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NOISE IN PRESCHOOLS AND ITS EFFECT ON THE HEART RATE VARIABILITY OF PRESCHOOL TEACHERS

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ABSTRACT

As noise exposure in preschools may be one of the main stress factors for preschool teachers worldwide, such effects on cardiovascular activity and psychological response were investigated in 23 preschool teachers from nine private preschools. The participants were equipped with 24-hours-ECGs and stationary noise recordings were conducted in the group rooms during working time. Furthermore, questionnaires on noise-related stress, well-being, stress perception, burnout risk, noise annoyance and noise sensitivity were provided. The average sound pressure level in the rooms during the first four hours was $L_{Aeq,4h}$ 74.7 dB(A) (*SD* = 1.74). The sound $peak_{max}$ ranged from 90.8 to 127.6 dB(A). A significant correlation between heart rate and sound pressure level ($L_{Aeq,4h}$) was found, $r = .40$, $p = .04$ (one-tailed). Noise sensitivity and noise annoyance showed no effect on the correlation. With increasing sound level classes (≤ 65 dB(A), 66 - 75 dB(A), 76 - 85 dB(A)), the heart rate increased significantly, and the heart rate variability decreased significantly. It was also found that tolerating noise becomes more difficult with increasing length of employment and increasing age. Measures to reduce noise in preschools are recommended.

Keywords: *noise, preschools, preschool teachers, heart rate, heart rate variability*

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1. INTRODUCTION

Noise exposure in preschools and its stress on preschool teachers has been investigated for many years around the world, whereby stationary noise measurements in preschool classes reaches in average levels from L_{eq} 70 dB(A), up to more than L_{eq} 80 dB(A) and personal recordings with noise dosimeters can reach even higher levels above L_{eq} 85 dB(A).[1],[2],[3],[4] Preschool teachers reported a high physical and emotional strain due to the noise.[2],[5] It was also found that those who have been in the profession for many years and with higher age feel more stressed by noise today than in the past.[2]

Reasons for the generation of noise in preschool classes can be found in the sounds that children produce, in particularly from the activities they are engaged in,[6],[7],[4],[8] in the number of children in a group,[7],[1],[4] in the age of the children,[7],[8] and in the construction of the buildings.[9] Furthermore, higher noise levels being found in preschools that follow an open plan concept compared to enclosed classrooms[10] and in buildings with a lack of sound-proofing measures.[11],[12]

As research has shown, acute noise effects can already occur at environmental sound levels that are not considered as harmful to hearing, when certain activities such as concentration, relaxation or sleep are disturbed[13],[14] and the complexity of work activities increases. Low intensity noise already showed cognitive and physiological effects.[15][16] Extra-aural noise effects have been found to increase noradrenalin,[17] heart rate (HR)[15][18],[19], [20],[11] and lead to changes in heart rate variability (HRV), with a shift towards sympathetic dominance at higher noise levels.[15][21]

It has been shown that noise annoyance and noise sensitivity can also lead to physiological reactions in

connection with noise exposure, such as higher heart rates or a higher risk of cardiovascular disorders. [22],[23],[24],[25]

The aim of this study was to investigate whether noise in preschools has an impact on the cardiovascular activity of preschool teachers. Noise sensitivity and noise annoyance were considered as possible confounding variables. The study also aimed to provide insight into the health status of preschool teachers in relation to noise-related stress, well-being, stress perception and burnout risk. Furthermore, it was investigated if the preschool teachers of the current study feel also more stressed with higher age and years of service than at the beginning of their profession.

The following research questions were delineated:

- Do noise levels in preschools affect the cardiovascular activity (heart rate and heart rate variability) of preschool teachers?
- Do noise sensitivity and noise annoyance have an impact on the relationship between noise and cardiovascular activity?
- Do preschool teachers find it more difficult to tolerate noise with increasing duration of employment as well as with higher age?

2. RESEARCH DESIGN AND METHODS

The study was conducted in nine private preschools in Vienna, involving 23 preschool teachers (22 females and one male). Data was collected per individual on one day. Noise level in the classroom was recorded throughout the preschool teachers' working day. The preschool teachers were provided with 24-hour ECGs and asked to fill in questionnaires. A detailed observation took place during the entire study.

3. DATA COLLECTION

3.1 Stationary sound recordings

The sound level in the preschool classrooms was recorded by Voltcraft® "DL-160S Sound Pressure Data Logger", a device with an accuracy of ± 1.4 dB, according to the European standard EN 61672-1 Class 2, with a 1.27 cm (1/2") electret condenser microphone. The microphone was placed in the preschool classrooms at a height of 1.5 to 2 m above the floor on one of the side walls. Sound level was recorded in dB(A) values, according to 10 seconds intervals. In addition to the dB(A) value, the peak level was recorded. The recordings varied between 4 and 8 hours, with starting times from 7.30 a.m. to 12.40 p.m.
Two equivalent A-weighted sound pressure levels, L_{Aeq}, were calculated for each individual: (1) $L_{Aeq,4h}$, standardized over the first four working hours, and (2) $L_{Aeq,5min}$ over the entire working time of each preschool teacher.

3.2 Physiological data

Physiological activity was measured with an ECG recorder "TOM Medical Development GmbH" and analyzed with the program Medilog Darwin. Five-minute intervals of cardiovascular activity during the preschool teachers work shifts and mean values of the five-minute intervals during the first four hours of work were calculated. Heart rate (HR) and heart rate variability (HRV), measured by the pNN10 value, as a convenient und sensitive time domain parameter for cardiovascular activity,[26] were used for the analysis. It has been shown that low pNNxx parameters (pNN10 - pNN40) correlate negatively with stress and depression and positively with well-being.[27]

3.3 Questionnaires

At the beginning of the study, preschool teachers were asked to complete questionnaires on (1) sociodemographic information and noise-related stress, (2) psychological characteristics such as well-being, stress, and burnout risk, and (3) perceived noise sensitivity and noise annoyance.

- Sociodemographic information included age, gender, years of service, extent of employment, group size, supervision key, availability of acoustic ceiling and the option to hold a break. Noise-related stress was measured by "Erhebungsbogen zu lärmbedingtem Stress für ErzieherInnen in Kindertagesstätten", which was developed for a study with preschool teachers in Cologne, Germany [2]. Toleration of noise was assessed with the question: "Compared with the beginning of my professional activity, today I find tolerating high sound levels …": (1) harder, (2) unchanged, (3) easier.[2]
- Well-being was assessed by the WHO-Five Well-being Index (WHO-5), which measures current mental well-being with a time frame over the previous two week. The raw score ranges from 0 to 25, whereby a score < 13 indicates poor well-being as an indication for testing for depression (ICD-10). Stress was assessed by the Perceived Stress Questionnaire (PSQ, short version), which consists of 20 items. It contains the four subscales: "worries", "tension", "joy", and "demands".

Burnout risk was measured by Maslach Burnout Inventory (MBI), which measures three aspects of burnout using 22 items: “emotional exhaustion”, “personal accomplishment”, and “depersonalization”.

- Noise sensitivity was assessed by „Kurzfragebogen zur Erfassung der Lärmempfindlichkeit“ (engl. Short questionnaire for the assessment of noise sensitivity), which consists of nine items with a row score range from 0 to 27. Noise annoyance was assessed using the “Questionnaire on general noise annoyance” (developed by M. Trimmel), a rating scale with seven statements about noise annoyance, answered on an 11-point scale with the endpoints “agree” vs. “disagree”. A high score indicates a high level of noise annoyance.

4. STATISTICAL ANALYSIS

Statistical analyses were performed using SPSS 20.0. Sociodemographic data and perception of noise-related stress were analyzed descriptively. Correlations between noise exposure and physiological data were calculated using Pearson's correlation. The influence of noise sensitivity and noise annoyance as possible moderators was assessed by partial correlations. One-way repeated measures ANOVAs were performed to determine whether heart rate (HR) and heart rate variability (pNN10) changed with the magnitude of three sound level classes. Pairwise comparisons were used to assess differences between the groups. To test whether noise sensitivity and noise annoyance have an effect on the change in cardiovascular activity with the magnitude of the sound level classes, Pearson's correlations were performed between these parameters and the difference in the change in sound level classes.

5. RESULTS

5.1 Stationary noise recordings within preschool classes

The equivalent sound pressure level, for the first four hours of the preschool teachers’ work shifts, ranged from L_{Aeq} 70.3 dB(A) to L_{Aeq} 78.6 dB(A) and showed a mean value of L_{Aeq} 74.7 dB(A) (*SD* = 1.74). The average maximum sound $peak_{max}$ yielded a value of 96.9 dB(A) (*SD* = 7.31), with a range of 90.8 to 127.6 dB(A).

5.2 Sample characteristics

The average age of the preschool teachers was 31.4 years (*SD* = 8.6), with a range of 20 to 59 years. The average working time was 32.3 hours per week (*SD* = 8.6). About half of the sample had been working in a preschool for less than four years. More than three-quarters stated to work with a group size of 20 to 25 children and more than half in a team of two staff. An acoustic ceiling was only available in group rooms of two preschool teachers. The majority of preschool teachers described their professional activity as physically and mentally stressful (73.9%) and reported that it is often or always true that they feel tired and exhausted at the end of a working day (82.6%).

5.3 Health status of preschool teachers

The perception of stress, well-being, burnout risk as well as the extend of noise sensitivity and noise annoyance of the preschool teachers was in the average range. However, seven participants fell below the stated WHO threshold of 13, which indicates poor well-being and testing for depression according to ICD-10. Furthermore, four individuals showed a high risk for burnout in the emotional exhaustion scale of the Maslach Burnout Inventory (MBI).

5.4 Results of cardiovascular activity

Due to technical and individual issues, one defective ECG device and two cases of medication influence, three individuals had to be excluded and the calculations have been performed with 20 preschool teachers. The preschool teachers’ mean heart rate (HR) during the first 4 hours of working time was 91.1 beats per minute (*SD* = 7.29), with a range of 78.8 to 105.6. The average mean of pNN10 showed a value of 60.9 (*SD* = 8.47) and ranged from 40.3 to 72.3.

The progress of sound level and heart rate over the entire working time was graphically depicted for each participant. Figure 1 shows an example of the correlation of the sound pressure level $L_{Aeq,5min}$ and the heart rate of one preschool teacher during the entire working day.

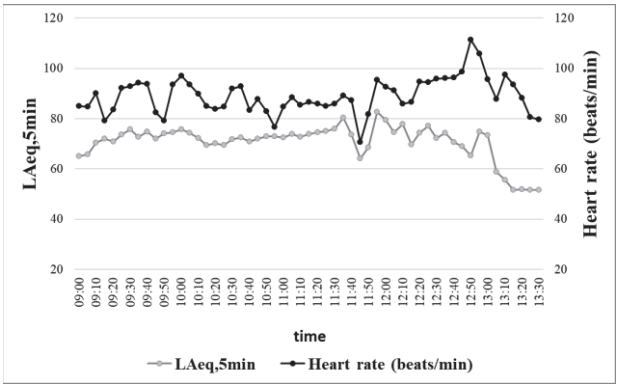

Figure 1. Sound pressure level $L_{Aeq,5min}$ and heart rate (beats/min) of one preschool teacher.

5.5 Correlation between sound pressure level and heart rate (HR) and heart rate variability (pNN10)

Pearson's correlation was used to analyze the association between the sound pressure level during the first four hours of work shift ($L_{Aeq,4h}$) and heart rate (HR) as well as heart rate variability (pNN10). The analysis showed a statistically significant positive correlation between the sound pressure level ($L_{Aeq,4h}$) and heart rate, r = .40, p = .04 (one-tailed) (Figure 2).

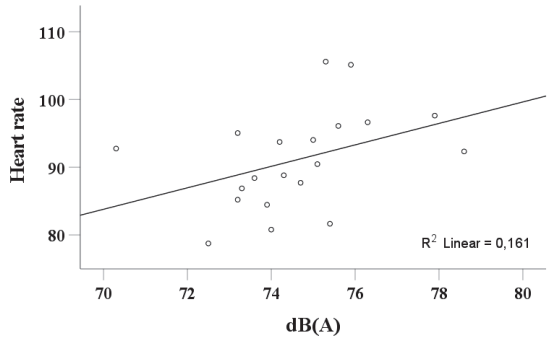

Figure 2. Scatterplot of the correlation between sound pressure level ($L_{Aeq,4h}$) and heart rate.

No significant correlation was found between the sound pressure level ($L_{Aeq,4h}$) and heart rate variability (pNN10), r = -.05, p = .41 (one-tailed).

5.6 Noise sensitivity and noise annoyance as possible moderator variables on the correlation between sound pressure level and cardiovascular activity

To test whether noise sensitivity and noise annoyance are moderator variables for the correlation between sound pressure level ($L_{Aeq,4h}$) and cardiovascular activity, partial correlations were performed. The result showed that after controlling noise sensitivity and noise annoyance, the correlations between sound pressure level and HR remain statistically significant, r = .41, p = .04 (noise sensitivity), r = .43, p = .03 (noise annoyance).

5.7 Change in cardiovascular activity (HR and pNN10) with increasing sound level classes

Three noise classes were created: (1) "low noise" ≤ 65 dB(A), (2) "medium noise" 66 - 75 dB(A), and (3) "high noise" 76 - 85 dB(A), with the five-minute intervals, $L_{Aeq,5min,}$ over the entire working time of each preschool teacher. Conspicuous values caused by influences on cardiovascular activity other than the sound level (e.g. irritation at the beginning of the recording, leaving the room, movement and nicotine consumption) were removed. The calculation was performed only with 16 preschool teachers, as four other cases had to be excluded because no data of noise class (1) were available for these participants. One-way repeated measures ANOVAs were performed to examine a change in HR and pNN10 with respect to the three noise classes.

5.8 Change of HR with increasing noise classes

The result show that the HR was statistically significantly affected by the noise classes, F(1.38, 20.63) = 15.39, p < .001, η2 = .51. Post hoc comparisons using the Bonferroni correction indicated that the mean score of the HR in the "low noise" condition (M = 84.66, SD = 7.76) was statistically significantly different than in the "medium noise" condition (M = 89.38, SD = 6.55), p = .006 as well as in the "high noise condition" (M = 91.11, SD = 6.29), p = .002. Figure 3 shows the change in heart rate between the three noise classes.

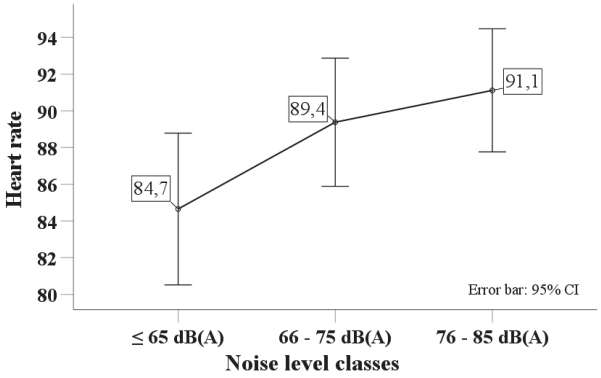

Figure 3. Mean heart rate and 95% CI at different noise classes.

5.9 Change of pNN10 with increasing noise classes

The results show that the pNN10 was statistically significantly affected by the noise classes, $F(2, 30) = 9.48$, $p = .001$, $\eta 2 = .39$. Post hoc comparisons using the Bonferroni correction indicated that the mean score of pNN10 in the "low noise" condition ($M = 67.72$, $SD = 7.49$) was statistically significantly different than in the "medium noise" condition ($M = 62.67$, $SD = 8.30$), $p = .009$ as well as in the "high noise" condition ($M = 62.06$, $SD = 7.22$), $p = .015$. Figure 4 shows the change in pNN10 between the three noise classes.

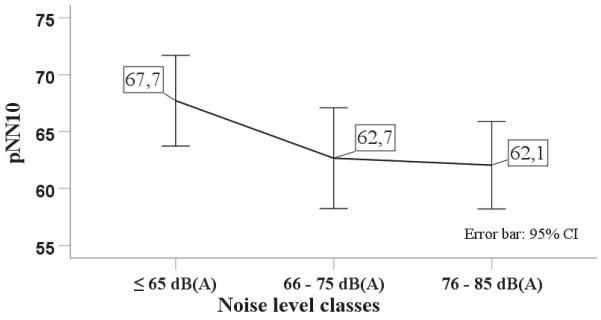

Figure 4. Mean values and 95% CI of heart rate variability (pNN10) at different noise classes.

5.10 Influence of noise sensitivity and noise annoyance on the change in cardiovascular activity with increasing noise class

To determine whether noise sensitivity has an influence on the change in HR and pNN10 with increasing noise class, the difference in HR as well as in pNN10 between the low noise class ≤ 65 dB(A) and the high noise class 76 - 85 dB(A) was calculated. The correlations between the difference in HR between low and high noise classes, and noise sensitivity as well as noise annoyance showed no significant result, (noise sensitivity: $r = .23$, $p = .20$; noise annoyance: $r = -.06$, $p = 41$). There was also no significant correlation between the difference in pNN10, with noise sensitivity, $r = -.36$, $p = .08$ and noise annoyance, $r = -.02$, $p = .47$. This indicates that noise sensitivity has no influence on the change in cardiovascular activity with increasing noise class.

5.11 Toleration of noise with increasing age and increasing years of service

The preschool teachers were asked whether tolerating noise has become more difficult, unchanged, or easier compared to when they first started working. A distinction was made according to years of employment, based on the median ($MD = 3.0$) between those who had been employed for up to four years and those who had been employed for four or more years. Furthermore, preschool teachers were compared within two age groups (< 30 years, ≥ 31 years) based on the median ($MD = 30.0$). The result shows that preschool teachers who have been in their profession for four or more years find it statistically significantly harder to tolerate noise today than at the beginning of their carrier ($\chi^2(2) = 7.50$, $p = .023$) (Figure 5). Furthermore, a trend to statistical significance could be found between the age groups. Preschool teachers aged over 31 reported finding it more difficult to tolerate noise now than when they started working. ($\chi^2(2) = 5.23$, $p = .073$) (Figure 6).

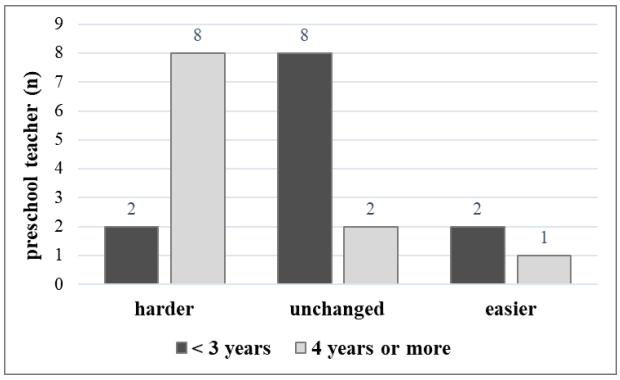

Figure 5. Toleration of noise with years of service.

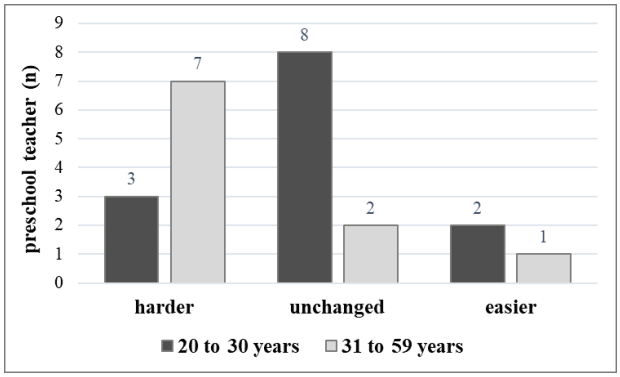

Figure 6. Toleration of noise with age.

6. DISCUSSION

The aim of the study was to investigate whether noise in preschools has an impact on the cardiovascular activity of preschool teachers. For this purpose, changes in heart rate (HR) and heart rate variability (pNN10) were examined in relation to the noise level. Noise annoyance and noise sensitivity were considered as possible confounder variables. Furthermore, the health status of the preschool teachers as well as the toleration to noise regarding increasing age and years of service was assessed by questionnaires.

The majority of the preschool teachers described their professional activity as physically and mentally stressful (73.9%) and reported that it is often or always true that they feel tired and exhausted at the end of a working day (82.6%). This finding is in line with previous research. [2],[5]

The perception of stress, well-being and burnout risk of the preschool teachers was in the average range. However, seven participants fall below the stated WHO threshold of 13, which indicates poor well-being testing for depression according to ICD-10, and four participants showed a high risk in the emotional exhaustion scale of the MBI for burnout.

A largely synchronous correlation was found between heart rate and sound level during working hours for individual preschool teachers. As in previous research, a statistically significant positive correlation between the sound level and the heart rate was also found in the present study.[15][18],[19],[20],[11] However, no significant correlation was found between the sound level and the heart rate variability (pNN10). Noise sensitivity and noise annoyance had no effect as moderator variables in the correlation between sound level and heart rate.

It was investigated whether cardiovascular activity changes at different noise levels classes. With increasing sound level classes, an increased heart rate with a simultaneous decrease in heart rate variability (pNN10) was found, which can be assumed to indicate an increased stress load.[27] The heart rate increases by about five beats per minute at sound level class 66 to 75 dB(A) compared to sound level class ≤ 65 dB(A). In the pairwise comparisons between the low and medium sound level class as well as the low and high sound level class, statistically significant differences were found. No significant correlations could be found for the change in heart rate by sound level classes and noise sensitivity as well as noise annoyance. Furthermore, no significant correlations could be found for the change in pNN10 by sound level classes, and noise sensitivity as well as noise annoyance.

Regarding tolerating noise between two different age groups and years of service it was shown that it becomes more difficult for preschool teachers, who had been in their profession for four or more years, to tolerate noise than at the beginning of their profession. Furthermore, preschool teachers from the age of 31 years and more reported to find it more difficult to tolerate noise today than in the beginning of their career.

The results of the stationary noise measurements in the preschool classrooms are in accordance with previous findings from different countries. Acoustic measures such as sound absorbing ceilings were only present in the classes of two preschool teachers, which shows that most participants of the current study had to work in rooms without acoustic measures. As studies have shown, sound-absorbing measures help to reduce long reverberation times in rooms[11],[12] which leads to a decrease in stress levels.[11] It is therefore of vital importance that sound-absorbing constructure measures are also installed in the preschool classrooms.

7. CONCLUSION

In the present study, preschool teachers were exposed to equivalent sound pressure levels of L_{Aeq} 70.3 dB(A) to L_{Aeq} 78.6 dB(A) during their first four hours of their work shift.

The majority of the preschool teachers described their professional activity as physically and mentally stressful and stated that they felt tired and exhausted after a working day. The impact of the noise level on the cardiovascular activity of preschool teachers could be confirmed. Therefore, noise in preschool can be considered as an indicator of psychophysiological stress. Since it was shown that the toleration of noise gets harder for preschool teachers already after four years of service, it is crucial to take measures to reduce noise in preschool classrooms. Sound absorbing construction measures should be compulsory in every class. Construction measures should also be taken to reduce background noise levels as much as possible.

Given the small sample size of the present study and that some cases had to be excluded from the analyses due to technical problems, the influence of medication and missing values in the "low noise class", the results should be taken with caution and future research with larger sample sizes is recommended. As the study was mainly conducted on female subjects, with the exception of one male subject, it is also suggested that follow-up studies include more male subjects if possible.

8. ACKNOWLEDGMENTS

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