The value of control for acoustic satisfaction in open plan offices: a case study

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ABSTRACT

Acoustic conditions were investigated on two different floor plate designs within an organisation’s building. One is a traditional layout, with assigned desks arranged in rows. The other is a complete re-design for activity-based working (ABW), with a variety of work settings, without assigned places. Both floor plates have the same ceiling, lighting, flooring, facade, and HVAC systems; both floor plates are open to the same central atrium. The organisation’s staff surveys demonstrate a significant improvement in satisfaction with environmental conditions for thermal comfort, lighting, and acoustics for people on the ABW floorplate. This study investigated the acoustic conditions on the two different floor plates.

Measurements of the room acoustics were conducted according to ISO 3382-3, revealing very similar indicators. Occupied acoustic measurements demonstrate that the in-situ acoustic environment is also similar between the two designs. The improvement in satisfaction with the acoustic conditions is ascribed to the increased personal control that people have over their work environment; this is explored through interviews. Acoustic satisfaction, environmental comfort and a sense of control are all positively correlated with productivity at work.

BACKGROUND

A programme of transformation took place over a number of years at a large office complex. A new approach to workplace strategy went hand in hand with a redesigned floor plate and new IT provisions for staff. Both floor plates have the same ceiling, lighting, flooring, facade, and HVAC systems; both floor plates are open to the same central atrium. People working on the traditional floor plates had fixed, assigned desks; on the new floor plate, they had no assigned spaces. Repeated satisfaction surveys were used to evaluate the success or otherwise of the redesigned space.

The traditional layout is illustrated in Figure 1. There are 130 assigned workstations arranged perpendicular to the façade, as shown in Figure 5. There is a small number of meeting rooms at the ends of the floor plate, the number varying between locations (not shown in Figure 5). The new redesigned layout is illustrated in Figure 2 and Figure 3. The provision is for 100 desk spaces and 80 alternative work settings. The layout is shown in Figure 6, and accommodates more people than the traditional layout.

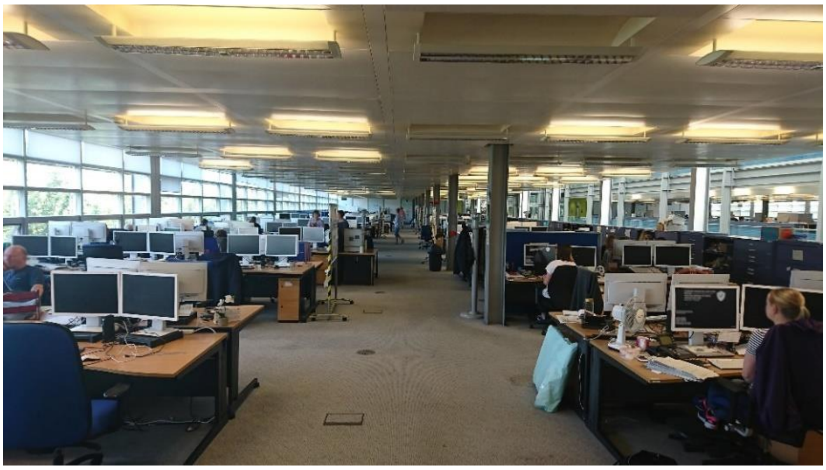

Figure 1: The traditional layout

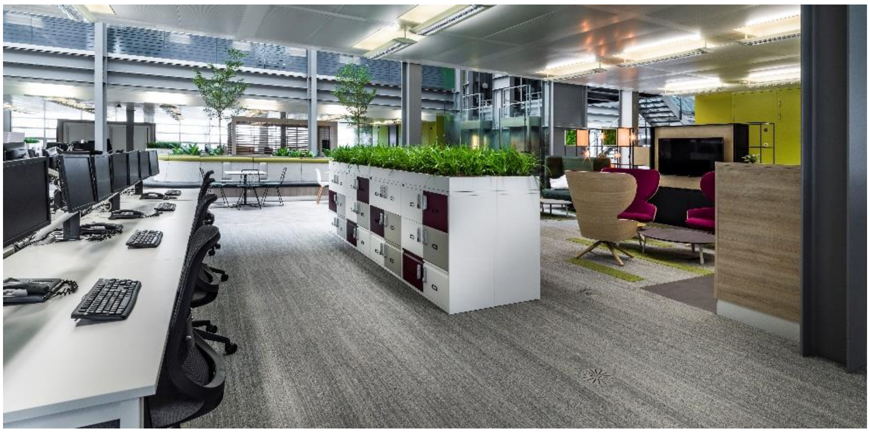

Figure 2: The new, redesigned layout (view A), courtesy of Ward Robinson

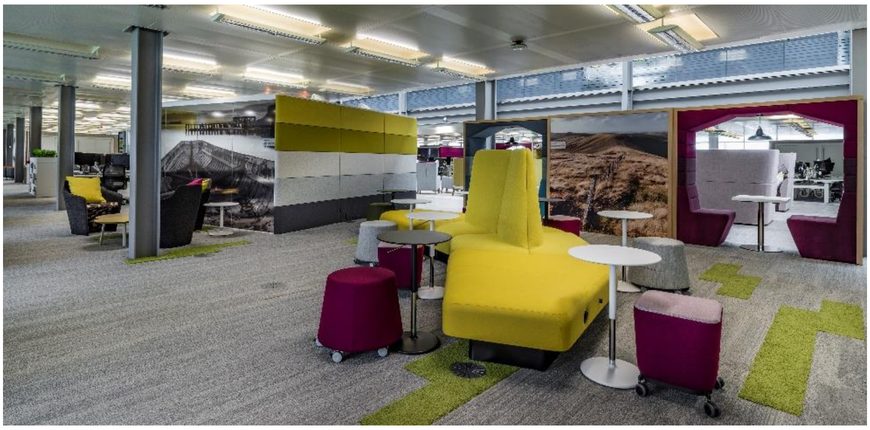

Figure 3: The new, redesigned layout (view B), courtesy of Ward Robinson

Staff surveys

The staff survey was conducted by the employer organisation. It included the question:

"*Please rate your level of agreement with the following statements about your working environment at* [workplace]":

- I am satisfied with the lighting
- I am satisfied with the acoustics
- I am satisfied with the climate in the office

The chart in Figure 4 shows the pre and post occupation responses to these questions.

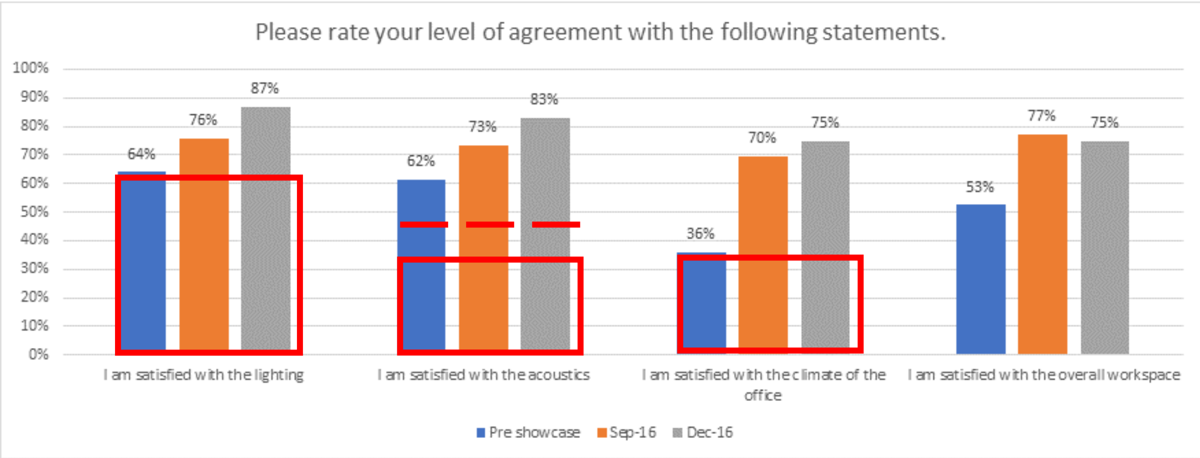

Figure 4: Results of pre- and post- showcase (new) floorplate occupation.
Red boxes and lines represent global average response from the Leesman Index for comparison.

On the new floorplate, after sufficient time to acclimatise, the level of acoustic satisfaction is recorded as 83%. This is a remarkable achievement, and may be compared with the Leesman Index [1] question “How satisfied are you with noise levels”. The Leesman Index has over 800,000 responses with an average satisfaction of 32 %, as shown in the red box overlaid in Figure 1. High-performing workplaces achieve the Leesman+ certification, where satisfaction with noise levels is 45 % globally (shown with a dashed line in Figure 1). There may be a difference in the way people respond to a question about “acoustics” rather than “noise levels”. Haapakangas [2] has shown there is a high level of correlation between being “disturbed by noise” and “disturbed by speech”, whereas the term “acoustics” may be interpreted to mean different things.

As a result of the success of the new design, Apex Acoustics was commissioned to undertake measurements to benchmark and review the acoustic conditions within the traditional and new office floorplates. The aspiration was that these measurements would reveal a measurable difference, and that the acoustic parameters of the new floor plate could be encapsulated in the brand standard design guidance, such that the level of satisfaction could be replicated with different physical layouts and design solutions. To this end, a survey scope was determined to include both occupied and unoccupied measurements.

COMPARING THE MEASURED CHARACTERISTICS

The details of the measurements are presented in Appendix A. The measured indicators, in both empty, unoccupied offices, and when occupied, do not reveal differences of any significance between the two floor plates, despite the significantly different appearance and furnishing. This result is actually also consistent with lighting and thermal comfort – none of those physical characteristics were changed in the new office layout. How could the remarkable differences in employee experiences be understood, when the physical environment had not changed?

Interview with new floorplate leader

Following the presentation of the measured results to the management team, we met with the person responsible for the new ways of working. She explained how they had tried not to label spaces, because words filled people with expectations. They have moved well away from conceiving of spaces as “core, collaborate, concentrate, and amenity”, for example. They also resist using descriptions such as “agile” and “flexible working”. Personality has been the biggest obstacle to adopting the new practices, rather than age, as some people had anticipated. Old-fashioned “command and control” style managers found it hardest to let go of knowing where people are and what they are doing.

The new floorplate design accommodates more people than the traditional layouts. As is common in offices with unassigned desks, some people like to congregate to the same areas. We asked if particular work stations were unpopular – for example adjacent to the large meeting area, where teleconference calls were also held. The people who liked to sit there had initially complained about the disturbance from meetings, but then they stopped complaining and continued to occupy those positions – their choice. In other areas, the furniture has been rearranged following feedback from users, to enable greater privacy and discretion. Focused work happens in back to back pods, meeting pods, telephone booths, or at home (NB this was much less common, pre-Covid).

DISCUSSION

Productivity, control, noise and acoustic satisfaction

Leaman and Bordass [3] demonstrate how perceived productivity is strongly and significantly correlated with perceived comfort. Control is described as the “killer variable” for comfort and satisfaction with the physical environment in buildings. Indeed, even the speed of response of the facility management (FM) team to complaints about discomfort in the environment is strongly correlated with a sense of control. The notion of the importance of personal control underpins the adaptive thermal comfort model [4]; people declare themselves to be comfortable at a wider range of temperatures when they have a sense of control over the environment with an opening window, compared to having no control over their environment.

But a sense of control is also much more than just a moderator of response to one’s physical environment; Leotti et al [5] claim that:

Belief in one’s ability to exert control over the environment and to produce desired results is essential for an individual’s wellbeing. …perception of control is not only desirable, but is also probably a psychological and biological necessity. …the need for control is a biological imperative for survival.

Thus conferring opportunities for personal environmental control is an end in itself, as well as increasing satisfaction with environmental conditions. Hanc [6] describes the gap of knowledge between the environmental and social sciences approaches: the environmental sciences perspective emphasizes the role of the physical ‘workspace’ environment on productivity and wellbeing. In contrast, the social sciences approach focuses on the psychosocial processes in the ‘workplace’. Considering the physical and psychosocial determinants as independent from each other leads to an incomplete understanding of workspace productivity and wellbeing. This is especially so when considering noise, which is overwhelmingly treated as a physical factor of the workplace environment. One definition of “noise” is sound which the recipient does not wish to hear. The lack of control is implicit in the word “noise”. People’s relationship with the environment can be more important than its physical characteristics.

Designing for acoustic satisfaction

A soundscape approach [7] explicitly identifies a sense of personal control as part of the context: this determines the auditory sensation, interpretation and response to sounds, as part of the perceptual construct of soundscape. To date, this has been largely omitted from what is considered part of the "acoustic design" for an office. Lee and Aletta [8] used a soundscape approach to investigate acoustic design for workplace health and wellbeing. Of all the measures, acoustical space planning and user control were the most significant factors affecting acoustic satisfaction. They indicate that guidance to increase occupants' auditory comfort, well-being, and performance should be sought by designers in a holistic and integrative way.

In practice, the acoustic space planning is typically undertaken implicitly by the interior designer, based on their experience rather than any specific education or training. The extent of control that people have is not usually considered to be part of the acoustic design, which rather focusses on the acoustic treatment to the room. Beyond the acoustical characteristics of the room, the context and control that occupants have over their environment can be more significant for the level of acoustic satisfaction reported. The excellent German Standard VDI 2569 [9] claims:

Finally it shall be mentioned that only approximately 30 % to 40 % of the annoying effect resulting from noise can be explained by technical-acoustic factors. The predominant portion originates from so-called moderators of annoyance. The personal and situational moderators of annoyance include the following factors:

- *noise control / noise handling*
- *attitude towards the noise-maker*
- *predictability of the sound event*
- *activity profile of the employee*
- *organizational & business structure, including identification with the business workload*
- *other environmental factors such as illumination and thermal comfort*
- *individual noise sensitivity.*

Thus when designing for acoustic satisfaction, proportional attention should be given to these factors as to the "technical-acoustic factors", which refers to the physical acoustic response of the room.

Oseland and Hodsman [10] have proposed a psychoacoustic approach to resolving office noise. They discuss how a psychoacoustic approach can be used to create people-centred work environments based around four key factors: task and work activity; context and attitude; perceived control and predictability; and personality and mood. They conclude that:

The solution to noise distraction is as much to do with the management of the space and guidance on behaviour as it is about the design and acoustic properties. A choice of different types of space with different acoustic properties and agreed behaviours is essential for reducing noise distraction.

ABW – workplace panacea?

ABW can be described as more of a business transformational strategy rather than simply a workplace strategy. People can be offered choices – for example an opportunity to use a quiet space protected from noise – without the business moving to ABW. However, to enable people to perform their work as effectively as possible, simply offering choice and some control over their work environment may not be enough in itself. Jahncke and Hallman [11] demonstrate that cognitive performance varies widely within an ABW office, and that people need quiet areas free from distractions to perform best. But people do not always move to the most appropriate area for the task in hand, so that the potential benefits are not always realised. Leesman investigated ABW [12] and found a similar story: ABW environments can deliver significant performance improvements for people who modify their behaviour to their new surroundings. However, these people are usually dramatically outnumbered by those who maintain distinctly traditional workstyles, without moving to the most appropriate place for the task in hand; this puts them in conflict with their new environment. Thus the opportunity to exercise control comes responsibility to take control. Many factors are likely to influence the extent to which people take the control offered to them, not least personality.

Case study results in context

Despite the similarity of the measured acoustic indicators for both the unoccupied and occupied conditions, the user surveys (Figure 4) demonstrate a very significant difference in their acoustic satisfaction with each arrangement, as well as difference in satisfaction for the other environmental factors. It is suggested that the very significant difference is the level of control people have over their environment. The responses to equivalent questions about office lighting and temperature control are also shown. It is evident from the scope of the redesigned floor plate that no changes were made to the physical environment in terms of heating or lighting, yet satisfaction also increased for these aspects of the environment.

CONCLUSION

Both the new and traditional floor plates perform equivalently in terms of all the physical acoustic performance measurements undertaken in unoccupied spaces. The spaces cannot be distinguished on the basis of acoustic performance indicators for the room acoustic response. The occupied measurements of Liveliness suggest that a greater variety of acoustic environments is found in the new floorplate layout. There are more instances of calmer, quieter environments on the new floor plate compared with the traditional layout. However, this indicator cannot be used to characterize the physical environment for design purposes.

The breath-taking levels of satisfaction with the acoustic environment, and other aspects of the physical environment, are attributed to the level of control that occupants enjoy over where and when to work, and in their interaction with their workplace. A sense of personal control is strongly correlated with perceived productivity, and is essential for wellbeing in its own right. A sense of control also strongly affects satisfaction with the physical environmental factors. Acoustic design may be most successful when it considers the psychosocial aspects, not just the physical environmental aspects, of the workplace. Design methods to address acoustic satisfaction holistically, to optimise people’s experience at work, are emerging and should be promoted.

Acknowledgements

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APPENDIX A: MEASUREMENTS

The acoustic measurements carried out included:

Unoccupied measurements of the room acoustic response	**Occupied measurements of the room acoustic conditions**
Ambient noise levels unoccupied, $L_{p,B}$ Spatial decay of speech, $D_{2,s}$ Speech level at 4 m, $L_{p,A,S,4m}$ Reverberation time, S	Ambient noise levels occupied, $L_{Aeq,\ T}$ "Liveliness" measurements

Although the Speech Transmission Index, STI (and hence radius of distraction, r_D) was not measured directly, the values may be inferred from the spatial decay measurements and the background sound level. The test data was compared with criteria from the current guidance at the time, but the commentary below is in the context of current guidance, standards and international research.

Guidance and standards

Current international guidance and research is reviewed to inform the meaning of the measured values in context. It is important to distinguish between metrics that describe the building fabric - without occupants - and those that describe in-use conditions, with occupants undertaking their normal activities. The vast majority of guidance and Standards refer to the acoustic response of the office when it is unoccupied.

ISO 3382-3 [13]

ISO 3382-3 defines methods of measuring a range of room acoustic performance parameters applicable to open-plan offices. ISO 3382-3 defines spectral sound pressure levels for normal speech, which are used in the calculation of $D_{2,S}$ and $L_{p,A,S,4m}$. ISO 3382-3 has an informative annexe that suggests that the values in Table 1 may represent the acoustic conditions in open plan offices:

Table 1: Values for indicators given in ISO 3382-3 informative annexe

Indicator	**Typical values in offices with…**	
	… poor acoustic conditions	**… good acoustic conditions**
$D_{2,S}$ / dB	< 5 dB	≥ 7 dB
$L_{p,A,s,4m}$ / dB	> 50 dB	≤ 48 dB
r_D / m	> 10 m	≤ 5 m

However, the adoption of particular values in other countries' classification systems (as there is none in the UK) is controversial, as it includes the implicit cultural expectations of how an open plan office may be designed. This is discussed in "Acoustics of open plan offices: contrasting design implications from emerging French, German & Finnish standards" by Harvie-Clark & Larrieu [14]

Draft ISO/ FDIS 22955 [15]

ISO/FDIS 22955 remains in final draft form at the time of writing but may be published by the time of this conference. The contents of ISO 22955 has been described by Harvie-Clark et al [16]. It has been derived from the French Standard NF S31-199, and proposes a set of acoustic performance standards for different types of open-plan office spaces depending on the proposed use.

A summary of the proposed acoustic performance criteria for three different use types are shown in Table 2. ISO/FDIS 22955 adopts the use of some parameters defined in ISO 3382-3, and also proposes a new parameter for in-situ attenuation between workstations, $D_{A,s}$. There are target values for ambient noise in use (these are not imperative for qualification of the Standard), as well as performance criteria for the building fabric.

Table 2: Summary of proposed acoustic performance criteria from ISO/FDIS 22955

Space type	Target $L_{Aeq,T}$ / dB	Required $D_{A,S}$ / dB *	Required $D_{2,S}$ / dB	Required $L_{p,A,S,4m}$ / dB
Contact centre	≤ 55	≥ 6	≥ 7	≤ 47
Collaborative work	≤ 52	≤ 4	≥ 8	≤ 48
Individual work	≤ 48	≥ 6	≥ 7	≤ 47

Liveliness [17]

ISO 3382-3 provides guidelines for measuring the room acoustic response in unoccupied open plan offices. However, those metrics do not take any account of the actual behaviour of people, and the resulting acoustic environment. The Liveliness method has been developed to describe the office sound environment in an accessible way with a semantic scale that matches people's perceptions, and that is also objectively measurable. It comprises four labels, going from 'Quiet' via 'Tranquil' and 'Lively' to 'Turbulent'. Different types of activities are better suited to different types of acoustic environment.

Sound levels are measured during normal office use as equivalent levels, $L_{Aeq,5min}$, and percentile levels $L_{A5,5min}$. The sound environment is interpreted to a degree of 'Liveliness' based on an algorithm that has been matched to people's subjective responses. The algorithm is used to calculate an index between 1 and 10, which rates the average perception of the acoustical environment in the monitored office, i.e. Liveliness. The numerical rating is also translated into one of four categories: quiet, tranquil, lively and turbulent. The Liveliness scale is described in Table 3. The algorithm determines the value to the nearest 0.5.

Table 3: Liveliness ratings and descriptions

Liveliness rating	Description		Liveliness rating	Description
1	QUIET		6	almost lively
2	almost quiet		7	LIVELY
3	more tranquil		8	more than lively
4	TRANQUIL		9	almost turbulent
5	almost tranquil		10	TURBULENT

Measurements of ambient noise levels

Unoccupied measurements

Ambient noise level measurements were undertaken in the evening when the building had very few people still working, such that they were unaffected by those still in the building. The measured ambient noise levels ranged between 29 and 35 dBA across the floor plates.

Occupied measurements

Ambient noise level measurements with typical occupation were undertaken on a normal working day. The measurement positions are shown in Figure 1 and Figure 2 for the traditional and new layouts respectively. The results are shown in Table 4 and Table 5. Overall the measured ambient noise levels were similar on the two floorplates, although the observed activities appeared to differ. On the traditional floorplate lone working with minimal collaborative activity seemed to be most common. On the new layout floorplate more people were engaged in discussions with each other in the desk areas, the break-out spaces and pods. A greater number of telephone discussions audible across the new layout floorplate were also observed. There was a slightly greater proportion of positions with lower noise levels on the new floorplate.

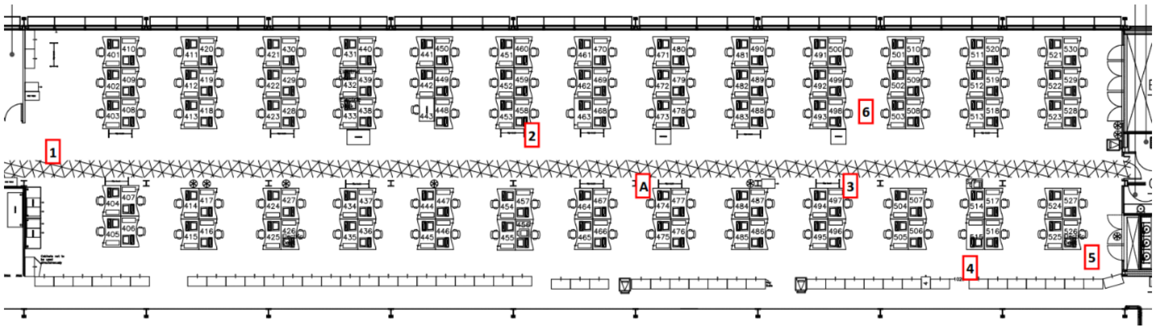

Figure 5: Traditional layout measurement positions

Table 4: Measured ambient noise levels on the traditional layout floorplate

Position	Duration (T), hh:mm	Level, $L_{Aeq,T}$ /dB	Comments
A	03:00	53	Observations not made at this location
1 - 5	00:15	50 – 56	Occasional discussion between people, printer, typing, noise from other floorplates audible, minimal collaborative working, conversation from more populated central area, intermittent telephone conversations

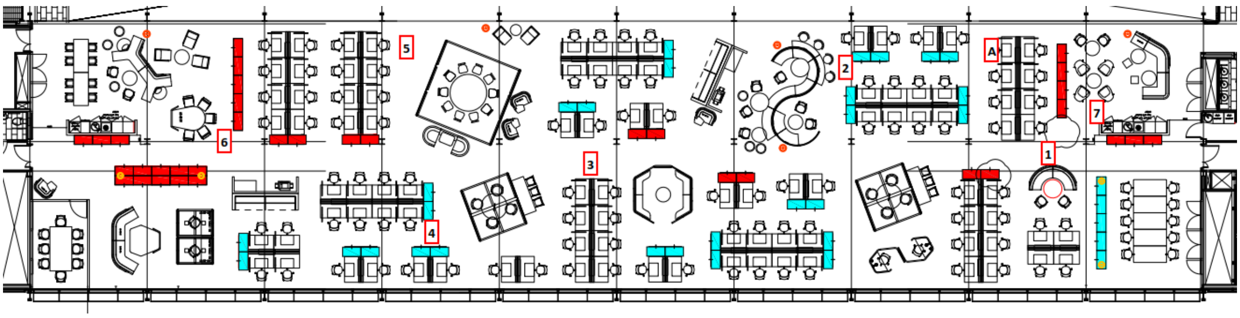

Figure 6: New layout measurement positions

Table 5: Measured ambient noise levels in new layout floorplate

Position	Duration (T), hh:mm	Level, $L_{Aeq,T}$ / dB	Comments
A	03:00	54	Observations not made at this location
1-7	00:15	48 - 56	General chatter, telephone conversations, noise from other floorplates through atrium, people walking past

Spatial decay of speech and speech level at 4 m

Measurements of the spatial decay of speech, $D_{2,S}$ and speech level at 4 m, $L_{p,\,A,\,S,\,4m}$ were made following the guidance of ISO 3382-3. The loudspeaker and microphone approximate positions for each test are shown in Figure 3 and Figure 4 for the new and traditional offices respectively. The calculated results are shown in Table 6.

Table 6: Measured $D_{2,S}$ and $L_{p,A,S,4m}$

Floorplate	Measurement	$D_{2,s}$ dB	$L_{p,A,S,4m}$ dB
New	1	7.4	51.3
	2	6.0	51.1
	3	6.0	54.1
Traditional	1	6.1	50.7
	2	6.3	48.9

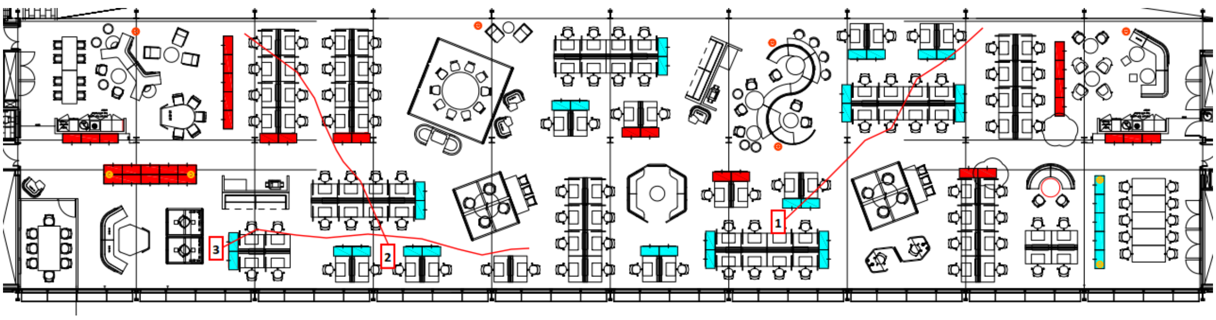

Figure 7: Loudspeaker positions and measurement paths, $D_{2,S}$ measurements on new floorplate

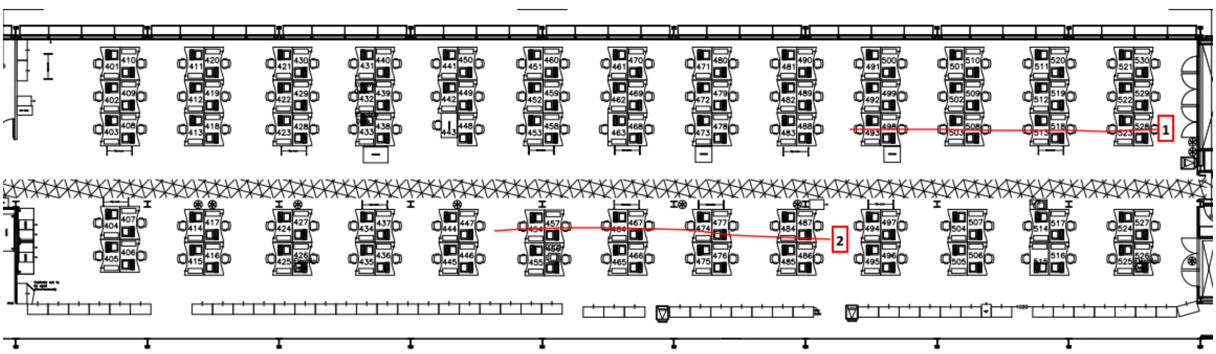

Figure 8: Loudspeaker positions and measurement paths, $D_{2,S}$ measurements on traditional floorplate

The time histories of the measured equivalent levels, $L_{Aeq,5min}$, and percentile levels $L_{A5,5min}$. are used to calculate the Liveliness coefficient for each five-minute period of measurements in the occupied offices. The results are normalised so that the distribution of values can be compared.

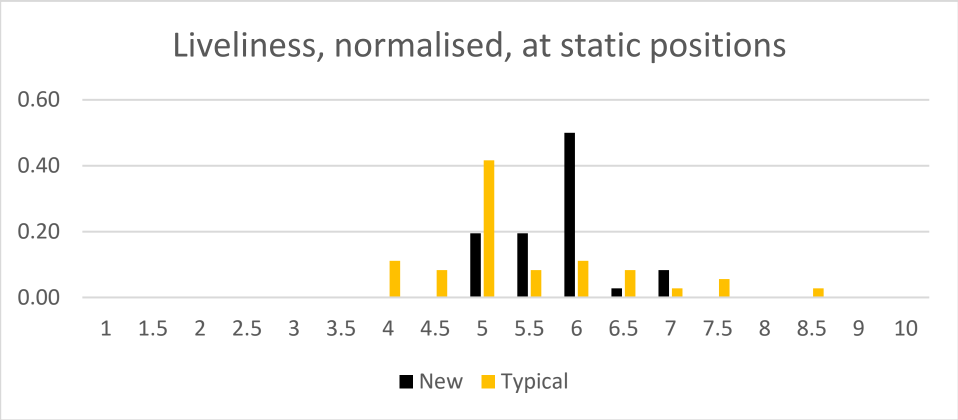

Figure 9: Normalised Liveliness ratings at static measurement positions, compared between the new and traditional floor plates.

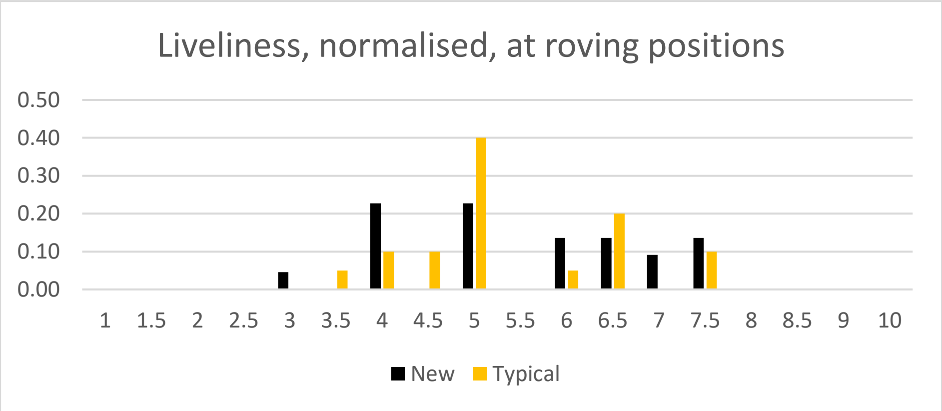

Figure 10: Normalised Liveliness ratings at roving measurement positions, compared between the new and traditional floor plates.

Discussion of results – unoccupied measurements

The background noise levels from building services show that noise from building services is low, and compliant with all relevant standards and guidance discussed, on both the traditional and new floorplates.

The spatial decay of speech is generally between 6 and 7 dB on both the traditional and new floor plates. This is slightly short of the required value for non-collaborative work (7 dB) in the ISO /FDIS 22955 standard, and short of the value for collaborative work (8 dB).

The measurement paths selected on the new floor plate (Figure 8) were selected across the open areas rather than across the barriers of greater height. Thus they represent the lines of lowest spatial decay, whereas in the traditional layout, the spatial decay is approximately equal in all directions. In practice there are many areas within the new floorplate where speech does not travel across the space in the same way it does on the traditional floor plate.

The indicator does not represent this difference unless measurement paths are chosen across significant obstructions such as meeting booths, for example.

Discussion of results – occupied measurements

It is interesting to note the significant difference in observed activities between the traditional and new floor plates (Table 4 and Table 5 respectively), with significantly more interaction between people noted on the new floor plate. Despite this, overall the ambient noise levels measured on both floor plates are very similar, considering both the static and roving measurement locations. There is a slightly higher instance of lower noise levels recorded on the new floor plate at some positions compared to the traditional floor plate, where noise levels are more spatially homogeneous. The ambient noise levels would slightly exceed the target values for collaborative working in the ISO/ FDIS 22955, and more significantly exceed the target values for non-collaborative work. The results are consistent with the average level across 43 open plan offices found by Yadav et al [18] of 53.6 dBA.

The Liveliness ratings for the static position on the traditional floor plate (Figure 9) are centred around a value of 5, described as “almost tranquil”; on the new floor plate, the distribution of measurements at the static position is centred at a slightly higher rating of 6, or “almost lively”. These ratings reflect the single locations used for the static measurements. The average Liveliness ratings for both floor plates, static and roving positions, are between 5 and 6, i.e. between “almost tranquil” and “almost lively”, although the distribution of results is noticeably different.

The distribution of ratings for the static position on the traditional floor plate is greater than the variation for the new floor plate. This indicates that the acoustic environment is temporally more variable on the traditional floor plate than it is on the new floor plate at the one position. This is as may be expected, as all the different activities – between individual focussed work and collaboration – are more likely to take place at the same location on the traditional floor plate, whereas the new floor plate offers different settings for different activities. Hence on a temporal basis a narrower range of liveliness ratings indicates that the space on the new floor plate is being used more consistently for similar activities than for the traditional layout.

The Liveliness ratings for the roving positions on the traditional floor plate (Figure 10) are again centered around a value of 5, described as “almost tranquil”; on the new floor plate, the distribution of measurements at the roving positions (Figure 10 again) is more varied, with no clear centre of distribution. This indicates that there is a greater spatial variation in Liveliness across the new floor plate that is not observed on the traditional floor plate. On the new floor plate there is also a much greater proportion of spaces rated as “Tranquil”, with a value of 4 or less. This corresponds with the higher instances of lower ambient noise levels measured on the new floor plate.