject's waist. Three recordings were made for each child during the day. Each recording was calibrated and started with three repetitions of three sentences containing only sonorants. The recording technique allowed separate analyses of the background noise level and of the sound pressure level (SPL) of each subjects' own voice. Results showed a mean background noise level for the three day care centers at 82.6 dBA Leq, ranging from 81.5 to 83.6 dBA Leq. Day care center no. 2 had the highest mean value and also the highest value at any separate recording session with a mean background noise level of 85.4 dBA Leq during the noontime recordings. Perceptual evaluation showed that the children attending this day care center also received higher values on the following voice characteristics: hoarseness, breathiness, and hyperfunction. Girls increased their loudness level during the day, whereas for boys no such change could be observed.

1 Department of Speech and Language Pathology, Faculty of Health Sciences, University of Linköping, Linköping, Sweden

2 Department of Speech, Music, and Hearing, Royal Institute of Technology (KTH), Stockholm, Sweden

## Introduction

Voice plays an important role in human communication. According to Laukkanen, about 43% of the total Finnish labor force is dependent on a functioning voice in their everyday work.<sup>1</sup> A dysfunctional voice has been found to be a serious social and psychological handicap.<sup>2</sup> It seems reasonable to assume that vocal habits are established during childhood. Thus, many undesirable vocal habits may originate as early as in infancy and continue into adult life.<sup>3</sup> In that light, studies of vocal behavior in relation to environmental factors typical for children seem important.

In a previous study of 10-year-old children's voices, it was found that those who attended after-school care had dysfunctional voices more often than children who did not.<sup>[4] and [5]</sup> Some of these children had chronic problems, that is, the hoarseness lasted for at least 2 months.<sup>5</sup> A correlation was also found between vocal dysfunction and children who attended preschool day cares. Also short-term group activities have been found to affect vocal quality in children. A study of voice quality pre- and postsummer camp showed an increased hoarseness on camp termination.<sup>6</sup> It is possible that the effort involved in “making yourself heard” in larger groups required in most day cares with high noise levels and a lack of acoustic absorbents, is detrimental to developing voices.

However, boys and girls do not seem to behave uniformly with respect to voice problems. Several studies report that boys have voice problems more often than girls.<sup>[4], [5] and [7]</sup> After puberty this gender difference is reversed.<sup>8</sup> In the study of 10-year-old children, boys and girls typically displayed different voice-quality characteristics, where girls tended to have a breathier voice and boys tended to have a more hyperfunctional voice quality.<sup>[9] and [10]</sup>

To date, no evidence of gender differences in vocal anatomy has been found in young children. Hence, the difference in voice quality between boys and girls may be attributed to diverging role models, where girls aim for a typical female voice with a more breathy quality.<sup>[11] and [12]</sup> However, compared to adults, children's larynxes are not just scaled-down versions.<sup>13</sup> The differences also include structure. During puberty, the vocal fold growth involves a differentiation into a layered structure. This maturation process of the muscle, ligament, and cover of the vocal folds is not completed until after puberty.<sup>14</sup> It has been proposed that this structural difference may cause children to be more prone to tissue reactions because of vocal abuse.<sup>[15] and [16]</sup>

In adult voices, high background noise levels have been found to influence several vocal parameters such as loudness, subglottal pressure,<sup>17</sup> fundamental frequency,<sup>[18], [19], [20], [21], [22]</sup> and voice quality.<sup>24</sup> Does the same pattern apply also for children? Because this is largely an unexplored field, it seems particularly important to investigate the effects of noise on the developing voice, considering this is the period when future vocal habits are being established.

Background noise has been found to be one of the main environmental problems in today's society.<sup>25</sup> For children, the preschool or school constitute a large part of the daily environment. Several investigations have studied noise levels in day cares and preschools or kindergartens. Most investigations have focused on the exposure to noise from a work environmental perspective, aiming at lowering recommended upper noise limits during preschool teachers' workdays. In a comprehensive study of the acoustics in preschools and after-school care during the late 1970s to early 1980s, noise levels between 35 and 100 dBA were recorded with a mean at 61 dBA.<sup>26</sup> Truchon-Gagnon and Héту<sup>27</sup> found background noise levels between 72 and 80 dBA during an 8-hour working day in a large study of noise levels in day cares in Canada. This is similar to the mean background noise level found in a study of 10 day cares in the greater Stockholm area at 76.1 dBA Leq,<sup>23</sup> and 72 dBA mean background noise found in 16 schools in the UK,<sup>28</sup> but somewhat lower than the noise levels at 80–90 dBA found in an early study of German kindergartens.<sup>29</sup> Between 2002 and 2003, a large survey of background noise levels was conducted in two small towns in southern Sweden.<sup>30</sup> The investigation consisted of 103 day cares and schools. Mean noise level with children present was 80 dBA Leq which is in correspondence to the higher values found in the German study.

Background noise may also impair speech comprehension.<sup>31</sup> At a noise level of 55 dBA, approximately 95% of running speech is perceived at a distance of 1 m (ISO/TR 3352, 1974). However, children seem to be more sensitive to background noise and need up to 5 dB lower noise levels to perceive 95% of the same speech material as the adults.<sup>32</sup> Full sentence intelligibility in listeners with normal hearing require the signal-to-noise ratio (ie, the difference between the speech level and the sound level of the interfering noise) to be at least 15 dBA. Because, typically, the SPL of normal speech is about 50 dBA at a listener's ears, ambient noise with sound levels of 35 dBA or more reduces the intelligibility of normal speech.<sup>33</sup>

The aim of the present study was twofold: (1) to investigate the actual noise levels that children are exposed to at the level of the ears during a normal day in a day care setting and (2) to study the effects of a day at the day care on vocal parameters by perceptual evaluation of voice quality.

The study is part of a larger investigation “BUG.”<sup>1</sup>

## **Material and methods**

### **Subjects**

Three day cares were selected in Linköping, a university town with approximately 135 000 inhabitants in the southeastern part of Sweden. The day cares were selected to represent different socioeconomic areas. An information sheet was sent to the day care centers and distributed to the parents of children aged 5 years. Several parents were interested in the participation of their child. Eleven children with no history of hearing or speech problems, or frequent ear, nose, and throat infections were selected as subjects. An informed consent form was signed by the parents together with a short survey regarding the selection criteria. Thus, 11 5-year-old children, five girls and six boys were selected.

### **Recording method**

A binaural recording technique was used to record the background noise and the subjects own voice simultaneously. Two omnidirectional electret condenser microphones (TCM 110, AA-video, Linköping, Sweden) were used and placed directly in front of the ears on each child, at equal distance from the mouth. The mouth to microphone distance varied from 4, 5 to 6 cm across subjects. Before analyses, the microphone distance was normalized to 15 cm for all subjects. Symmetrical placement of the microphones was vital to record the subjects' own voice at an equal SPL and phase in both microphones. The signal was recorded on a DAT tape recorder. The recorder was placed in a small waist bag worn by the child. The recordings were calibrated at 90–92 dB using a sustained vowel and a sound-level meter (Brüel and Kjaer 2215, Borås, Sweden).

The investigation was conducted as a field study to record the children's vocal behavior in a natural setting and with natural background noise. The children were recorded three times during a normal day at the day care center. All recordings were gathered by the same test

leader. Each recording session started with a calibration of the loudness level. The first recording was on arrival followed by circle meeting activities with 14–18 children led by 2–3 preschool teachers. The activities consisted of a presentation of the days schedule and also some games, rhymes, and singing. The second recording was 1 hour later, during lunch, and during activities after lunch such as rest or silent play. The third recording was made in the afternoon during free-play indoors. One child's recordings had to be discarded because of problems with the recording equipment, leaving a total of 10 children's recordings from three day care centers, six boys and four girls. Three subjects attended day care center nos. 1 and 3, respectively, and four subjects attended day care center no. 2.

The background noise levels were measured at each day care center and recording session. The relationship of background noise levels and sound pressure level (SPL) in the vocal output; voice-quality variation over the day evaluated by means of a listening test; differences between boys and girls regarding these parameters; and the relationship between the vocal parameters and the background noise levels at the three day care centers were also measured.

The children's voices were separated from the background noise using the software *Aura* developed by Granqvist.<sup>34</sup> The separated recordings were then stored in individual computer files. This made it possible to do the perceptual evaluation and also to measure SPLs in the children's voices and in the background noise separately. The SPL measurements for both the children's voices and background noise were calculated from the separated channels supplied by *Aura*. The equivalent SPL for background noise was measured in both dBA and dB without the A-weighting. The equivalent SPL for the children's voices were measured in dB without the A-weighting because this measure has been found to be the most appropriate for voice production.<sup>35</sup> Because of ceiling effects occurring at 116 dB, the maximum SPL level for the children's own voices and background noise were set to 114 dB. This results in an underestimate of loudness levels particularly affecting the self-measures.

### **Speech material**

The speech material analyzed in the present study consisted of three repetitions of three short sentences at the beginning of each recording. The sentences consisted of only sonorants, “A blue car. A yellow car. A red car” (“En blå bil. En gul bil. En röd bil.”). The instructions were given by a female test leader in normal pitch and loudness. To reduce the imitation of intonation and pitch level, the instruction was “Can you say a blue car. A yellow car. A red

car?" When the child had done this once, he or she was asked to say it again three times. The last two repetitions were used in the analysis. The sentences had not been previously rehearsed.

### **Perceptual evaluation**

The randomized recordings of each child and the repeated sentences were perceptually analyzed by a group consisting of three expert listeners, all speech and language pathologists working with voice disorders. In the evaluation protocol, all parameters were represented by a 100-mm visual analog scale except pitch which was represented by a 200-mm line with *very high* and *very low* marked, respectively, at the extremes.<sup>[4] and [36]</sup> The other parameters were hoarseness, breathiness, roughness, hyperfunction, and an open parameter to offer other options to the raters if necessary (Appendix 1). The choice of parameters was based on previous studies of children's voices.<sup>[4] and [5]</sup> Three repetitions of each set of sentences were presented to the listener on a computer using Sennheiser PX200 headphones (AA-video, Linköping, Sweden). Thus, the listeners rated 30 voice samples each.

### **Statistical analysis**

Results were analyzed using *SPSS* 15.0 and Mann-Whitney *U* test, Kruskal-Wallis, and Spearman's rank correlation for nonparametric data. A linear trend analysis was performed in *Microsoft Office Excel* 2003 for the parametric data.

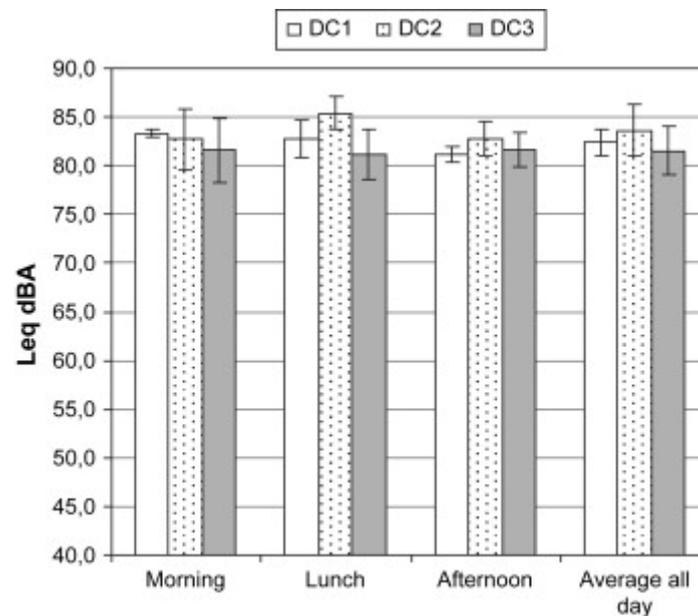
### **Ethical approval**

Before data collection, ethical approval was received from the Research Ethical Committee at Linköping University, no. 03-173.

### **Results**

The total recording time for each child varied between 125 and 193 minutes. The mean all-day noise level for the three day care centers was 82.6 dBA Leq, ranging from 81.5 to 83.6 dBA Leq. The highest mean value for any day care center throughout the day was observed during noon-/lunchtime at day care center no. 2 with a mean value from four separate recordings of 85.4 dBA Leq. The overall mean background noise level for the three day cares across recording sessions are shown in Figure 1. The differences in background

noise levels between day care centers did not reach significance according to a Kruskal-Wallis test. However, the lunchtime value for day care center no. 2 showed a tendency with  $P = 0.09$ .



*Figure 1. Mean background noise levels for the three day care centers across the three recording session and all-day mean values. Notice the high mean noise level during the noon recordings at day care center no. 2. In day care center no. 1, there is a clear decrease of background noise over the day.*

To compare the present data on background noise levels with that of a previous investigation of preschool teachers using the same binaural recording procedure and equipment, our data were plotted against equivalent data from Södersten et al<sup>23</sup> (Figure 2). The values found in the present study are higher throughout.

Results from the perceptual evaluation of voice quality showed highest mean values throughout for day care center no. 2 (Figures 3A–D). The three most prevalent voice characteristics were hoarseness, breathiness, and hyperfunction. Roughness was present to a smaller extent as can be seen in Figure 3D. A statistical analysis of correlation using Spearman's rank correlation showed that hoarseness correlated with the perceptual parameters hyperfunction and breathiness at 0.81 and 0.91, respectively. The correlations were significant at  $P < 0.001$ .

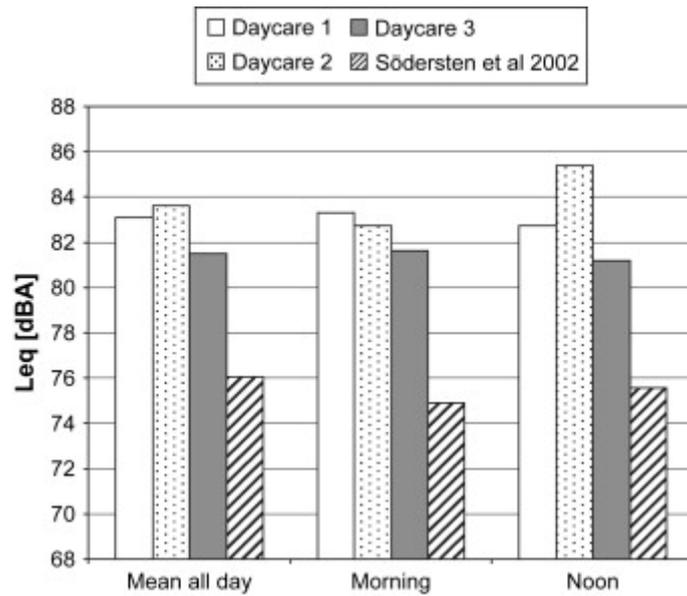


Figure 2. The present data regarding background noise levels are compared to a previous investigation of preschool female teachers using the same recording method and equipment.

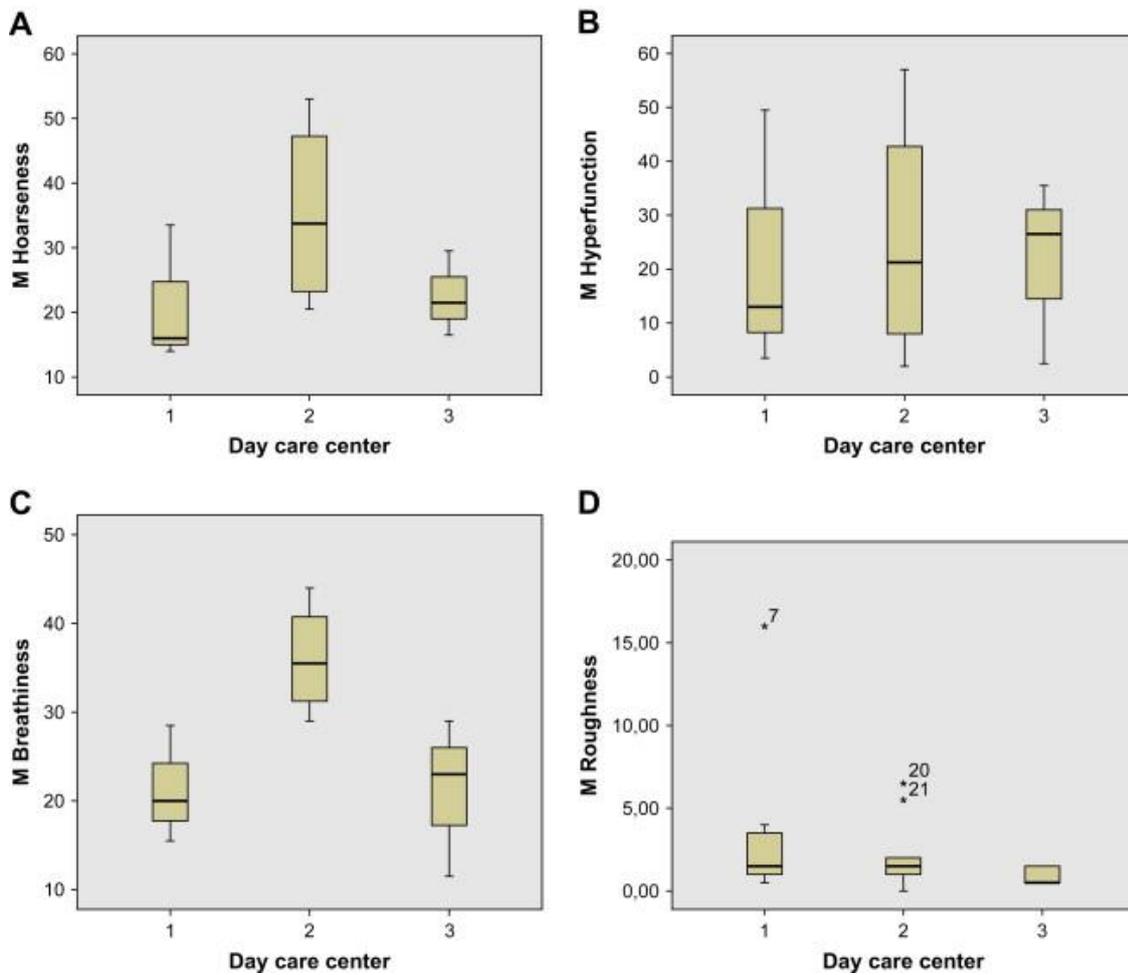
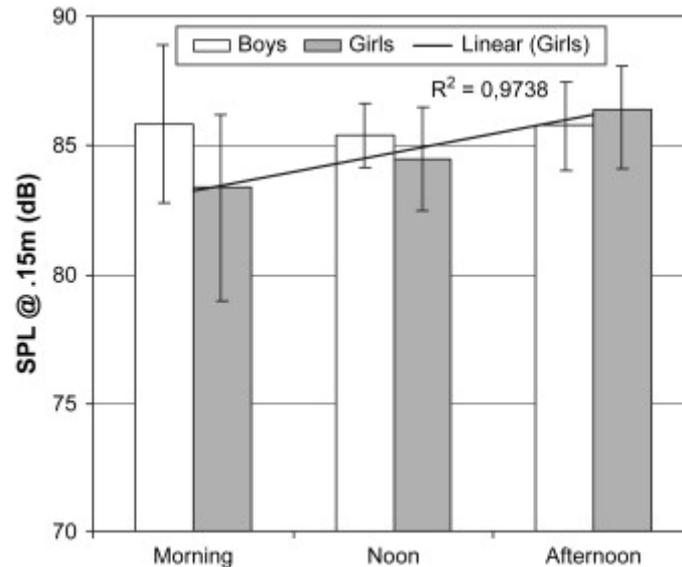


Figure 3. Mean perceptual ratings of the four most prevalent voice characteristics for 10 children's recordings and the three day care centers. Notice the high mean values for day care center no. 2. **A.** Hoarseness. **B.** Hyperfunction. **C.** Breathiness. **D.** Roughness.

In Figure 4, the mean loudness levels for boys and girls depending on recording session are shown. Girls show a clear increase in loudness over the day with a linear regression at  $r^2 = 0.9838$ . For boys, no such trend could be observed.



*In Figure 4, the mean loudness levels for boys and girls depending on recording session are shown. Girls show a clear increase in loudness over the day with a linear regression at  $r^2 = 0.9838$ . For boys, no such trend could be observed.*

For girls, an increase in the mean perceptual ratings for the parameters hyperfunction and breathiness during the day could be observed (Figure 5). The change was most obvious between the morning and lunch recordings. None of these changes were statistically significant. For the parameter hoarseness, the highest value was observed during lunchtime. For boys, the hoarseness and hyperfunction showed a minor increase during the day, however, still to a lower level than those for girls (Figure 6). For girls, the perceptual parameters hyperfunction, breathiness, and roughness correlated with hoarseness at 0.914, 0.868, and 0.84, respectively. All correlations were significant at  $P < 0.001$ . For boys, only hyperfunction and breathiness correlated with hoarseness at 0.673 and 0.786, respectively. The correlations were significant at  $P = 0.002$  for hyperfunction and at  $P < 0.001$  for breathiness. None of the differences between boys and girls were significant according to a Mann-Whitney  $U$  test.

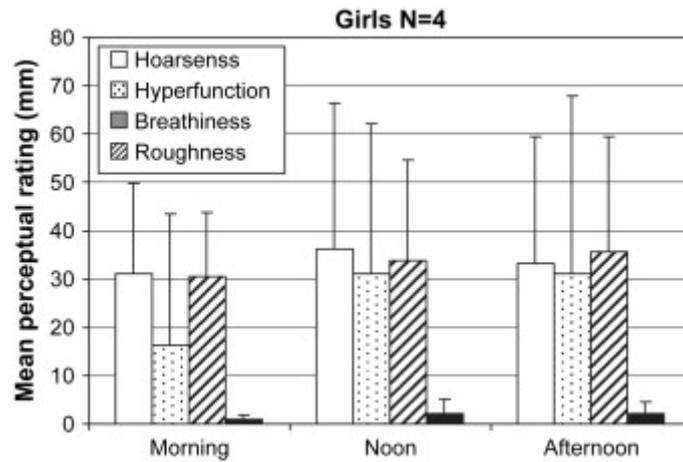


Figure 5. The perceptual rating for the girls related to recording session. Note the increased perceptual rating for breathiness and hyperfunction over the day.

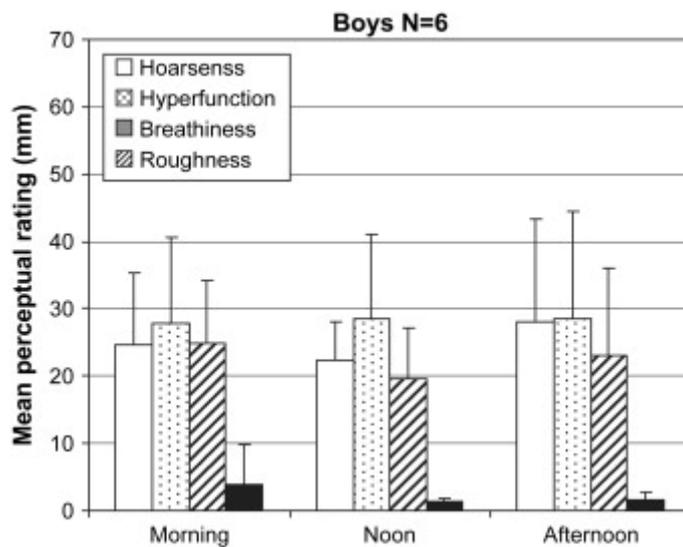


Figure 6. The perceptual rating for the boys related to recording session. There was a moderate increase regarding the perceptual rating for hyperfunction and a decreased rating for roughness over the day.

## Discussion

High background noise levels were observed in all three day care centers. For day care center no. 2, the ambient noise level exceeded the level above which hearing protection is normally advised. However, the method of recording background noise in the present study is not comparable to most studies of noise in work environments, because the children themselves and their activities constitute the main noise source. A correlation between the number of children present and recorded noise levels has been found previously. An increase from six to 12 children resulted in a raise between 1 and 6 dBA.<sup>26</sup> It is well known that noise exposure

may lead to hearing impairment. If the noise exposure is concentrated to shorter periods during the day, the basic criterion of 75 dB Leq during an 8-hour working day implies that the risk would also be negligible with a 4-hour exposure to 78 dBA, a 2-hour exposure to 81 dBA, and a 1-hour exposure to 84 dBA. Conversely, if additional exposure occurs outside the 8 working hours, for example, as a result of commuting to work or leisure activities, the limit of safe exposure, despite the lack of conclusive evidence, may be estimated to be 70 dB Leq averaged over a 24-hour day.<sup>25</sup> This would imply that the children are at a risk of developing hearing impairment because of the mean noise exposure above 81 dBA Leq for all three day care centers. According to the EU safety directives for workers, hearing protection should be provided in environments with noise levels at or above 80 dBA Leq for 8 hours.<sup>37</sup> Children at day care centers are not incorporated in these safety regulations.

The noise levels in the present study were clearly higher than those found in a previous study of adult preschool teachers using an identical recording procedure.<sup>23</sup> Several factors may contribute to these differences. Because the children themselves constitute the primary noise source, one obvious explanation is the distance from the noise source, where adults are further from the playing children and also roughly twice as tall. The difference in height alone would correspond to approximately a 6-dB reduction in noise exposure, which is almost exactly the difference between our observed mean noise levels at 82.6 dBA Leq and the results observed by Södersten et al<sup>23</sup> at 76.1 dBA Leq.

Different patterns were observed for boys and girls with regard to vocal loudness. Girls get louder as the day progresses but no such change could be observed for boys because they are rather loud all the way through. The perceptual evaluation of the girls' voices show higher values on breathiness, hyperfunction, and roughness at the end of the day; for boys, this is true for hyperfunction and for roughness there is even a minor decrease. However, as indicated by the large standard deviation, there are large individual differences in the material, especially for the girls. Because the boys are already loud in the morning, it is possible that some girls try to “compete” to be heard, driving the increase over the day. Could this variation in loudness contribute to the adverse effects being more apparent in the girls' voices? Highest mean values for background noise and also for the perceptual voice parameters were found in day care center no. 2. This corroborates the link between high background noise levels and voice problems despite the lack of significant differences between gender and day care centers.

This study indicates that a day at the day care center can induce both audible and measurable effects on children's voices. Considering the increased number of children attending day care centers and also the increased number of children in the day care center groups, this is indeed an important finding. Whether these effects also are long term cannot be concluded from the present study. On the other hand, higher values on deviant voice characteristics throughout for day care center no. 2 together with the highest noise levels may be interpreted in that direction. Despite the small number and large individual variations in the present study, results clearly indicate detrimental effects on children's voice quality that need to be investigated further on a larger group of participants.

## Acknowledgments

The participation and enthusiasm of the children and day care centers are gratefully acknowledged much depending on the contacts and well-completed recordings by Susanna Andersson, SLP-student at Linköping University. The thorough perceptual evaluation of the expert listeners is also gratefully accredited. Statistical advice was provided by Torbjörn Ledin and Elisabeth Ericsson.

## References

- 1 Laukkanen A-M. *On speaking voice exercise* [Doctoral Dissertation]. Finland: Department of Phoniatics, Faculty of medicine, University of Tampere; 1995.
- 2 M.S. Benninger, A.S. Ahuja, G. Gardner and C. Grywalski, Assessing outcomes for dysphonic patients, *J Voice* **12** (1998), pp. 540–550.
- 3 W.A.C. Zerffi, Functional vocal disabilities, *Laryngoscope* **49** (1939), pp. 1143–1147.
- 4 E. Sederholm, A. McAllister, J. Sundberg and J. Dalkvist, Perceptual evaluation of hoarseness using continuous scales, *Scand J Logop Phoniatr* **18** (1993), pp. 73–82.
- 5 A. McAllister, E. Sederholm, J. Sundberg and P. Gramming, Relations between voice range profiles and physiological and perceptual voice characteristics in ten-year-old children, *J Voice* **3** (1994), pp. 230–239.
- 6 M. Casper, A.L. Abramson and B. Forman-Franco, Hoarseness in children: summer camp study, *Int J Pediatr Otorhinolaryngol* **3** (1981), pp. 85–89.
- 7 P.N. Carding, S. Roulstone, K. Northstone and ALSPAC study team, The prevalence of childhood dysphonia: a cross-sectional study, *J Voice* **20** (2006), pp. 623–630.

- 8 P. Yu, R. Garrel, R. Nicollas, M. Ouaknine and A. Giovanni, Objective voice analysis in dysphonic patients: new data including nonlinear measurements, *Folia Phoniatr Logop* **59** (2007), pp. 20–30.
- 9 McAllister, A. *Acoustic, perceptual and physiological studies of ten-year-old children's voices* [Doctoral Dissertation]. Stockholm: Department of Logopedics and Phoniatics, Karolinska Institute, Huddinge University Hospital and Department of Speech, Music and Hearing, Royal Institute of Technology (KTH); 1997 ISBN 91-628-2392-2.
- 10 Sederholm, E. *Hoarseness in ten-year-old children. Perceptual characteristics, prevalence and etiology* [Doctoral Dissertation]. Stockholm: Department of Logopedics and Phoniatics, Karolinska Institute, Huddinge University Hospital and Department of Speech, Music and Hearing, Royal Institute of Technology (KTH); 1996 ISBN 91-628-2287-X.
- 11 J. Laver, *The Phonetic Description of Voice Quality*, Cambridge University Press, London (1980).
- 12 M. Södersten and P. Lindestad, Glottal closure and perceived breathiness during phonation in normally speaking subjects, *J Speech Hear Res* **33** (1990), pp. 601–611.
- 13 J. Kahane, Growth of the human prepubertal and pubertal larynx, *J Speech Hear Res* **25** (1982), pp. 446–455.
- 14 M. Hirano, S. Kurita and T. Nakashima, Growth, development and aging of human vocal folds. In: D. Bless and J. Abbs, Editors, *Vocal Fold Physiology*, College Hill Press, San Diego (1983), pp. 22–43.
- 15 E. Sédlacková, Les dysphonies hypercinétiques des enfants, causées par surmenage vocal, *Folia Phoniatr* **12** (1960), pp. 48–60.
- 16 J. Casper, R.H.K. Colton and R. Leonard, *Understanding Voice Problems* (3rd ed.), Lippincott Williams & Wilkins, Baltimore (2006).
- 17 E. Vilkman and Vinturi Alku, Dynamic extremes of voice in the light of time domain parameters extracted from the amplitude features of glottal flow and its derivative, *Folia Phoniatr Logop* **54** (2002), pp. 144–157.
- 18 P. Gramming, J. Sundberg, S. Ternström, R. Leanderson and W. Perkins, Relationship between changes in voice pitch and loudness, *J Voice* **2** (1988), pp. 118–126.
- 19 J.C. Stemple, J. Stanley and L. Lee, Objective measures of voice production in normal subjects following prolonged voice use, *J Voice* **9** (1995), pp. 127–133.
- 20 L. Rantala, T. Määttä and E. Vilkman, Measuring voice under teachers working circumstances: F0 and perturbation features in maximally sustained phonation, *Folia Phoniatr Logop* **49** (1997), pp. 281–291.

- 21 P. Alku, J. Vintturi and E. Vilkmann, Measuring the effect of fundamental frequency raising as a strategy for increasing vocal intensity in soft, normal and loud phonation, *Speech Commun* **38** (2002), pp. 321–334.
- 22 E. Sala, E. Airo and P. Olkinuora *et al.*, Vocal loading among day care center teachers, *Logoped Phoniatr Vocol* **27** (2002), pp. 21–28.
- 23 M. Södersten, S. Granqvist, B. Hammarberg and A. Szabo, Vocal behavior and vocal loading factors for preschool teachers at work studied with binaural DAT recordings, *J Voice* **16** (2002), pp. 356–371.
- 24 M. Södersten, S. Ternström and M. Bohman, Loud speech in realistic environmental noise: phonetogram data, perceptual voice quality, subjective ratings, and gender differences in healthy speakers, *J Voice* **19** (2005), pp. 29–46.
- 25 B. Berglund, T. Lindvall and M.E. Nilsson, Buller och höga ljudnivåer, Noise and High Loudness Levels in Environmental Health Report 2005 in Miljöhälsorapport 2005, The National Board of Health and Welfare, Institute of Environmental Medicine, Center for Public Health, Sweden (2005).
- 26 R. Colven, Akustisk i förskolor och fritidshem, Acoustics in Day-Cares and After-School Environment Final Report from the MAFF-project, Royal Institute of Technology, School of Architecture, Stockholm (1986).
- 27 C. Truchon-Gagnon and R. Héту, Noise in day-care centers for children, *Noise Control Eng J* **30** (1988), pp. 7–64.
- 28 B. Shield and J.E. Dockrell, External and internal noise surveys of London primary schools, *J Acoust Soc Am* **115** (2004), pp. 730–738.
- 29 H.G. Dieroff and C. Siegert, Zum problem der stimmstörungen bei kindergärtnerinnen, *Monatsschr Ohrenheilkd Laryngorhinol* **98** (1964), pp. 72–80.
- 30 A. Bertilsson, A. Haggæus, Y. Sandqvist, K. Skagelin, M. Björkman and L. Barregård, Rapport från ljudnivåmätningar på förskolor och skolor i Lidköping och Skara, Report on sound levels measured at pre-schools and schools in Lidköping and Skara, Västra Götalandsregionens Miljömedicinska centrum, Lidköpings kommun, Skara Kommun (2003).
- 31 C.C. Crandell and J.J. Smaldino, Classroom acoustics for children with normal hearing and with hearing impairment, *Lang Speech Hear Serv Sch* **31** (2000), pp. 362–370.
- 32 L. Marshall, J.F. Brandt, L.E. Marston and K. Ruder, Changes in number and type of errors on repetition of acoustically distorted sentences as a function of age in normal children, *J Am Aud Soc* **4** (1979), pp. 218–225.

- 33 In: B. Berglund, T. Lindvall, D. Schwela and K.T. Goh, Editors, *Guidelines for Community Noise*, World Health Organization (WHO), Geneva (2000).
- 34 S. Granqvist, The self-to-other ratio applied as a phonation detector for voice accumulation, *Logoped Phoniatr Vocol* **28** (2003), pp. 71–80.
- 35 P. Gramming and J. Sundberg, Spectrum factors relevant to phonetogram measurements, *J Acoust Soc Am* **83** (1988), pp. 2352–2360.
- 36 M.E. Wewers and N.K. Lowe, A critical review of visual analogue scales in the measurement of clinical phenomena, *Res Nurs Health* **13** (1990), pp. 227–236.
- 37 European Parliament, Directive 2003/10/EC on the minimum health and safety requirements regarding exposure of workers to the risk arising from physical agents (noise) Feb 6, 2003, *OJEC* (2003), p. L 042.

## Appendix 1.

Perceptual evaluation of 5-year old children's voices, recorded at DCC  
(Lyssnarbedömning, 5-åriga barnröster, inspelade på dagis).

Terminology in Swedish is given within parenthesis.

Voice no \_\_\_\_\_ Listener \_\_\_\_\_

*Not at all* (Inte alls)

*A lot* (Mycket)

*Hoarseness* \_\_\_\_\_  
(Heshet)  
*Breathiness* \_\_\_\_\_  
(Läckage)  
*Hyperfunction* \_\_\_\_\_  
(Hyperfunktion)  
*Roughness* \_\_\_\_\_  
(Skrovlighet)  
*Other* (Annat) \_\_\_\_\_

*Pitch* (Röstläge)

*Low* (Lågt)

*High* (Högt)

---

*Comments*  
(Kommentarer) \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_