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THE INFLUENCE OF A "QUIET HUB" ON THE INDOOR ACOUSTICS IN AN OPEN OFFICE ENVIRONMENT. A CASE STUDY.

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ABSTRACT

The global COVID-19 pandemic ushered in an era of hybrid work, where a combination of remote work and in-person work is increasingly prevalent. [1-3]. Research shows that because of this there is a growing demand for workplace environments with a flexible office design [4]. Good acoustic workplace design is crucial. Especially people working in an open office often complain about a lack of privacy or not having a quiet space to work in [5]. The purpose of this case study was to investigate the impact of a quiet hub in an open office environment. The hub, as a separate area in the centre of the open- plan office, consists of a free-hanging ceiling section with a highly sound-absorbing top layer and lateral acoustic curtains that serve as screening and act like a visually separated room. The effects of the hub on the acoustic environment were measured using SPL (Sound Pressure Level), reverberation time (T20), speech intelligibility (STI) and level measurements at different distances as acoustic parameters. Based on the results, an evidence-based design was developed to improve acoustic comfort, speech intelligibility and privacy within the centre of the workspace. Outside the centre it was leading to a reduction in intelligibility by a significant level decrease when the distance is doubled.

Keywords: *open-plan office, acoustic comfort, workplace, speech privacy, speech intelligibility, noise annoyance*

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1. INTRODUCTION

1.1 Activity-based Flexible Offices

Open offices are designed with the goal of promoting collaboration, communication, and teamwork among employees. They typically work in a shared space, often with a large number of desks or workstations arranged in an open layout. This allows employees to see and interact with each other more easily, which can encourage collaboration and increase productivity. Additionally, open offices can be more cost-effective than traditional closed offices, as they require less construction and fewer materials. However, open offices have also been criticized and may have long-term negative effects on privacy and perceived office support in terms of individual work and well-being [6] which can lead to decreased productivity, performance and job satisfaction [7 -10].

As such, many organizations have implemented hybrid office models, where employees have access to both open and closed spaces, depending on the activity, their needs and their preferences. These Activity-based Flexible Offices (AFOs) are becoming increasingly popular in modern workplaces as they can increase productivity by allowing employees to move around and find the work environment that best suits their needs and preferences [11]. For example, some employees may prefer a quieter space for focused work, while others may prefer a more social environment for brainstorming and collaboration. In contrast, research shows that AFO environments may not be a good fit for workers demanding routine, concentrated work, or frequent contact with teams [12].

But even though employees can choose where to work in the office, acoustic comfort is still the biggest dissatisfaction within todays workspace environments [13] (Figure 1). According to the questionnaires in another research, auditory privacy was significantly better in the AFO compared to the open-plan office; however, noise and distraction complaints still occurred [14].

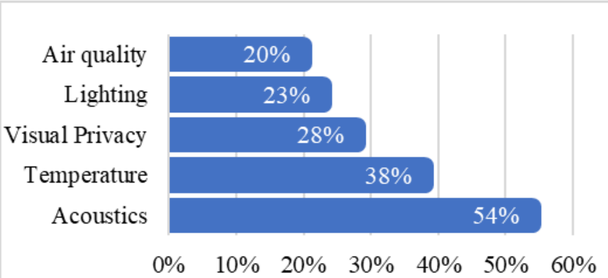

Figure 1: Common sources of occupant dissatisfaction

In the past a lot of research has been done on the biggest sources of distraction within an office environment [15 – 17]. The outcome is not really surprising: the most annoying sound source is irrelevant speech. According to a research from 2023 on the indoor acoustic environment in 600 office buildings, the top 3 is; people talking (78 percent), speech privacy (74 percent) and people talking on the phone (72 percent) [13].

1.2 The balance between speech privacy and speech intelligibility.

The need for privacy has been shown to play an important role in users' satisfaction in AFO environments [18,19], therefore one of the main challenges is achieving a balance between speech privacy and speech intelligibility.

Speech intelligibility refers to the degree to which spoken words or utterances can be accurately understood and comprehended by listeners. It is a measure of how effectively the message is conveyed through speech, without ambiguity or confusion. Speech intelligibility is influenced by various factors, including the clarity of individual speech sounds (phonemes), the articulation and enunciation of the speaker, the presence of background noise, and the room acoustics of the listening environment [20 - 22]. A good estimation of speech intelligibility can be made by measuring the Speech Transmission Index (STI) between the speaker and listener.

Speech privacy refers to the level of confidentiality and protection of spoken information in a given environment. It involves ensuring that conversations or verbal communication cannot be overheard or understood by unintended listeners, thus safeguarding sensitive or private information. When sound levels are too low or there is not enough background noise, conversations can be easily overheard, leading to a perception of a lack of privacy. On the other hand, when appropriate sound masking is used, conversations are less likely to be overheard, leading to a perception of increased privacy [23, 24]. Speech privacy is related to the speech-to-noise ratio and is more or less the opposite of speech intelligibility.

Different research shows a clear correlation between the STI and Speech privacy [25, 26], as shown in Table 1 and Figure 2.

Table 1: Correlation between the Speech intelligibility and Speech privacy, (Hongisto V, 2008)

STI	Speech intelligibility	Speech privacy
0,00 – 0,05	very bad	confidential
0,05 – 0,20	bad	good
0,20 – 0,40	poor	reasonable
0,40 – 0,60	fair	poor
0,60 – 0,75	good	very poor
0,75 – 1,00	excellent	none

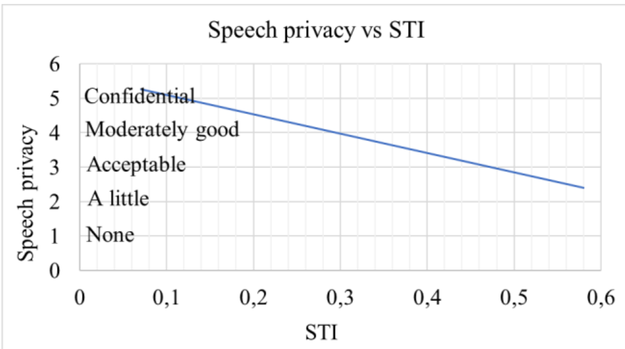

Figure 2: Subjective rating of speech privacy versus Speech Transmission Index (STI), (Pop C, 2005)

1.3 The need for quiet spaces

A survey among 5151 office workers worldwide shows that, if employees want to flee or hide from distractions, the first thing they do is try to find a quieter space in the office. Quiet spaces allow employees to concentrate on their work without being distracted by noise or interruptions from co-workers. This can lead to improved focus, increased productivity, and higher-quality work [27].

Office furniture manufacturer, Steelcase, claims that 95 percent of today's workers need quiet, private spaces but 40 percent say their workplaces don't provide them [28]. A study from Interface, a global manufacturer of commercial flooring, reports that 28 percent do not have a quiet space to work in their office [5].

Creating effective quiet zones is not as simple as cordoning off a corner of the office and adding in a couple of extra desks. Quiet zones should be an area or space that people will go when they need to sit down and concentrate, probably using a laptop for an extended period of time. People using this section don't want to be distracted, but they also need to be seated in an area which is comfortable, supportive, and pleasant. Introducing a "quiet hub" can be the ideal answer to this issue and create quiet, compact surroundings within the larger office environment.

2. MATERIALS AND METHODS

2.1 The office

The purpose of this case study was to investigate the impact of a quiet hub in an open office environment. It concerns an office in Munich, Germany which is used by a management consultancy company. One of the open office spaces is being used for internal and external communication, concentration and collaboration with a coffee corner and 10 workstations in total (Figure 2).

The dimension is 19,5m x 6,3m (avg.) and 3,2m high. The construction consists of a concrete floor, plastered walls, double glased windows and a concrete ceiling. There is no meeting room in the office, so there was a clear demand for adding a flexible space where employees could collaborate with colleagues or focus on individual tasks. This was met by adding a *hub* in the middle of the open office.

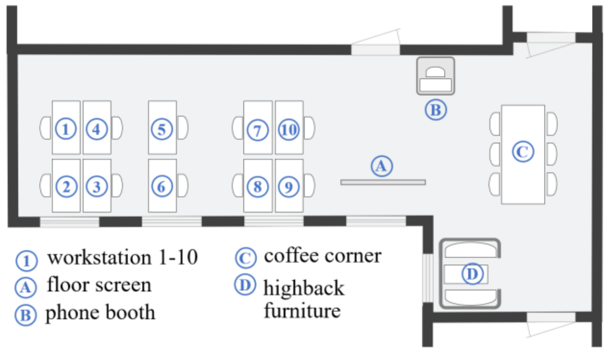

Figure 2: layout of the open office

2.2 The hub

The hub, as a separate area in the centre of the open-plan office, consists of a free-hanging ceiling section (3,6m x 4,2m) with a highly sound-absorbing top layer and lateral acoustic curtains that serve as screening and act like a visually separated room (Figure 3). The curtains are not fitted all around, only on three sides. The facade side has not been applied due to daylight entry. The ceiling section with attached closed curtains are mentioned in the paper as the "hub".

Figure 3: overview of the room including the hub with half open curtains.

The framed ceiling element contains a concealed system with 20mm stone wool ceiling panels mounted within a frame. The curtains are attached to the frame and are build up in three layers. They feature an acoustic fabric on its front and back and a Molton coated layer in between.

2.3 The measurements

The effects of the hub on the acoustic environment were measured using sound levels (Leq), reverberation time (T20) and speech intelligibility (STI) as acoustic parameters. They were measured with the use of a sound level meter (Norsonic, type 118, class 1) and a sound source (Fostex speaker, type 6301B). For the T20 measurements an impulse sound source was used (Geco alarm pistol 6mm, mod. 7762). The sound levels and speech intelligibility were measured on different distances (m) left and right from the centre of the hub (Figure 5).

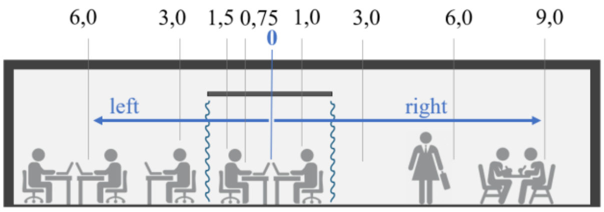

Figure 5. section view with measured distances (meters)

3. RESULTS

The measurements were performed in three different situations: 1. without the installation of the ceiling element and curtains, 2. with the installation of the ceiling element, 3. with the installation of the ceiling element and curtains (Figure 6).

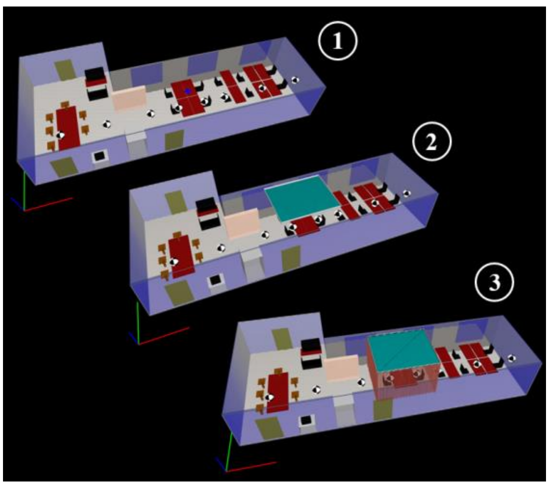

Figure 6. different situations measured

3.1 Sound pressure level

The results of the measurements show that adding sound-absorbing materials has a clear influence on the reduction of the sound levels over different distances (Table 2.). The biggest differences are visible in situation #3, from the position inside the hub to the first position outside the hub (Table 3.). To the left the difference from measurement position 1,5m to 3,0m is 7 dB(A) and to the right from 1,0 m to 3,0m is 10 dB(A).

Table 2: Sound level measurements

Leq, dB(A)	left					right			
distance (m)	6,0	3,0	1,5	0,75	0	1,0	3,0	6,0	9,0
1. without ceiling and curtains	83	84	84	86		86	83	80	80
2. with ceiling	76	77	79	83		82	76	73	73
3. with ceiling and curtains	72	72	79*	84*		81*	71	69	68

* values measured inside the hub.

Table 3: Sound level differences between distances

Δ Leq, dB(A)	left				right		
between distance (m)	3,0 - 6,0	1,5 - 3,0	0,75 - 1,5	0	1,0 - 3,0	3,0 - 6,0	6,0 - 9,0
1. without ceiling and curtains	1	0	2		3	3	0
2. with ceiling	1	2	4		6	3	0
3. with ceiling and curtains	1	7	5		10	2	1

3.2 Speech Transmission Index

The results of the STI measurements, performed according DIN EN 60268-16:2021 [29], towards left side (Figure 7.) and right side (Figure 8.) show that adding sound absorption slightly improves the speech intelligibility from situation #1 to situation #2. In situation #3 there is clear reduction of the speech intelligibility from the measurements inside the hub compared with the measurements outside the hub.

3.3 Speech Privacy

The degree of speech privacy is derived from the measured STI values. The correlation between the speech intelligibility and speech privacy (Table 1.) shows in general a reasonable speech privacy (STI is between 0,20 –

0,40) in situation #3 when working in the office space outside the hub. (Table 4.).

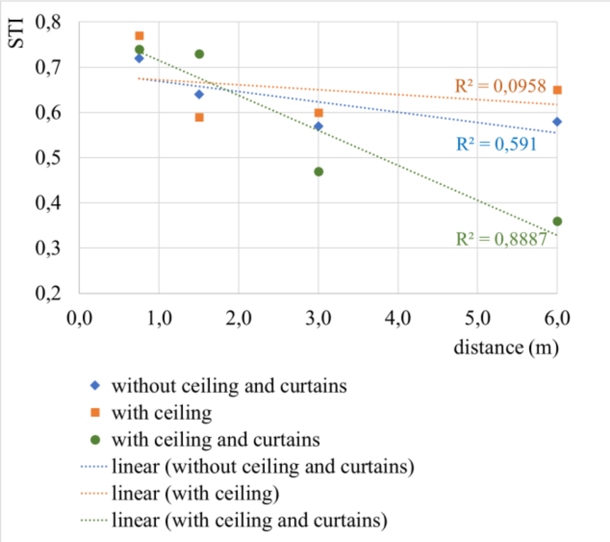

Figure 7: STI measurements left side

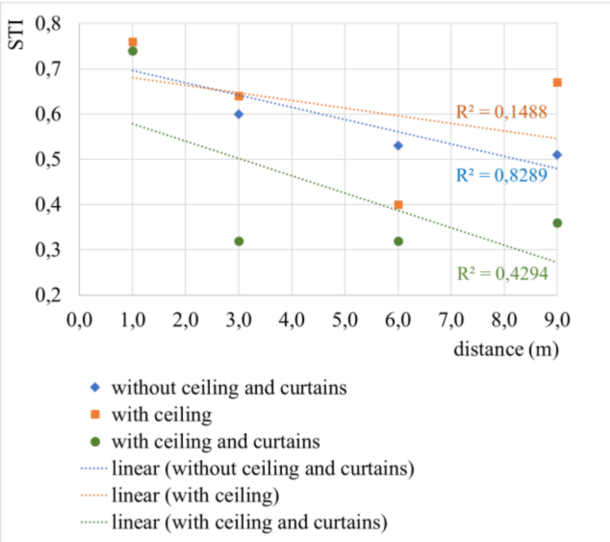

Figure 8: STI measurements right side

3.4 Reverberation times

The results of the measured reverberation times (Figure 9.) show that adding sound-absorbing materials in situation #2 an #3 have a clear influence on the room acoustics with a 40% reduction of the reverberation times. The avg. T20 in situation #1 is 1,13 sec. in situation #2, 0,69 sec., in situation #3, 0,67 sec. and in situation #4 it is 0,44 seconds. The target values are taken from the ISO 22955 – Acoustic quality of open office spaces. [30]

Table 4. color coding Speech privacy (derived from Table. 1) with measured STI values

Speech privacy	left					right			
distance (m)	6,0	3,0	1,5	0,75	0	1,0	3,0	6,0	9,0
1. without ceiling and curtains	0,58	0,57	0,64	0,72		0,74	0,60	0,53	0,51
2. with ceiling	0,65	0,60	0,59	0,77		0,76	0,64	0,40	0,67
3. with ceiling and curtains	0,36	0,47	0,73*	0,74*		0,74*	0,32	0,32	0,36

* values measured inside the hub.

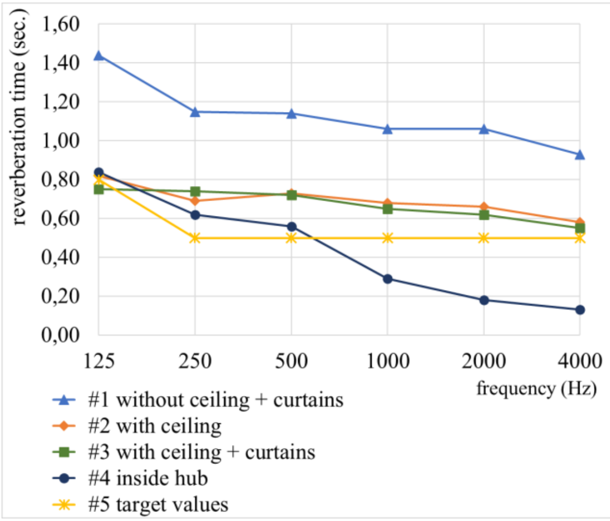

Figure 9: overview of reverberation times

4. DISCUSSION AND CONCLUSION

This study aimed to investigate the impact of the hub on the indoor acoustic environment and the acoustic comfort in the open office. Can you reduce noise annoyance and improve acoustic privacy in an AFO with simply adding a sound absorbing ceiling element/island with attached acoustic dividing curtains?

Some results and outcomes are not surprising, if you add highly sound absorbing materials in a space where none is present, it is generally known that it will reduce the reverberation times and the sound pressure levels when the distance is doubled. It is clearly noticeable however that at the location of the ceiling element (without curtains) the sound pressure levels are reduced 4 – 6 dB(A) which gives an improved speech intelligibility.

The calculated reverberation time T20 (performed with using CadnaR software) is close to what is measured (furnished and unoccupied situation). As the ceiling element (without curtains) only contains 12% of the floor surface it was expected it would not comply the target values according the ISO 22955. A survey among the users will give more information how this will affect the acoustic comfort.

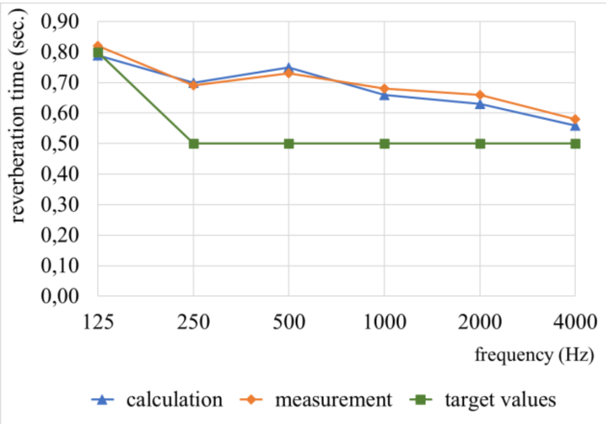

Figure 10: reverberation time calculated vs. measured in the situation with ceiling element (without curtains)

A *reasonable* speech privacy was achieved on the left position from measurement point 1,5m to 3,0m with a difference of 7 dB(A) and on the right side from 1,0 m to 3,0m with a 10 dB(A) difference (Table 4). When looking at the subjective rating of speech privacy versus Speech Transmission Index in Figure 2., the outcome from these positions give an *acceptable* speech privacy.

Future research is needed to see how much the speech privacy can be improved when installing curtains fully closed around the hub instead of only three sides as in this case study.

The first reactions of the employees is that they mention an improved acoustic comfort. A detailed survey is being conducted and the outcomes will be shared when ready.

5. DISCLOSURE STATEMENT

The authors of this paper, whose names are listed, declare a conflict of interest as the ceiling element discussed in this paper is an acoustic solution from the company they work for.

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