Group 975, Signal Processing and Acoustics, Aalborg University

Classification and Measurement of Noise

Christoph Kirsch, Jonas Buchholdt and Jorge Bravo

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Course ..... Architectural And Environmental Acoustics
Measurement Location 1 ..... Flex room area in A4
Measurement Location 2 ..... B3-107 group room area in B3
Date of Measurements ..... September 20th and 24th, 2018
Time of Measurements ..... 09:30 - 13:30
The measurement is inspired by ..... ISO 9612:2009 [2]

1 Introduction

Undesired sound, commonly referred to as noise, is known to have adverse effects on well-being and performance at certain tasks [1, p. 22 ff.]. Measurements were conducted at student workplaces in two different sized group rooms at Fredrik Bajers Vej 7. The purpose of these investigations is to compare the acoustical conditions and assess whether an impairment of productivity due to noise is to be expected at either of the two locations.
Analysis will be performed by looking at the recorded sound pressure levels over time and by looking at one-third-octave-band levels. The former allows for characterising the noise regarding short term characteristics like impulsiveness and long term characteristics like the equivalent continuous sound pressure level. Frequency content will be analysed in order to further investigate acoustical conditions that occurred during the measurement period.
The measurement locations were chosen to have a large disparity in terms of rooms dimensions and number of intended occupants. Measuring at only one day per location may not be a representative characterisation of the typical acoustical conditions at those locations. It can however give clues about the tendencies, that might make one or another room concept preferable from an acoustical standpoint.
Ideally, the results could be combined with measurement results for room acoustical parameters (e.g. reverberation time RT_{60}) and subjective assessments of some kind. These more extensive investigations are not within the scope of this measurement report.

2 Test locations

2.1 Flex room

The Flex room is a free open workspace intended to be used by all 9^{th} semester students. This room is separated into 5 different sections, each of them intended to be used by one group. The sections are not divided by walls, but with the use of room dividers. There are 3 different kinds of divider present in the room, but they are not divided equally amongst every section. The present type of dividers are standing pinboards and whiteboards with a gap between the board and the floor, and open storage units with shelves. Within every section, there are 3 tables and 6 chairs. For the recording purpose, we used the only available section (section 4).

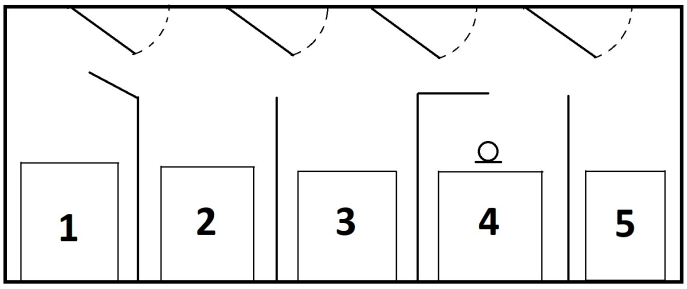
At the beginning of the measurement, there were only 2 people sitting in section 5, but the number of people present throughout the day fluctuated heavily, reaching the maximum around 11:00, when there were 20 people in the room. This rooms has air conditioning, which was active for almost the whole duration of the measurements.

The microphone is placed in a way that would mimic the position of an average student's head, with a height of 1.2 m and at a position in the workspace, where the chair is removed. The room has a length of 14.73 m, a width of 5.71 m and a height of 2.75 m. In one of the longer sides of the room, there are 4 doors, 3 of which remained closed through the whole measuring time. On the opposite wall there are windows facing the canteen. These windows were closed for the whole duration. Without taking the recessed position of the windows into account, the room has a volume of $231.3\,\text{m}^3$.

The following 1 shows pictures of the room and the microphone position, as well as an approximated floor plan. The sound field found in this room can be described as a semi-reverberant field, similar to what could be found in an open-plan office, due to the presence of moderately reflective surfaces, such as tables, whiteboards and shelf racks.

(a) The figure shows the position of the microphone

(b) The figure shows a picture of the room from one corner



(c) Approximated layout of the Flex room

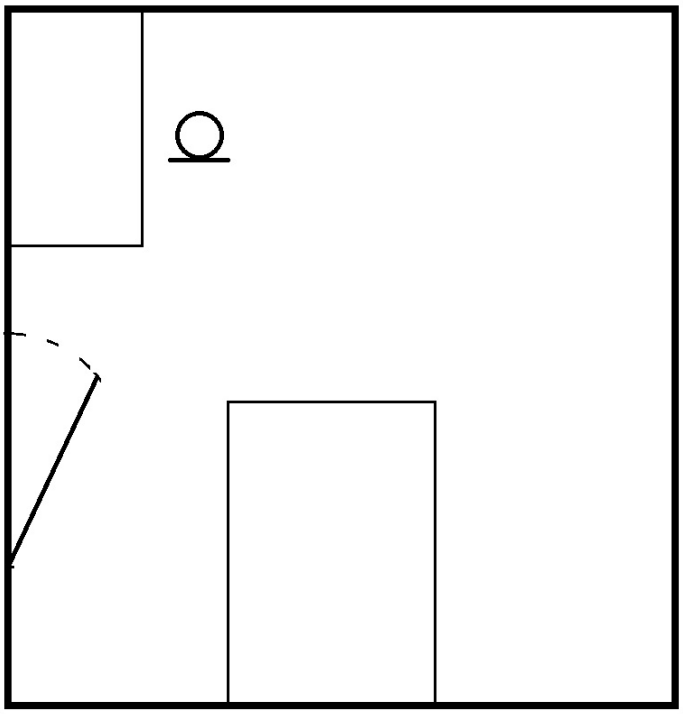
Figure 1: Pictures and layout of the Flex room

2.2 B3-107

Room B3-107 is a group room with a group of 5 students. The group is located around 3 tables in the right side of the room, when entering it from the door. At the left side of the room 2 tables are situated along the wall, one on each longer side. The microphone is located in a similar way as for the Flex group, so with a height of 1.2 m and at a possible work position where the chair is moved away. For this case, and in order not to obtain non-representative results due to proximity to noise sources, the microphone has been placed with some distance to the group members. The room is equipped with ventilation and not air-condition as in the Flex room. The ventilation is coupled to the lab ventilation system, and cannot be controlled by the group. The room wall is equipped with a metal rail system where whiteboards and pinboards are attached. The room has a length of 5.66 m, a width of 3.72 m and a height of 2.74 m. Without taking the recessed windows into account, the room has a volume of 57.7 m^3.

(a) The figure shows the position of the microphone

(b) The figure shows a picture of the room from one corner



(c) Approximated layout of room B3-107

Figure 2: Pictures and layout of the Flex group room

3 Measurement Equipment

- Audio interface: RME Fireface UCX
  - Serial number: 23811948
  - AAU number: 108230

- Calibrator: B&K 4231
  - Serial number: 2694647
  - AAU number: 78301
- Measurement microphone: Presonus PRM 1
- Analysis Software: MATLAB® R2018b
- Recording Software: Ableton Live 9 and Reaper 5

4 Procedure

The measurements have been conducted inspired by standard ISO 9612:2009 [2], but adapted to the conditions of the exercise. This allowed us to take a 4 h recording instead of a full 8 h day. The microphone is connected to the sound card, where the gain is adjusted such that clipping is avoided while recording. After several tests and adjustment of the pre-amp, the gain was chosen to 33 dB for both measurements.

The per-amp is connected to a computer via USB, where recording software is used for recording and storing the original time signal. The measurement in the Flex room was recorded with Ableton Live 9, while the recording in the group room B3-107 was recorded in Reaper 5. Both recordings started with a calibration tone of 94 dB for approximately 30 s and afterwards the calibrator was removed from the microphone. The measurement was conducted over 4 h, and it started in the morning such that the lunch break is taken into account within the measurement time.

5 Measurement Results

Several values and graphs have been derived from the measured sound pressure. Figure 3 and Figure 4 show the A-weighted sound pressure level, that has been measured within a time period of approx. 4 h. Additionally, characteristic values have been calculated and are displayed in Table 1.
In Figure 3 the level is fluctuating between approx. 38 dB and approx. 84 dB. The equivalent A-weighted sound pressure level L_{Aeq} is 55.6 dB. In Figure 4 the level is fluctuating between approx. 38 dB and approx. 83 dB. The equivalent A-weighted sound pressure level is L_{Aeq} 61.3 dB.

Table 1: Equivalent sound pressure levels and percentiles derived from the A-weighted sound pressure for the time period between 09:32 and 13:36.

	Flex room	B3-107
	all values in [dB]	
L_{Zeq}	66.6	64.9
L_{Aeq}	61.3	55.6
L_{Ceq}	66.1	63.2
P_{A90}	65.3	58.1
P_{A50}	56.5	46.5
P_{A10}	46.1	39.3

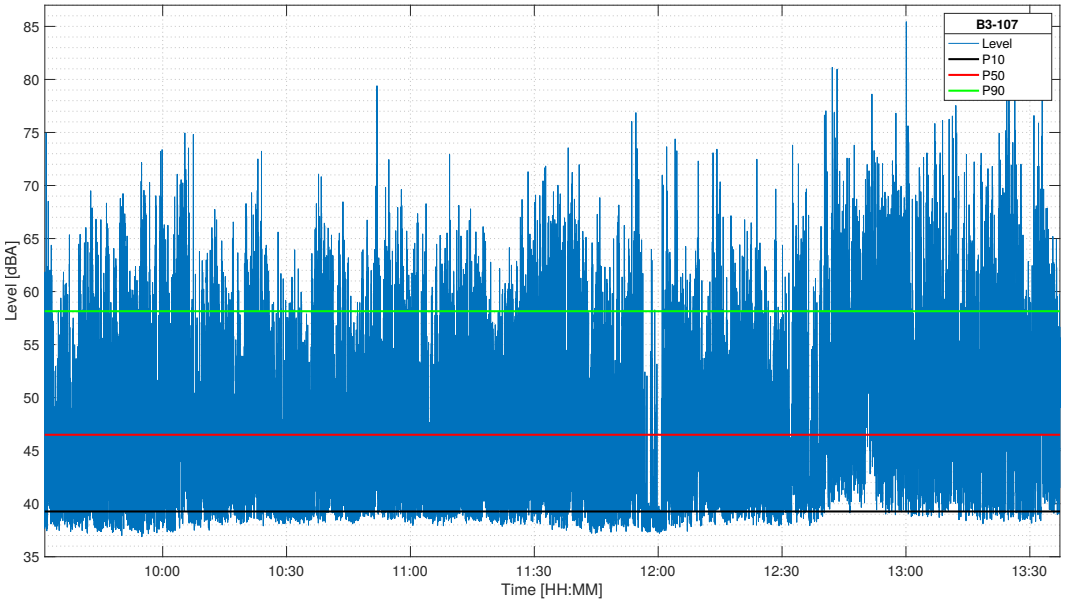


Figure 3: B3-107, A-weighted sound pressure level, fast time weighting, the horizontal lines represent different percentiles: 10 (black), 50 (red) and 90 (green).

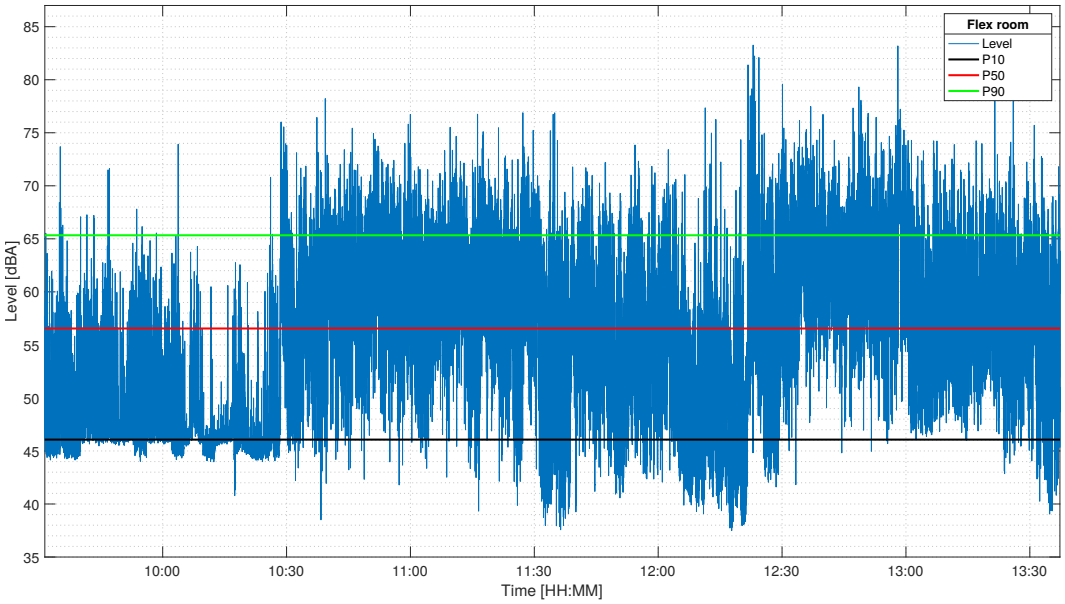


Figure 4: Flex room, A-weighted sound pressure level, fast time weighting. The horizontal lines represent percentiles: 10 (black), 50 (red) and 90 (green).

Figure 5 shows the A weighted sound pressure level, that has been recorded in B3-107, during an arbitrarily chosen 1-minute-segment. The figure displays the curves for fast

($\tau = 0.125\,\mathrm{s}$), as well as for slow ($\tau = 1\,\mathrm{s}$) time weighting. It is visible, that for curve, that is corresponding to the slow time weighting, the peaks and dips are less distinctive than for the curve, that is corresponding to fast time weighting.

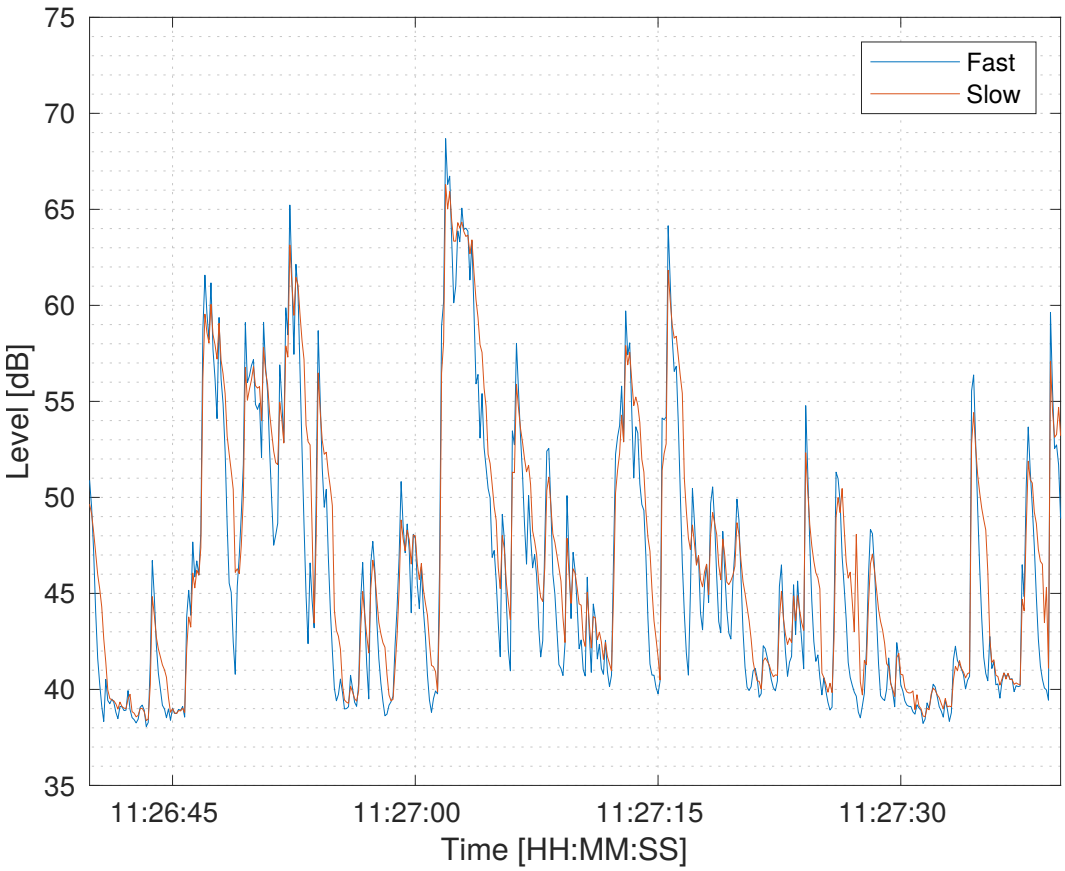


Figure 5: A-weighted sound pressure level B3-107, comparison between fast and slow time weighting, arbitrarily chosen one-minute-segment.

A one-third octave equivalent sound pressure for the total measuring period has been calculation for both room, since the environment for both room is a working area for students. Both the A-weighted and C-weighted sound pressure level is calculated and compared between both room. The following Figure 6 shows the A-weighted sound pressure level and the next Figure 7 shows the C-weighted sound pressure level. Since Both A-weighted and C-weighted is a subtraction of the unweighted data, the relation in dB between the room stays the same compare to the unweighted data.

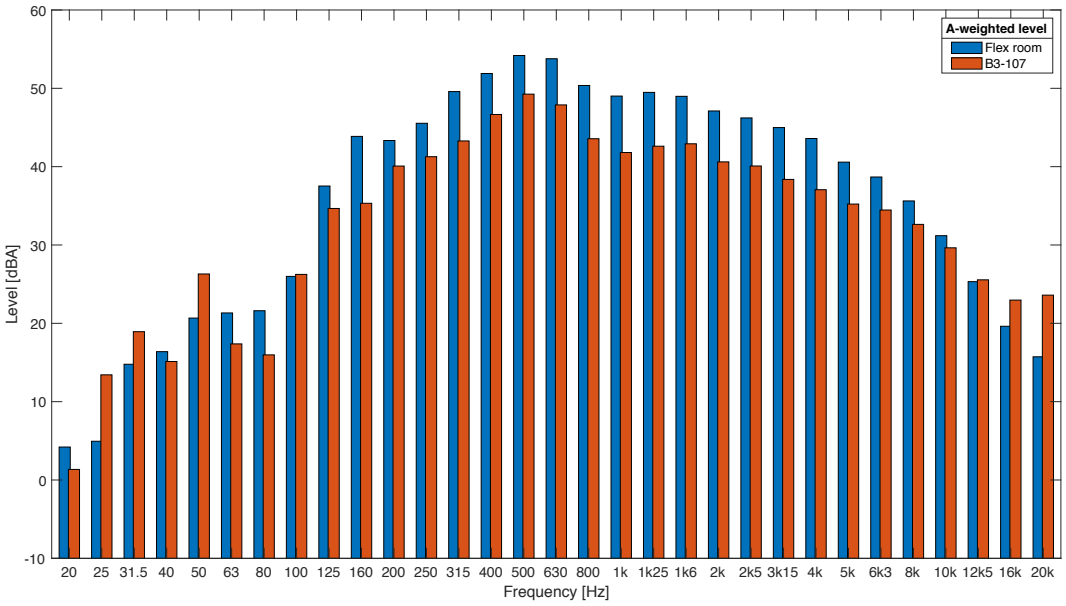


Figure 6: The figure shows the A-weighted one-third octave equivalent sound pressure for the total measuring period for both room

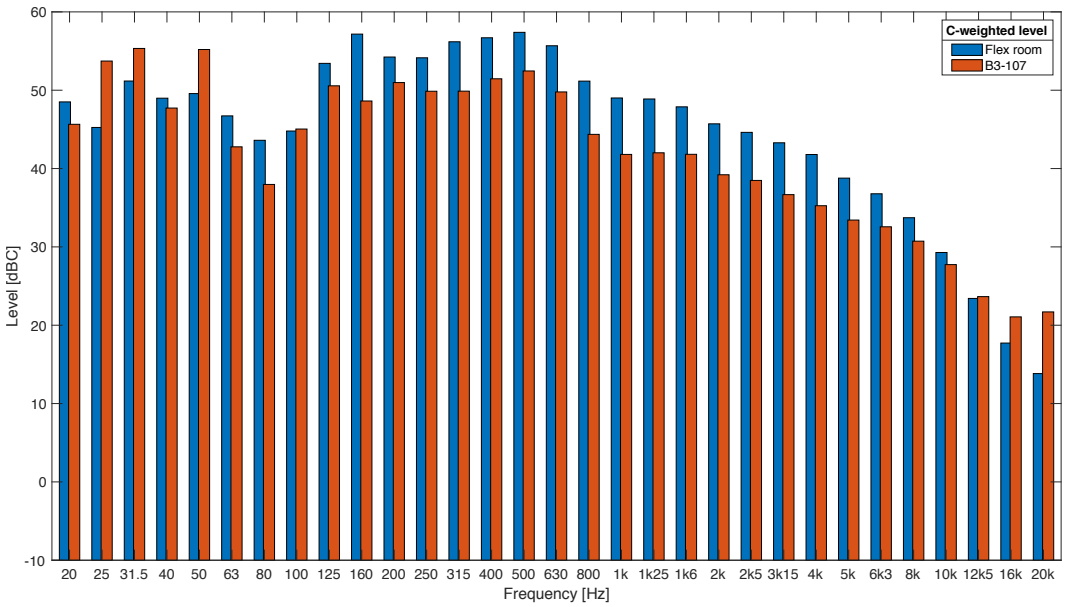


Figure 7: The figure shows the C-weighted one-third octave equivalent sound pressure for the total measuring period for both room

When looking at Figure 6, it becomes apparent, that the noise within the both rooms is strongest within the mid frequencies. The highest A-weighted one-third octave level in

both rooms is at a center frequency of 500 Hz. By comparing both Figure 6 and Figure 7 it can be observed that the noise at low frequency is different in both rooms and none of the rooms has significantly higher more frequency noise than the other. Going up to the area of human voice, it is clear to see that the sound pressure level is higher in the Flex room compare to B3-107. The difference is approx. 6 dB in the frequency range from the fundamental frequency of the voice to high pitch of the voice, 120 Hz to 7 kHz [3]. For center frequencies above the voice range, the sound pressure level in B3-107 tends to be higher.

6 Discussion

6.1 Comments

In comparing the different the values displayed in Table 1, some assumptions on the temporal and spectral behaviour of the noise can be made, without looking at the level-over-time curves or third octaves. The difference between the Z-weighted and the A-weighted equivalent sound pressure levels in both rooms differs significantly. In the Flex room, it is approx. 5.3 dB, in room B3-107, it is approx. 9.3 dB. This indicates, that there is a difference in the spectral composition of the measured noise. The noise in room B3-107 must have more content in the frequencies, that are attenuated by the a-weighting, compared to the noise in the Flex room. Figure 7 shows, that this is actually true. There is a significant level difference at the center frequencies of 25 Hz,31.5 Hz,50 Hz,16 kHz and 20 kHz. At least in the low frequencies this can likely be accounted to the ventilation system, and it may also be because of the corner position of the microphone in B3-107.
The A-weighted percentiles in Table 1 show a dynamic range of slightly less than 20 dB between the 90^{th} and the 10^{th} percentile for both of the rooms. The 50^{th} percentile is not spaced evenly in between the two, but is also not very close the values of the other percentiles. This indicates, that level over time is not close to constant, like it would be for an almost static noise, like e.g. a ventilation system, but also is not dominated by extreme impulsiveness, like it would be e.g. for ramming noise. The 10^{th} percentile can be used as an estimator for the background noise within the rooms. Similar to the A-weighted equivalent sound pressure level, the difference in the 10^{th} percentile levels between the two rooms is roughly 6 dB. A assumption, that might be derived from this, could be, that the people working in the respective rooms adjust their voices according to the background noise, leading to a higher L_{aeq} in the room with higher 10^{th} percentile level. This effect certainly is not the only reason, why the A weighted equivalent sound pressure levels differ, but it might be worth considering.

6.2 Noise Annoyance

Taking into account that the microphone in the Flex room was placed in it own section, with students only in other different sections, and that the microphone in B3-107 was placed 2 m away from the group, the sound pressure level in the speech area was 6 dB higher in the Flex room compared to B3-107. This difference may be caused by the number of students in each room. The B3-107 has around 5 students in the room throughout the whole measurement, whereas the Flex room had various changes in students' count and most of the time there were more than 6 student in the room. Students in the Flex room were more likely to speak louder to mask the other students in different sections. In addition, continuous changes in the loudness of "non relevant" speech from other groups in the Flex

room is more annoying for individual students than group speech in B3-107, as the discussed topics are of importance for all involved participants. This annoyance factor for students in the Flex room is induced by speech from other groups while trying to concentrate in their own topics. Since most groups are speaking English, most students understand each other and therefore non relevant speak from others generates a brain response to try to understand their conversation. This is an annoyance factor that is less/not present in B3-107 since the discussed topics are mostly related to their own work/experiences.

The low frequency difference in both rooms can be caused by different ventilation systems and room modes. In the Flex room the ventilation is managed by air-conditioning, which reuses the air from the room, where the B3-107 has a ventilation system coupled to the lab ventilation system, which continuously renews the air in the room. These two different systems might generate noise with different frequency components. The ventilation system in B3-107 is not student controllable, while the air-condition can be controlled by the students. Along the measurement the students continuously changed the settings on the air-conditioning, forcing peaks in which it was turned on with high power and small dips in which the air conditioning unit was at a low level or completely turned off. These cycles kept repeating throughout the whole measurement without following a specific pattern, but the full-blast stretches were longer and more prominent throughout the day (as confirmed by the measurement observer). The size and layout of these two rooms is very different, and therefore the room modes might also be different. While the ventilation system is running without changes, the annoyance factor is more likely to be low, because the brain is able to adjust to the static noise. This mean that the low frequency noise from the ventilation system is less annoying while stationary. The annoyance in B3-107 due to the ventilation system is therefore likely to be less compared to the ventilation system in the Flex room, where the students repeatedly change the settings on the air-conditioning. These changes alter the noise emitted by the air-condition leading to additional disturbance.

6.3 Risk of hearing damage

The L_{Aeq} in both rooms is significantly less than 80 dB, which is the limit for a working day of 8 h. The measurements have only been conducted in 4 h period. Therefore, an assessment of the hearing damage risk can technically not be made. However, observing the tendency for the noise level in Figure 3 and Figure 4, the fluctuations in the noise level are approximately constant during the whole measurement period. Therefore it is likely, that the noise level do not change significantly during the missing 4 h of the working day. The 90 percentiles in Figure 3 and Figure 4 shows the level where 90 % of the observation is way below 80 dB and this also indicate that the $L_{\mathrm{Aeq,8h}}$ will not raise over 80 dB the last 4 h

7 Conclusion

Measurements were performed in two student group rooms, one of them being a Flex room, the other one being inhabited by a single group of students (B3-107). The measurement results showed a difference in the noise levels present in both rooms. It can be concluded that the acoustical comfort in B3-107 is higher than in the Flex room since the A-weighted equivalent sound pressure level is lower and there is less variation in the noise emitted by the ventilation system. It can also be concluded, that in both rooms it is not likely, that students obtain noise induced hearing loss due to the ambient noise. Both rooms comply

with the A-weighted equivalent sound pressure of $L_{\mathrm{Aeq}} \leq 80\,\mathrm{dB}$, which is commonly referred to as the maximum level, that an individual should be exposed to for a working day of 8 h.

References

[1] Birgitta Berglund, Thomas Lindvall, and Dietrich H. Schwela. *Guidelines for Community Noise*. World Health Organization, Geneva, Switzerland, 1999. ISBN 978-9-971-88770-4.

[2] ISO. *ISO 9612:2009 Acoustics – Determination of occupational noise exposure – Engineering method*, 2009.

[3] Ville Pulkki and Matti Karjalainen. *Communication Acoustics - An Introduction to Speech, Audio and Psychoacoustics*. John Wiley & Sons, New York, 2015. ISBN 978-1-118-86655-9.