The value of user feedback to improve the indoor environment in offices

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Abstract. A healthy, stimulating and comfortable office building positively influences health and the productivity of employees. To determine the indoor environmental quality of a building, indoor environmental parameters in buildings are often measured. While measurements are important, they do not give full insight in the indoor environmental quality of a building and often do not provide complete insight in the causes of potential problems.
Since the requirements for a good indoor environment depend on the type of activities that take place in the building and on the preferences of individuals, the feedback of the building occupants should be included in the assessment. Moreover, this contributes to the interpretation of indoor environmental data. We have started collecting data on user feedback, in which building characteristics and the approximate location of users is included, in a systematic way. This makes it possible to easily compare the results of different buildings. The results show among others that the motive to apply the survey appears to be, to a certain extent, a predictive factor in the satisfaction rates: buildings that aim for sustainability- or health certification score highest. The lowest satisfaction rates for indoor environmental parameters are observed for temperature and acoustics. For all parameters, respondents were more satisfied when they perceived control over it. Sharing a workplace with an increasing number of people decreases satisfaction with acoustics and people report a negative impact on concentration. This observation calls for re-evaluation of modern office layouts. In case studies, the results of the questionnaire can be combined with the characteristics of the building to obtain insight in possible risk factors and provide solutions to indoor environmental challenges. Overall, all data collected will be used to define a reference value. By expanding the database, more analyses can be performed to better understand the relation between building characteristics, indoor environment and user satisfaction.

Keywords. User-feedback, offices, indoor environment, health, comfort, risk factors
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1. Introduction

What defines a comfortable building and how to design one? It would be great if one could present a clear definition and a set of golden design rules that, by applying them correctly, would always lead to an office building in which building occupants are satisfied with the indoor environment and where their activities and mood are positively affected. In practice this unfortunately is not always the case: overall satisfaction with the indoor environment in offices is often low (e.g. [1-2]) The requirements for a good indoor environment largely depend on the type of activities that take place in the building and on the preferences of the building occupants.

1.1 Measuring and monitoring

A comfortable office building positively influences health and the productivity of employees. To demonstrate whether a building is comfortable, measurements of indoor environmental parameters such as temperature, humidity, CO_2-concentration, fine particles, light intensity and Volatile Organic Compounds (VOC's) are performed. These measurements are important and give valuable information about the indoor environment. They do however not give full insight in the building performance, since a lot of parameters that also affect the employee experience are not included. When combined with user feedback, collected indoor environmental data becomes much more valuable. As a result, expensive measurements to identify problems in a building and to confirm hypotheses

regarding the cause of these problems, can be applied more targeted. This approach is also known as the building in use method [3].

When adding user feedback, the collected data of the measurements can be interpreted better and the perceived quality of aspects that are difficult to measure during occupation, such as quality of light and acoustics, can be determined.

Continuously changing working methods, office layouts, building characteristics combined with cultural differences, result in time- and place-dependent outcomes of user feedback surveys. Because of these continuously changing factors it is important to keep including contemporary data to the databases. A database such as that of the Healthy Building Index can be used to learn which aspects are important for user satisfaction and which building characteristics might be labelled as risk factors.

1.2 Collecting user feedback

To collect user feedback in a systematic way, use of a thorough survey tool is recommended. For our research we used the "Healthy Building Index tool", in which user feedback on four indoor environmental parameters (light, temperature, indoor air quality and acoustics) is collected. Based on the results a Healthy Building Index of the building is determined that expresses the satisfaction of the building users with the indoor environment in their building, figure 1. The index varies between 100 and 1000 and, to give an idea of the value of the score in comparison to that of an average office building, the reference value of the database is included.

Fig. 1 – The Healthy Building Index

For each indoor environmental category the satisfaction rate is defined and presented to the building owner and/or -occupants, figure 2.

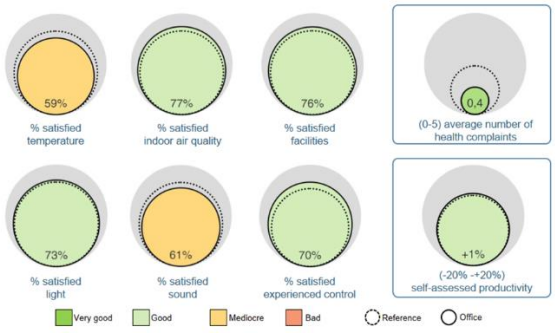

Fig. 2 – Partial results of the Healthy Building Index tool

1.3 Research objectives

What can we learn from the data collected? The purpose of this data analysis is to:

- provide insight into the satisfaction rates within the buildings.
- provide insight into the factors that influence satisfaction with the indoor environment.
- show the added value of collecting contemporary user feedback in order to continue to realize healthy and comfortable buildings.
- Determine the implications for future building design.

2. Method

2.1 Data collection

From the start of 2020 user feedback was collected from 710 respondents in thirteen office buildings using an online survey tool (*name will be added after review*) about their satisfaction with the indoor environment. The motivation to apply the survey differed between the buildings investigated. From all buildings evaluated, two buildings aimed for a WELL building certificate, six buildings were evaluated to map the indoor environmental status of the building, four buildings used the survey as input for their planned renovation and in one building the survey was used to systematically map the complaints about the indoor environment in order to take measures to solve possible problems. Respondents were invited via email to complete the questionnaire within two weeks. An overview of the buildings investigated and the number of respondents is indicated in Table 1.

Tab. 1 – Motivation to apply survey.

Building	Number of respondents	Motivation to apply survey
#1	21	Complaints
#2	56	Pre-renovation
#3	30	Pre-renovation
#4	41	Pre-renovation
#5	49	Pre-renovation
#6	16	IEQ status
#7	36	IEQ status
#8	139	IEQ status
#9	108	IEQ status
#10	56	IEQ status
#11	20	IEQ status
#12	58	WELL
#13	80	WELL

2.2 Survey

In all buildings the same questionnaire was used. The questionnaire focusses on four indoor environmental parameters: temperature, air quality, light and acoustics. Respondents were asked how satisfied they were with each parameter at their workstation on a 7 point scale from "Very dissatisfied" (1) to "very satisfied" (7). If respondents indicated they were not satisfied, score 1, 2 or 3, they were asked which aspects contributed to their dissatisfaction. For each theme, satisfaction rates per building were calculated; being the percentage of respondents who answered "neutral"(4) or higher, as applied in the CBE questionnaire [2]. Additionally building users were asked if they suffered from building related health symptoms (yes or no). If yes, a list of symptoms was provided, in which they could indicate which symptoms they suffered from. Finally respondents were asked to indicate how important each indoor environmental parameter is to them (1 "not important" to 5 "extremely important") and how much control they experience over each indoor environmental parameter (1 "no control at all" to 7 "full control"). The survey furthermore includes questions regarding the general location and characteristics of the workplace, the activities carried out and the amount of time spent in the building.

2.3 Data analyses

Data was analysed to map the average satisfaction rates with the indoor environment and to obtain insight in factors that influence the experience with the indoor environment. Using the satisfaction rate (percentage of people satisfied with one parameter) of each building, the average satisfaction rate for all indoor environmental parameters was calculated. Differences between parameters were compared using a two tailed t-test.

To analyse differences between groups, based on the answers given in the questionnaire (for example number of people who work together in a room), a two tailed t-test was used for the ordinal variables. Bi-nominal variables were compared using a Chi-squared test. A p-value <0.05 was considered to be statistically significant and indicated with * in the figures. The static analyses were performed in Microsoft Excel version 2102.

3. Results

3.1 Overall satisfaction rates

Based on the average satisfaction rates per building, it was observed that satisfaction of the respondents per indoor environmental parameter significantly differs. The percentage of respondents who indicated being satisfied with 'light' (77%) and 'air quality' (69%) at their workplace was higher compared to 'temperature' (56%) and 'acoustics' (52%). (Figure 3).

The motive to apply the survey appears to be, to a certain extent, a predictive factor in the satisfaction rates. Explorative analysis of the data shows that from all buildings evaluated, the two buildings that aimed for a WELL building certificate had the highest satisfaction rates for temperature, indoor air and acoustics, followed by the buildings that were evaluated to map the indoor environmental status of the building (except for acoustics) (Figure 4). Third are the buildings that used the survey as input for their planned renovation. As expected, in the building (n=1) in which the survey was used to systematically map the complaints about the indoor environment in order to take measures to solve possible problems, the satisfaction rates were the lowest. The differences are most pronounced for the satisfaction rates of temperature and indoor air quality. The satisfaction rates of light do not seem to be different among these groups. The number of buildings in each group was too small to perform statistical analyses.

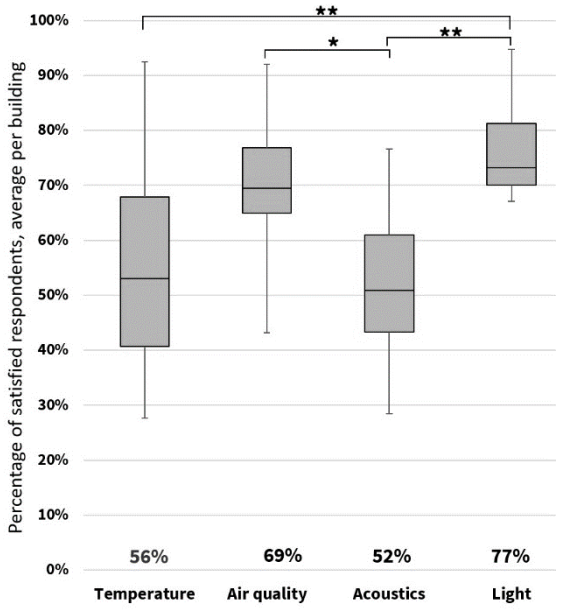

Fig. 3 – Box plots show the average satisfaction rates per theme based on the average per building.

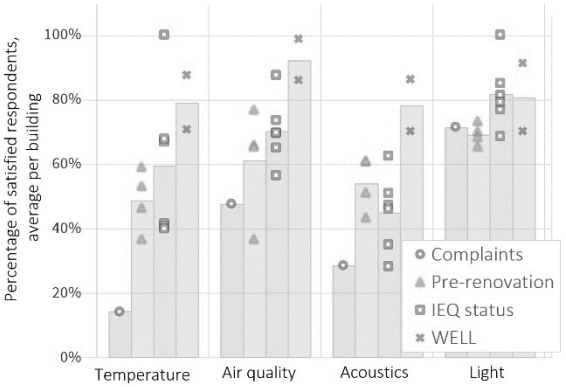

Fig. 4 – Satisfaction rates per theme differentiated among motives of applying the survey.

3.2 Importance and perceived control

The respondents rated "temperature" and "indoor air quality" as being the most important indoor environmental parameters. Differences among the parameters were small. Still "light" and "acoustics" were rated slightly but significantly less important ($p<0.05$ for all comparisons) (Figure 5). Surprisingly, the parameter "control over the indoor environment" was rated least important ($p<0.01$).

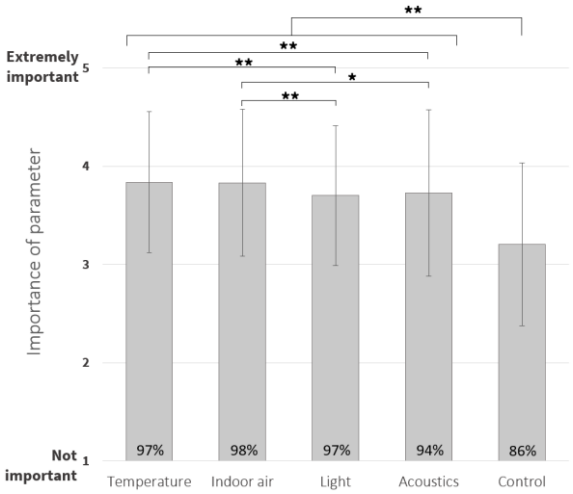

Fig. 5 – Importance of each indoor environmental theme. Percentage indicate rating "3" or higher.

The relation among the indicated importance and the satisfaction rate of each parameter is illustrated in figure 6. It shows, for all parameters, that the percentage of respondents that is satisfied, is highest for the respondents that indicated that parameter to be "not important" or "somewhat important'". The percentage of people satisfied is lowest for the respondents that indicated the parameter to be "extremely important".

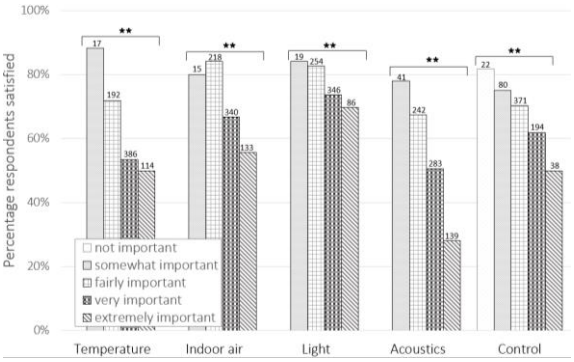

Fig. 6 – Importance of each indoor environmental parameter compared to satisfaction rates per parameter.

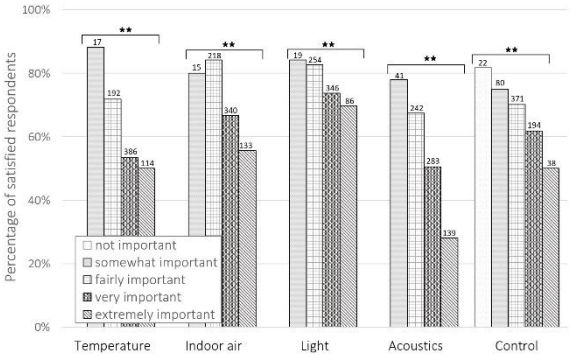

Fig. 7 – Perceived control over the indoor environment and corresponding satisfaction rates.

The level of perceived control affects the satisfaction rates per theme (Figure 7). For all parameters, respondents were significantly more satisfied when they indicated to have "reasonable control" (5), "high level of control" (6) and "full control" (7) as compared to "some control" (4) or "no control" (1) to "little control" (3) (Table 2 a - c).

3.3 Impact number of people working together

The number of people that work together in one room, significantly affects satisfaction with acoustics in the workplace (Figure 8). The more people working together in the same work space, the lower the satisfaction rate. However, the size of the standard deviation illustrates that more factors are involved. Satisfaction with the parameters temperature, light and air quality, was not affected by the number of people working in the room, see table 3.

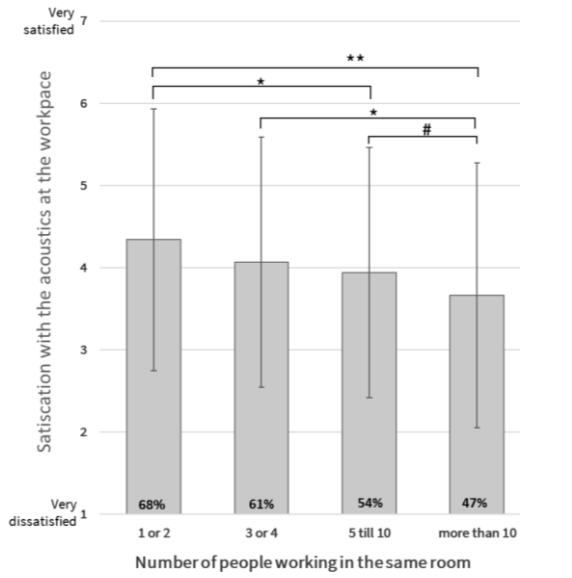

Fig. 8 – Satisfaction with the acoustics at the workplace. Percentages indicate the satisfaction rates.

Tab. 2a – Satisfaction scores of respondents experiencing "no control" to "little control".

		Group A	
		No control (1) to little control (3)	
		Avg ± stdev	**N**
Satisfaction	Temperature	3,6 ± 1,6	399
	Indoor air	4,1 ± 1,4	402
	Light	4,4 ± 1,5	352
	Acoustics	3,3 ± 1,3	413

Tab. 2b – Satisfaction scores of respondents experiencing "some control". Significant differences are indicated in bold.

		Group B		
		Some control (4)		
				A vs B
		Avg ± stdev	**N**	**p-value**
Satisfaction	Temperature	4,3 ± 1,4	183	**<0,01**
	Indoor air	4,4 ± 1,3	135	**0,02**
	Light	4,6 ± 1,3	203	0,73
	Acoustics	4,4 ± 1,3	185	**<0,01**

Tab. 2c – Satisfaction scores of respondents experiencing "reasonable control" to "full control". Significant differences are indicated in bold.

		Group C		
		reasonable (5) - full control (7)		
				B vs C
		Avg ± stdev	**N**	**p-value**
Satisfaction	Temperature	5,4 ± 1,4	123	**<0,01**
	Indoor air	5,6 ± 1,3	93	**<0,01**
	Light	5,8 ± 1,1	145	**<0,01**
	Acoustics	5,6 ± 1,2	97	**<0,01**

Tab. 3 – Satisfaction score (average ± standard deviation) of all respondents grouped by the number of people working together in one room. Observations that significantly differ from the other categories for one parameter are indicated in bold.

	Number of people working in the same room			
	1 or 2	3 or 4	5 to 10	more than 10
Temp.	4,1 ± 1,6	4,4 ± 1,5	**3,8 ± 1,6**	4,2 ± 1,7
Indoor air	4,3 ± 1,6	4,4 ± 1,4	4,2 ± 1,4	4,4 ± 1,5
Light	4,6 ± 1,7	4,7 ± 1,6	4,8 ± 1,5	4,7 ± 1,5
Acoust.	**4,3 ± 1,6**	**4,1 ± 1,5**	**3,9 ± 1,5**	**3,7 ± 1,6**

Conversations in adjacent rooms, conversations in the own room and disturbing reverberation of voice were indicated most often as being (one of) the cause(s) for dissatisfaction with the acoustics in the room. These causes for dissatisfaction were, together with noise from installations, mentioned more often by respondents that shared a work place with an increasing number of people (figure 8).

People working in larger rooms reported a higher amount of concentration problems (figure 10). Though a tendency was observed that people that work in larger rooms, more often have one or more building related health symptoms, this difference was not significant (figure 11).

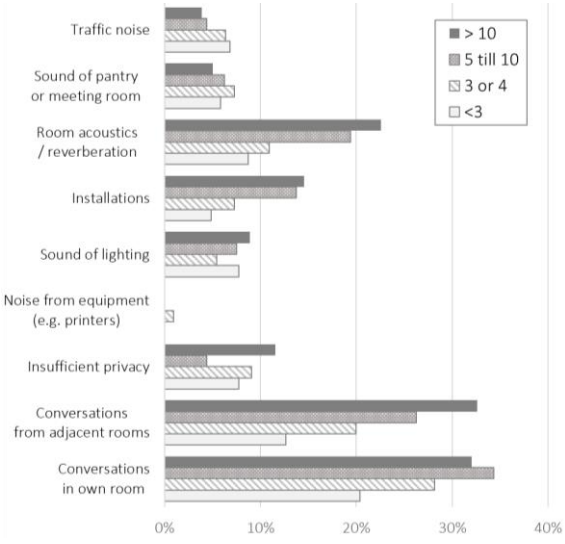

Fig. 9 – Reasons indicated to be dissatisfied with the acoustics, grouped by number of people working in one room.

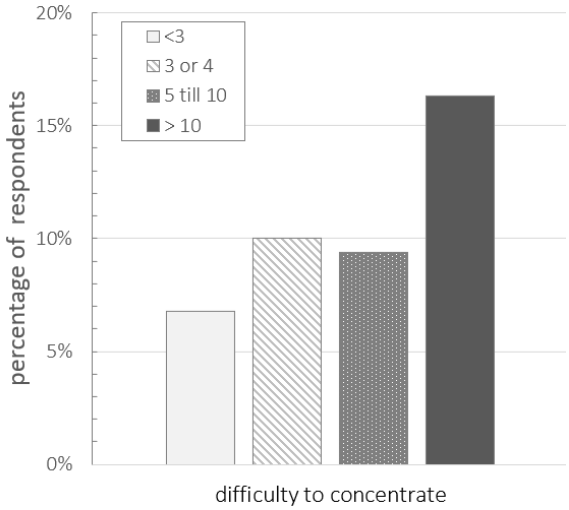

Fig. 10 – Impact of number of people working together on reported concentration problems

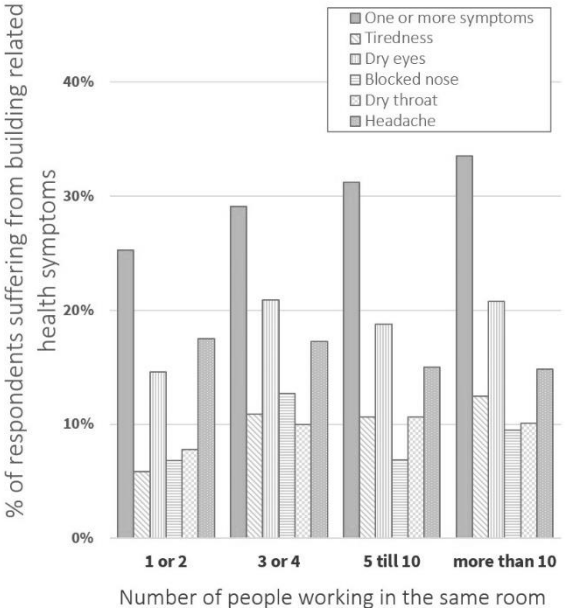

Fig. 11– Impact of number of people working together on reported health problems

4. Discussion

Based on the data analysed, the lowest satisfaction rates were observed for temperature (56%) and acoustics (52%). These parameters are also rated lowest in de CBE database. The satisfaction rates of the current study are lower as compared to the data from occupant surveys by CBE (containing approximately 90.000 respondents from 900 buildings): satisfaction with sound privacy (46%), temperature (61%) and noise level (66%) [2]. In both databases satisfaction rates of indoor air quality and light were higher. Due to the relative small number of buildings in the database analysed, the average values might be affected by the type of buildings included. Already within this small dataset, we observed a tendency that satisfaction rates are lower when user feedback is used as input for renovation of the building or to solve indoor environmental problems as compared to buildings that aim for a WELL Building Certificate or that want to map the satisfaction with the indoor environment just to obtain insight in the current status. This might not be surprising, but it illustrates the importance of a representative sample when drawing general conclusions based on satisfaction rates in office buildings.

Outcomes of the survey show that there is a relation among how important respondents rate a certain indoor environmental parameter and their satisfaction about that parameter. In general, respondents indicate to be less satisfied about the parameters they rate as being most important at their workplace. Whether this is because parameters become more important when you are not satisfied or because one is more critical about aspects which are important to him/her (or both) remains to be explored. The impact of control on the satisfaction rates are in line with the data analyses of the HOPE database [4] and an explorative study on the role of perceived control [5], the results show a clear positive impact of perceived control over the indoor environment on the satisfaction ratings with the indoor environment. Moreover, a recent field study in 167 buildings Europe, indicates the importance of control over the indoor environment on overall comfort and building-related symptoms [6] and self-estimated productivity [7]. These observations advocate for control opportunities over the indoor environment. Though it should be noted that care should be taken that available control opportunities also lead to an increased perception of control.

As expected, it was observed that lower satisfaction with acoustics is related to sharing a work place with a large number of people. These findings call for a careful reassessment of the layout of larger office spaces in future designs to improve user satisfaction, with attention to the type of work that will be performed and the required privacy for the employees. Especially conversations of colleagues in the same (30%) or adjacent rooms (26%) are factors that negatively affect user satisfaction. These percentages are in line with a 30-year old field study in 61 Dutch offices, containing 7000 respondents, that observed a complain rate of 33% about conversation in the same room and 20% in adjacent rooms [8].

The current database used for the analysis in this paper is still growing but already offers insights in experience of the indoor environment in offices and influencing factors. To be able to study the influence of building related factors, the dataset needs to be extended to a larger number of buildings with characteristics that are representative for current office buildings. The aim is to expand the number and type of buildings assessed to enable including the effect of building characteristics such as HVAC- and heating systems on user satisfaction in future analyses.

Next to conducting new analyses, it is recommended

to combine the results of the questionnaire with measurements of the indoor environment of the buildings. The combination of both sources of indoor environmental data will lead to an even better understanding of buildings.

5. Conclusion

A systematic approach to collect user feedback allows for meta analyses of the data to gain insight in user satisfaction and causes for dissatisfaction. In the current analyses, it was observed that average satisfaction rates are likely to differ among different type of buildings (for example pre and post renovation). Also, perceived control over- and self-rated importance of the indoor environmental parameters relate to user satisfaction. Expanding the database and including building characteristics and continuous measurements in the analyses, enables risk factor analyses.

As stated at the beginning of this paper, without user feedback some indoor environmental parameters (especially light and acoustics) are hard to map using continues measurements. Therefore it is not possible to make adjustments to better meet the needs of the building users regarding these parameters. In the buildings discussed in this paper, satisfaction about acoustics was low. Through the use of the survey this information has become available, including the most important causes for dissatisfaction per building. This allows for tailor-made measures for each office regarding acoustics, in order to better suit the requirements of the building users. This will likely benefit their health, well-being and productivity.

The coming years, the database will be expanded to be able to conduct more targeted and extensive follow-up research, among others on the correlation between perceived and available control and health related symptoms. With a more robust database, satisfaction- and complaint rates can be used to define a custom made, contemporary reference for office buildings. In practice, these references are of great value in communicating with managers / owners about the quality of the indoor environment in their building. Both follow-up research and an updated reference building will contribute to improving the quality and overall user satisfaction rates of the contemporary office building.

6. Acknowledgement

[Will be added in the after double review.]

7. References

[1] Brunia, S. and Beijer, M. (2014) Trends in werkplekbeleving. Center for people and buildings.

[2] Graham, L.T., Parkinson, T., Schiavon, S. (2020). Lessons learned from 20 years of CBE's occupant surveys.

[3] Vischer, J. C. (2018). Building-in-use assessment: Foundation of workspace psychology. In Building Performance Evaluation (pp. 129-139). Springer, Cham.

[4] Boerstra, A., Beuker, T., Loomans, M., & Hensen, J. (2013). Impact of available and perceived control on comfort and health in European offices. Architectural Science Review, 56(1), 30-41

[5] Hellwig, R. T. (2015). Perceived control in indoor environments: a conceptual approach. Building Research & Information, 43(3), 302-315.

[6] Sakellaris, I., Saraga, D., Mandin, C., de Kluizenaar, Y., Fossati, S., Spinazzè, A., ... & Bartzis, J. (2019). Personal control of the indoor environment in offices: Relations with building characteristics, influence on occupant perception and reported symptoms related to the building—The officair project. Applied Sciences, 9(16), 3227

[7] Chen, C. F., Yilmaz, S., Pisello, A. L., De Simone, M., Kim, A., Hong, T., ... & Zhu, Y. (2020). The impacts of building characteristics, social psychological and cultural factors on indoor environment quality productivity belief. Building and Environment, 185, 10718

[8] Zweers, T., Preller, L., Brunekreef, B., & Boleij, J. S. M. (1992). Health and indoor climate complaints of 7043 office workers in 61 buildings in the Netherlands. Indoor Air, 2(3), 127-136.

The datasets generated during and/or analysed during the current study are not available, because when obtaining the data it has been confirmed to the clients, based on privacy regulations, that the data will not be published or will not be accessible to anyone but the organisation that performed the user feedback survey.