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The Sound of Collaboration in Open Plan Offices: A Pilot Study

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ABSTRACT

Noise is one of the main areas of complaints from staff working in open plan offices. New office design trends promote having fewer partitions, more flexibility and more "breakout" areas. These are believed to promote connectivity and collaboration among staff. However, these also have the potential to increase noise levels, particularly intelligible speech, which is considered to be the most annoying and distracting noise source.

This work highlights some of the results of a pilot acoustic study of an open-plan office in Australia to understand the relationship between staff interactions, changes in the office noise levels and the subjective perception of staff to these factors. The study included among others: objective acoustic measurements of noise levels during working hours; evaluation of subjective perception of noise from the staff via acoustic survey; and analysis of staff interactions via social network maps. No clear correlation was found between noise levels and annoyance or noise levels and interactions. However, noise levels in architecturally equivalent areas were observed to be significantly different, likely affected by the levels of interaction.

Acoustic design for modern workspaces needs to account for non-architectural components to increase satisfaction and comfort, which could also lead to higher productivity and performance. Some preliminary results are provided.

Keywords: Perception, Noise, Workplace
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1. INTRODUCTION

Open plan layout is commonly used for workplaces, partly due to the economic benefits of allowing increased staff density, and the perceived benefit of increasing collaboration. However, the lack of partitions can lead to a reduction in privacy and increment on interruptions from other employees[1,2], and it has the potential to increase noise levels.

Noise is one of the main sources of complaint in open plan offices, with an average satisfaction rate of only 34% based on a report[3] summarising research across more than 2000 workplaces worldwide. Moreover, office noise has been found to impact staff performance and satisfaction[4,5]. Intelligible speech is considered to be the most annoying and distracting noise source. Distracting sounds are those that interfere with concentration and recreation[6]. The effects from noise can be linked to physical properties of the sound like its intensity or frequency, but also to other non-physical properties such as its predictability, necessity, message content, and others[7,8]. The impacts from noise exposure can manifest in different forms. Some have a psychological nature, and some are physiological, affecting health and wellbeing[9].

Acoustic design for modern workplaces needs to account for non-architectural factors to increase satisfaction and comfort, which could also lead to higher productivity and performance.

This research project aims to understand how factors such as staff behaviour, interactions, noise profiles, and staff noise satisfaction are interconnected.

2. DATA COLLECTION

Acoustic measurements were conducted at the office of one of Australia's largest rail freight operators, located in Brisbane (Australia), over five days in late 2017. The office was distributed between two buildings within the central business district (CBD), referred to here as Buildings A and B.

Noise levels were recorded by Arup via attended and unattended measurements across ten different floors, three in Building A and seven in Building B. For each floor assessed, Type 1 noise loggers were set up across the floor to capture the noise levels between 9 A.M. and 4 P.M. approximately, i.e., during working hours. Figure 1 shows a typical floorplan for each building including the location of the noise loggers on those floors.

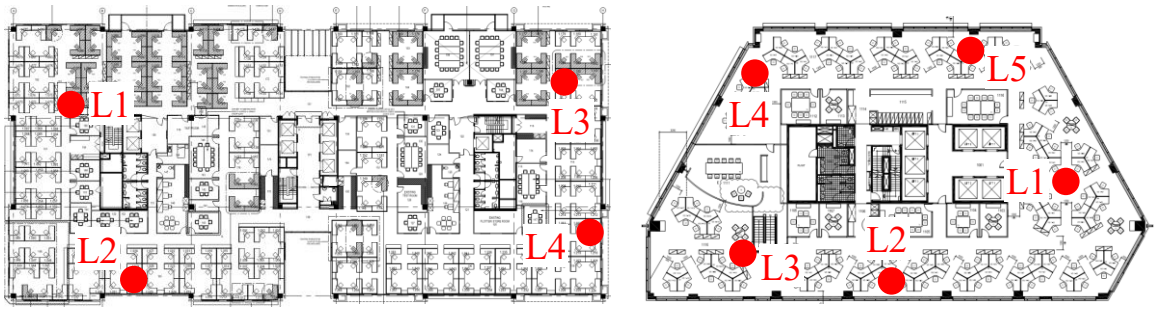

Figure 1: Floor plans of Floor 1 in Building A (left) and Floor 11 in Building B (right), both showing the location of the noise loggers.

Staff perception was assessed via electronic surveys, sent to all staff one week after the completion of measurements. Perception of the office environment was evaluated using the Leesman survey. Information about the social networks (type and frequency of interactions) was collected using the Optimice survey. This survey also

included questions used for the acoustic evaluation. The full acoustic questionnaire is shown on Figure 2.

ACOUSTIC QUESTIONNAIRE

1) Was last week representative of the normal office activity?
2) During the last week, what percentage of your time involved a high level of focus and concentration:

   a. 0%, b. 20%, c. 40%, d. 60%, e. 80%, f. 100%

3) For each of the following noise sources, please rate how it impacts your work for each of the two categories:
   - Focus work: Work that requires high level of concentration and minimum distractions.
   - General work: Work that requires low level of concentration and can be completed with some distractions.

1 = It has a positive impact on my work	2 = It does not impact my work (it is not distracting)	3 = It has some negative impact on my work (it is slightly distracting)	4 = It has a significant negative impact on my work (it is very distracting)

Noise source	**Focus work**				**General work**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Air conditioning noise								
General ambient noise in office (distant talking, photocopy machine, typing, etc.)								
Kitchen appliances								
Phone ringing								
Other people's face-to-face conversations that you can hear well enough to understand								
Other people's phone conversations that you can hear well enough to understand								

4) You are able to hear and understand conversations that happen:
   a. Only in your cluster of desks
   b. Up to the next clusters from your desk
   c. Up to two clusters from your desk
   d. Up to three clusters or more from your desk

5) On average, how many of the following types of conversations did you have at your desk on a single day during the last week:

	0	**1 - 5**	**6 - 10**	**10+**
Face-to-face meetings less than 15 minutes				
Face-to-face meetings more than 15 minutes				
Phone calls less than 15 minutes				
Phone calls more than 15 minutes				

Figure 2: Acoustic Questionnaire

3. RESULTS

3.1 Noise Levels

Noise level metrics L_{Aeq}, and L_{A90} were calculated in 1-minute intervals for each logger in each floor. Figure 3 shows these metrics for Floor 11 in Building B. In both cases the noise level fluctuates around an average value that spans from 47 to 50 dB(A) for L_{Aeq} and from 39 to 41 dB(A) for L_{A90} for the different noise loggers.

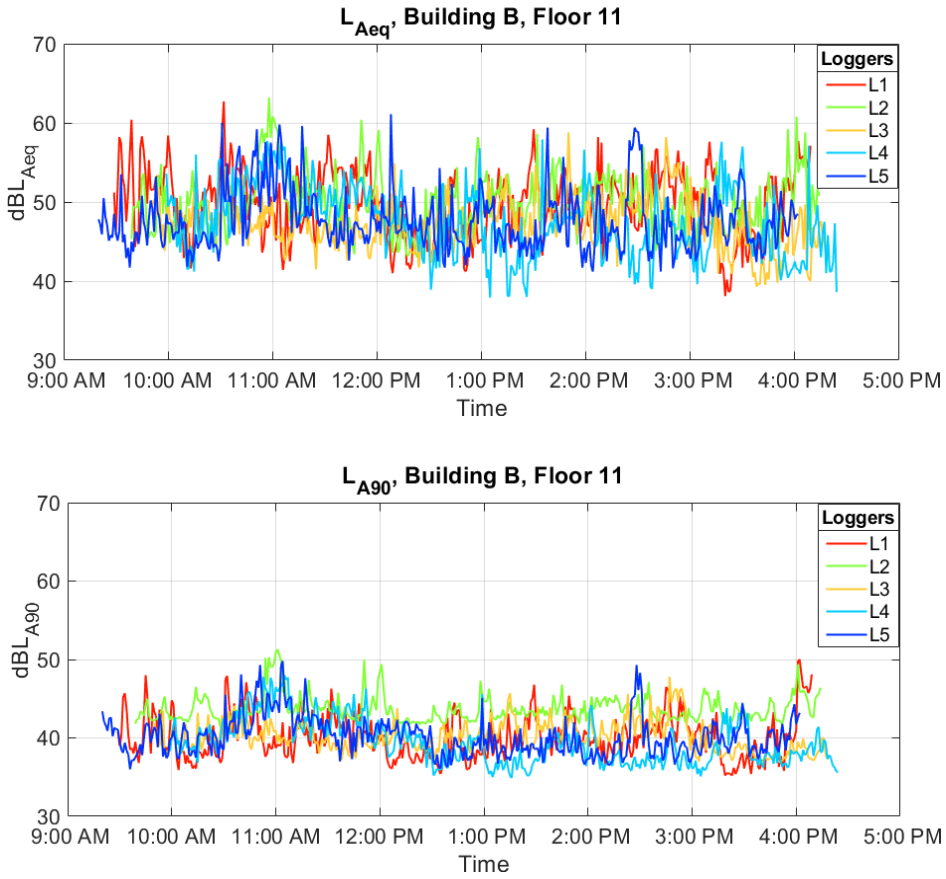

Figure 3: Measured $L_{Aeq,}$ (top) and L_{A90} (bottom) for each logger on Floor 11 in Building B.

Figure 4 shows the overall L_{Aeq} and L_{A90} for each floor, calculated by averaging the measured noise level of each logger in the floor. Given the variability of the logger recordings within a floor, the resulting overall levels across the different floors are in average very similar, and the standard deviation is significantly high (up to 5 dB(A) for L_{Aeq} and up to 4 dB(A) for L_{A90}).

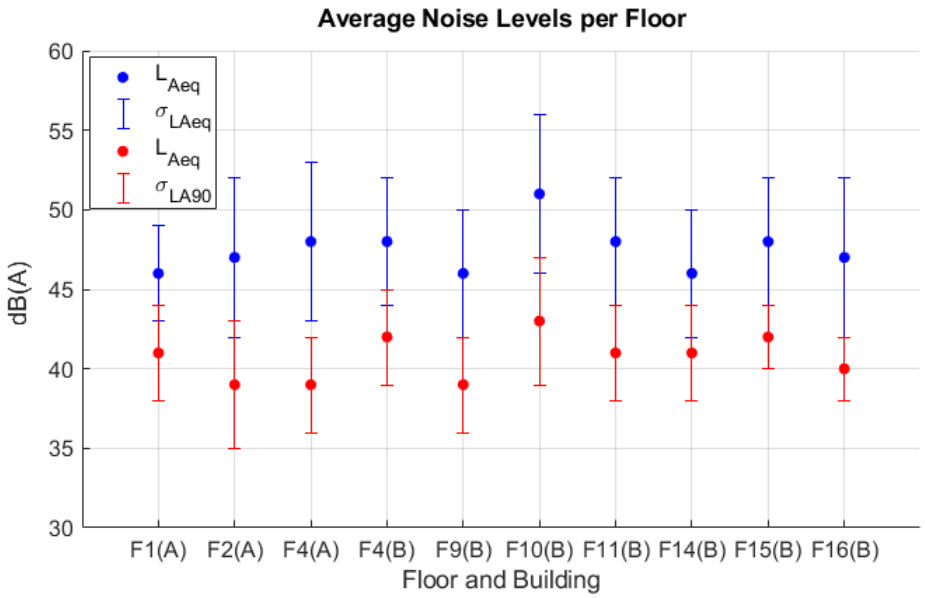

Figure 4: Average L_{Aeq} (blue) and L_{A90} (red) for each floor with error bars.

3.2 Staff Interactions

Noise levels recorded on each floor were compared to the number of interactions among the staff obtained from the Optimice survey. The type of interactions included were face-to-face, phone, email, videoconference, and social media. Two different categories of interactions were analysed, total number of interactions from staff on one floor with staff on all other floors, $Interactions_{Tot}$, (Figure 5, left), and the interactions from the staff on each floor with only staff on the same floor, $Interactions_{Floor}$, (Figure 5, right). In both cases a corrected value of interactions is also shown, $Interactions'_{i=Tot,Floor}$, to factor the difference in the number of staff responding the survey and those present during the noise measurements.

$$Interactions'_{i=Tot,\,Floor} = \frac{\rho_m}{\rho_s} Interactions_{i=Tot,\,Floor} \quad (1)$$

where ρ_m is the staff density measured on site, and ρ_s is the staff density from the Optimice survey. The staff density is defined as the number of staff divided by the area of the floor plan in m^2.

In both plots in Figure 5 data was sorted by increasing L_{Aeq}. In both cases no correlation was observed between interactions and noise levels.

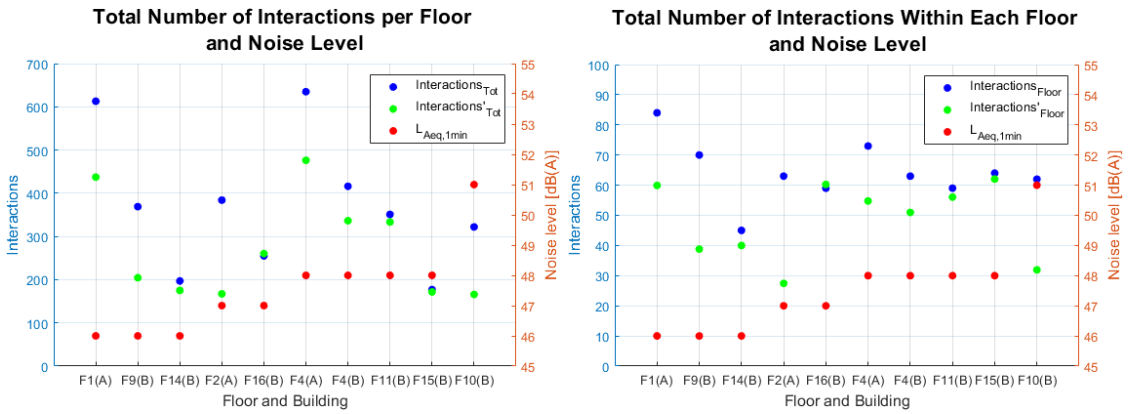

Figure 5: Total interactions from staff on one floor with all other floors (left) and interactions from staff on a floor with staff on the same floor (right). Noise levels are also included with the scale shown on the right. Data is sorted by increasing noise levels.

3.3 Perception of Noise

The selected results from the acoustic questionnaire are presented in this section. A total of 491 staff members responded to the questionnaire, 59% male and 41% female.

Figure 6 shows at the top the percentage of staff who scored different sources of noise as having a negative impact on their work. This negative impact was determined by combining categories 3 and 4 of question 3 in the Acoustic Questionnaire ("It has some impact on my work" and "It has a significant impact on my work" respectively). At the bottom, the figure shows the same negative impact on focus work separated for males and females. Other people's phone and face-to-face conversations are rated as the ones having the most negative impact on staff's focus and general work, while air conditioning noise was rated as having the least negative impact. All sources are perceived as having a higher impact on focus work compared to general work, as expected. On average, male staff rate all sources of noise as having a more negative impact on their focus work than the female staff.

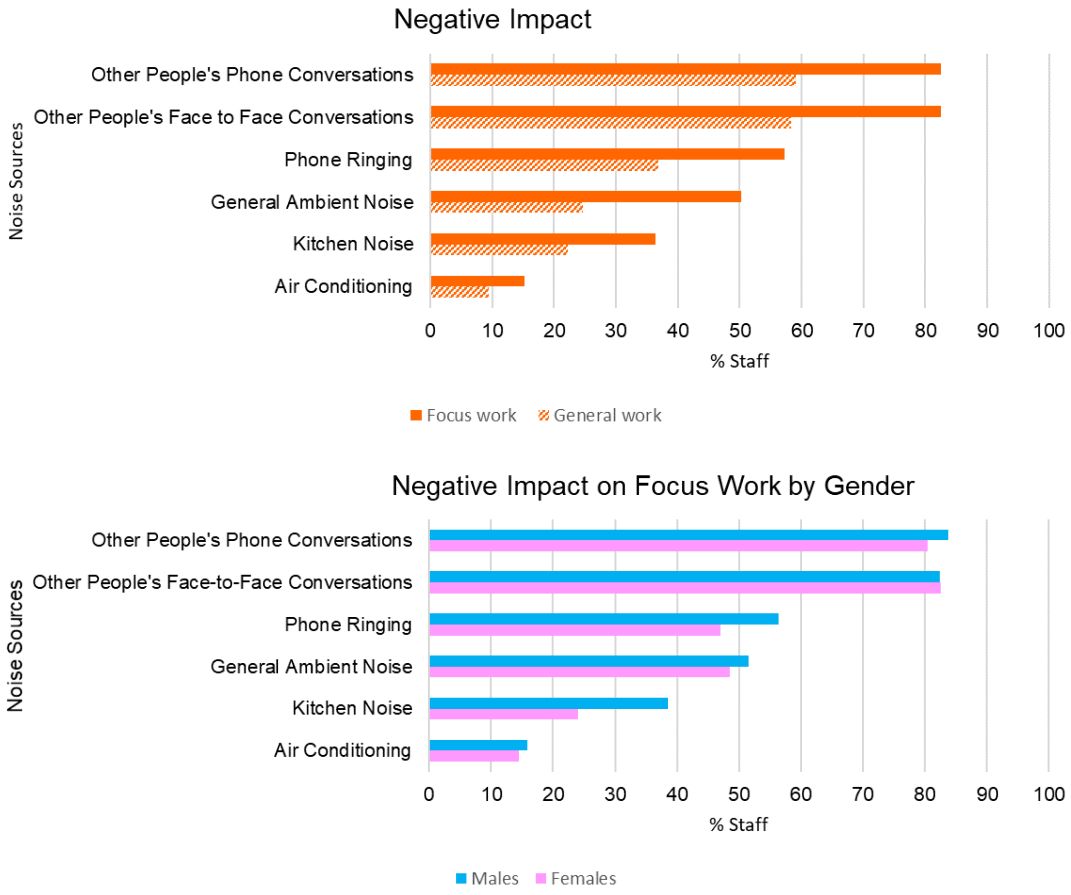

Figure 6: Percentage of staff who perceived a negative impact on their focus or general work for each type of noise source (top). Percentage of staff by gender who perceived a negative impact on their focus work (bottom).

The two types of sources that were perceived by the staff as having a higher negative impact on their work (face-to-face and phone conversations of other people) are analysed in Figure 7. The percentage of staff impacted by them is plotted against the percentage of staff who spend more than 50% of their time on focus work. This was determined by combining results in question 2 of the acoustic questionnaire where the last three answers were selected- 60%, 80% and 100%. A linear regression line $y = ax + b$ for each set of data is also included on the plot, where a is the slope and b is the offset. For other people's face-to-face conversations (blue), the coefficients of the best linear fit are $a = 0.5$ and $b = 38$, with $R^2 = 0.2$. For other people's phone conversations (black) the regression coefficients are $a = 0.7$ and b $= 16$, with $R^2 = 0.4$.

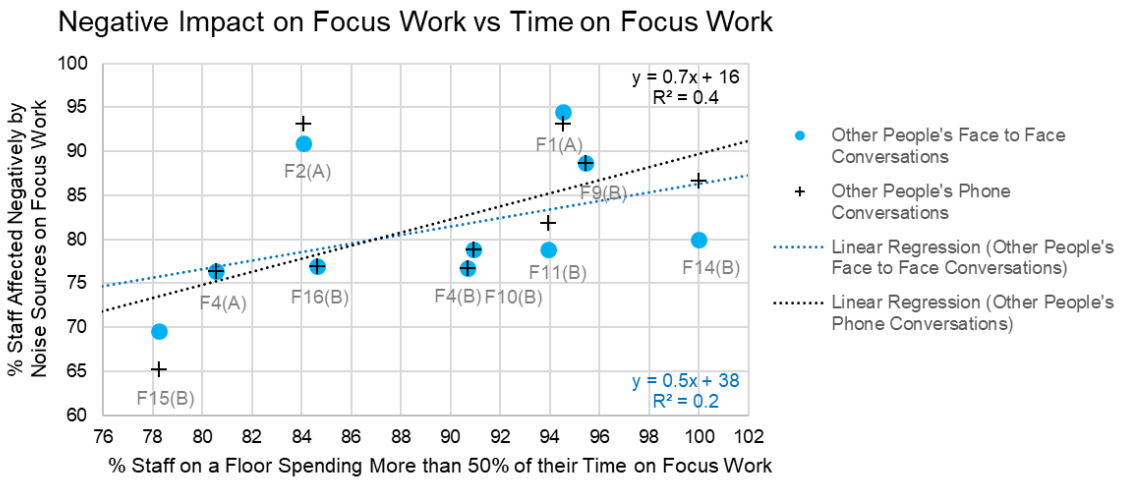

Figure 7: For face-to-face and phone conversations, this graph shows the percentage of staff on a particular floor reporting negative impacts on their work vs. the percentage of staff on that floor who spend more than 50% of their time on focus work. Linear regression lines and coefficients are also included for each set of data.

Figure 8 combines all sources that were perceived as having a negative impact on focus and general work for each floor, showing the percentage of staff giving that classification. It also shows the averaged overall noise levels for each floor. The data suggests an inverse relationship between the perceived negative impact and the noise levels. For example, Floor 10 in Building B registered the highest noise levels, while the overall negative impact is among the lowest for both focus and general work. At the same time, Floor 1 in Building A and Floors 9 and 14 in Building B registered the lowest noise levels, while the overall negative impacts are among the highest ones. Although this relationship was observed, a strong correlation was not found.

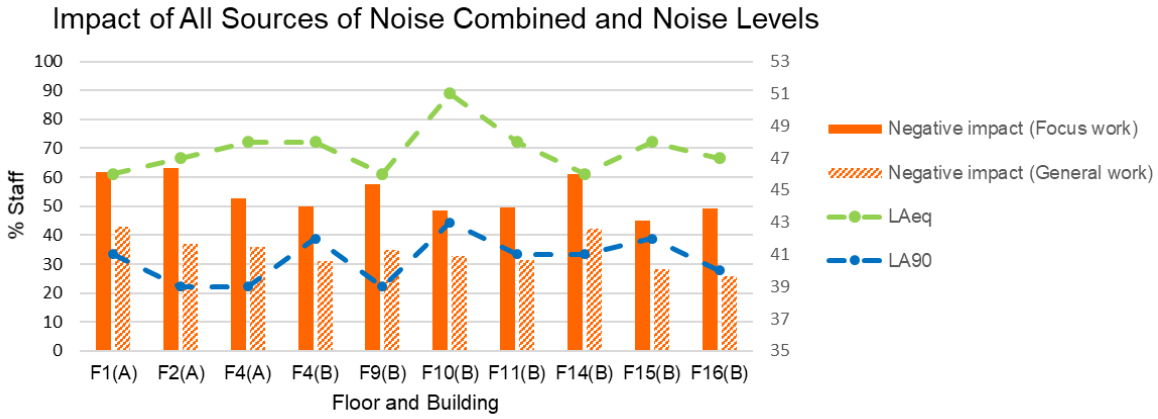

Figure 8: Percentage of staff perceiving as negative the impact of all sources of noise combined on their focus work (solid orange bars) and general work (dashed orange bars) for each floor. Additionally, the noise levels L_{Aeq} (green dashed line) and L_{A90} (blue dashed line) are represented.

4. DISCUSSION/CONCLUSIONS

- This pilot study had some limitations which may have impacted the results. These include:
    - Noise levels could only be measured per floor for a 1-day duration during normal working hours approximately. Longer recording periods may have provided different results.
    - Mismatch of sample: people who responded the survey were not necessarily the same who were in the office during the testing.
- Noise level metrics L_{Aeq}, and L_{A90} had different waveforms for each logger as a result of the different activity around each logger. The resulting overall levels for each floor were found to be very similar, with high standard deviation. Therefore, a single figure, while useful for concise reporting, does not appear to be particularly useful in adequately characterising the acoustics across the floor. Future work will consider additional parameters such as L_{A10}.
- No correlation was observed between collaboration (number of interactions) and noise levels, as shown on Figure 5. However, given the limitations of the study, it cannot be affirmed that such correlation does not exist. Further investigation is necessary.
- Phone and face-to-face conversations by others were perceived as the sources having the most negative impact on the staff for both focus and general work. Air conditioning noise was rated as having the least negative impact. For all sources the perceived impact on focus work was higher than on general work, as expected.
- On average, male staff rated all sources of noise as having a more negative impact on their focus work than the female staff.
- The percentage of staff on a particular floor reporting a negative impact of intelligible speech on their work increased slightly with the percentage of staff that spend their majority of their time on focus work (Figure 7). However, the confirmation of such correlation would require additional data.
- Annoyance/distraction of staff did not increase with L_{Aeq} and L_{A90}. The data shown on Figure 8 suggest an inverse relationship between the former and the noise levels, but further analysis with a larger data set is required to confirm the dependence.
- Future work would involve investigating a baseline tolerance or sensitivity of individuals to noise and correlating this to factors such as age, gender, work functions or percentage of focus work performed. These can then be compared to acoustic satisfaction to see if there are other factors which impact on staff acoustic satisfaction more than just the objective noise levels.

5. ACKNOWLEDGEMENTS

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