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Lessons to be learnt from open plan offices and classrooms

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1. INTRODUCTION

Much research has been carried out over the past 50 years on the acoustical effects and requirements in open plan offices. Research has generally involved determining what physical factors and performance criteria are required to provide an acoustic environment similar to that of cellular spaces. This paper will investigate and summarise some of the key findings from this research.

Many of the design guidance documents for offices (e.g. BS 8233: 1999, BCO guidelines, BREEAM for Offices) set out design criteria to enable optimized conditions for privacy between workers. However, there is no UK legislation that dictates how an office must be acoustically designed and it is common for conditions within the occupied office to be far from ideal.

The way we procure office developments in the UK does not help. The 3 key stages in commercial office procurement are as follows:

- Shell & Core (structural elements, cores, services)
- Category A fit-out (Shell & Core plus ceilings, possibly including carpets)
- Category B fit-out (Category A plus partitions and furniture)

This procurement route often leads to problems with the acoustic conditions within the office. However, the purpose of these categories is to allow developers to provide speculative buildings without any fixed tenant in mind, allowing future tenants maximum flexibility in their own fit-out.

Acoustics of open plan offices are similar in many ways to open plan teaching/learning spaces. Although office workers could be said to have a greater ability to cope and adapt to poor acoustic conditions, the same principles of concentration and productivity still apply. Just as there is a drive to open up office floor plates, the Transformational Learning agenda often requires teaching and learning spaces in schools to be opened up to allow maximum flexibility for present teaching and future possibilities. It would appear much more research has been carried out for offices, and due to the significant commonalities between the 2 types of space, there should be a sharing of knowledge which can ultimately benefit all concerned.

2. OPEN PLAN OFFICE RESEARCH

Almost without exception, available research into open plan offices is involved with investigating physical requirements and performance criteria to facilitate privacy normally

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afforded in cellular offices. There are obvious financial benefits in providing open plan offices, as it negates the need for costly and space-consuming partitions, enabling the number of occupants and cost per unit area of a given space to be reduced.

The following factors and criteria have been discussed and recommended in research dating over the last 50 years.

A. Sources of annoyance

- The most annoying sources of noise are activities within the same room (Langdon, 1966), the worst of which are telephones and other peoples' voices (Sundstrom *et al* 1994, Haapakangas *et al* 2008)
- Disturbance is greatest in large office areas with high numbers of occupants (Sundstrom *et al* 1982)
- Occupants to do not acclimatize to poor acoustic working environments (Schwede *et al* 2008)
- Noise from other workers is greatest when complex tasks are being undertaken (Kjellborg and Landstrom 1994)

B. Background noise

- Acceptable noise levels in open plan offices are between 45 and 50 dB(A) (Navai and Veitch 2003, Bradley and Gover 2004)
- Shaped masking noise can help in open plan offices (Navai and Veitch 2003)
- Relatively high levels of background noise level can be tolerated (up to 68 dBA, but fluctuations in level increased discomfort and distraction (Keighley, 1966)
- Noise from ventilation systems should be around 45 dBA (Hay and Kemp 1972)

C. Speech intelligibility between workers

- For acceptable speech privacy, STI[2] <0.20 is desirable, but for confidentiality < 0.10 is required (Bradley 2007)

D. Sound absorption

- The ceiling is the most important component in controlling noise in the office (Warnock 1973, Bradley 2003)
- Ceilings should be as absorbent as possible (Bradley 2003), typically 0.9 αw (Hongisto *et al* 2004)
- Screens are effective, only in the absence of reflections from the ceiling (Warnock 1973)
- Screens should have an STC[3] of > 20 dB, although significant increase in STC has negligible effect (Bradley 2003)
- Carpets and soft floor coverings help to deaden noise at source and minimize propagation under screens (Bradley 2003)
- Flat lens luminaires can have a detrimental effect on speech privacy and screen performance (Moreland 1989, Bradley 2003)

E. Suggested solutions

- Provide designated non-work areas, enforced quiet areas and separate enclosed rooms for private conversation (Banbury and Berry 2005)

[2] Speech Transmission Index
[3] Sound Transmission Class

- Office etiquette involving quiet speech should be encouraged (Bradley 2003)

3. AVAILABLE UK GUIDANCE

A number of guidance documents are currently available in the UK. Many of the criteria are derived from research detailed above. The main criteria in regard to open plan offices are summarized below.

A. BS 8233: 1999

- Unoccupied internal ambient noise levels 45 to 50 dBA for reasonable privacy
- Absorbent screening at 1.5 m height
- Ceilings to be less than 3 m and highly absorbent (0.9 αw averaged over speech frequencies)
- Floors should be carpeted

B. British Council for Offices (BCO)

- NR 38 (L_{eq}) for residual noise from external sources
- NR 38 (L_{eq}) for building services noise
- Implies unoccupied internal noise level of ≤ NR 41 / 47 dBA
- Recommends modular metal ceilings
- RT although there are fundamental problems in calculating and measuring reverberation time in large spaces with low ceilings. Virjonen *et al* (2009) suggests that reverberation time is not an appropriate method of characterizing open plan spaces

C. BREEAM 2008 for Offices

- 40 to 50 $dBL_{Aeq,T}$ when unoccupied

4. PROCUREMENT ROUTES

It is common in the UK for offices to be developed up to Category A fit-out prior to letting, unless being produced for a particular end user. Many offices are therefore constructed and fitted out with suspended ceilings and raised access floors.

When a tenant comes on board, they will invariably install a number of partitions, for cellular offices, meeting rooms etc. This brings the first challenge, in that provision of a good standard of sound insulation can only be achieved by carrying the acoustic barrier down to the structural floor and up to the soffit. Short of removing large sections of raised access floor and ceiling, the most common method is to install void barriers. However, these are fraught with design and detailing issues, as providing a good seal around edges and to services passing through, all in the tight confines of floor and ceiling voids, is problematic. Added to this, if either or both voids are used as supply or extract plenums for ventilation, the potential for cross-talk between adjacent spaces is exacerbated.

It is not unusual for an office to be rented in its Category A state, then for the tenant to remove large sections of ceiling to meet his own needs. One ceiling manufacturer estimates that up to 40% of Category A ceilings are wasted to accommodate Category B requirements. This is not a sustainable approach, but can be financially rewarding for ceiling manufacturers!

The only method of consistently achieving a good standard of acoustic separation between adjacent areas in an office is for the base design to reflect the finished layout. This way, solutions are built in, rather than bolted on and the risk of non-performance due to poor detailing is significantly reduced.

It is the opinion of the writer that the current procurement method in the UK can not deliver consistently good acoustic environments in office developments.

5. OPEN PLAN TEACHING AND LEARNING

Acousticians are renowned for bemoaning open plan teaching spaces. The whole concept of trying to carry out various concurrent teaching and learning activities in a single, open space, makes very little acoustic sense. Certainly when compared with the acoustic protection (in terms of sound insulation and absorption) afforded by cellular classbases, there is no comparison. However, this assumes that the same type of teaching and learning (pedagogy) would take place in both types of environment – when this is the case then open plan is clearly sub-standard. Where open plan does come into its own is when a more flexible pedagogical approach is required and the method of teaching and learning is **based around** the flexibility of the space, rather than shoe-horned into it.

As with any element of flexibility, compromise is always required. Even the most radical of teaching and learning styles will require some element of private study, or times when groups need to be taught with an element of privacy. The most appropriate method of providing open plan teaching and learning spaces is therefore to include a number of cellular spaces where teachers and/or pupils can 'retreat' to when required.

BB93 sets out performance criteria that should be met when designing open plan spaces. Criteria given are as follows:

- Average activity noise, Medium tolerance to noise
- 40 $dBL_{Aeq,30mins}$ maximum indoor ambient noise level
- 60 $dBL'_{nt(Tmf,max),w}$ maximum impact noise
- 0.8s mid-frequency (arithmetic average of 500 Hz, 1 kHz and 2 kHz octave bands) reverberation time for teaching spaces
- STI of >0.60 within a teaching and learning cluster

These criteria must be demonstrated by computer modeling, with a strong emphasis on providing an activity plan, whereby the way the spaces are to be used are accurately assessed and taken into account in the design of internal layout and finishes.

Many open plan teaching and learning spaces are being promoted under the Transformational Learning agenda, most commonly found in schools being rolled out as part of the Building Schools for the Future (BSF) programme. The concept of transformational learning is difficult to define, and various proponents will interpret it in differing ways. One of the key aspects of the agenda is for teaching and learning spaces to be flexible (which, in itself, is open to interpretation). Invariably, this involves a departure from the 'traditional' classroom model where one space has a single use, of a fixed size, for use by a single class. However, most teachers have been trained to teach in such environments and have been doing so for many years – a significant amount of re-training is therefore required to enable the educational vision of flexible learning to be put

into practice. Research carried out into this field confirms that “Successful designs have recognized the need for specialist teaching strategies to be used…” (Greenland 2009).

To better facilitate the delivery of such flexible spaces, there are revisions proposed for BB93 which, at the time of writing, remain in draft form only. These revisions include the following enhancements and recommendations over the published version of BB93:

- STI of <0.20 between adjacent teaching and learning clusters
- Installation of a Class A ceiling throughout
- Consideration to be given to grazing reflections from ceilings
- Soft floor covering
- Absorbent screens 1.6 to 1.8 m high
- Floor to ceiling height ≤ 3.5 m
- Warnings against the use of flat lens luminaires

Further revisions were also suggested, in terms of a performance value to reflect the above, although it was considered too restrictive by some. This was to provide a ΣSα per m^3 of no less than 0.36 in each of the octave band centre frequencies 500, 1000 and 2000 Hz.

The purpose of these revisions is to strengthen the position of acoustic design in these flexible spaces and to further demonstrate the need for good acoustic conditions in what would otherwise be spaces that are not fit for their intended purpose of teaching and learning.

6. THE SIMILARITIES

When optimum conditions for open plan offices and teaching/learning are compared, the similarities are impossible to ignore.

The norm, the traditional method of working, teaching and learning, is in enclosed spaces. This is the easiest type of environment to control and provides good standards of privacy for solo working or single class teaching. Even sound insulation criteria for cellular offices and classrooms are similar (BS 8233: 1999 suggests D_w 48 dB, BB93 requires $D_{nT(Tmf,max),w}$ 45 dB). These values are commonly accepted as necessary for good standards of privacy between adjacent activity spaces.

And when walls are removed, the recommended conditions are almost identical. Class A ceilings, absorbent screens, limited ceiling heights, masking noise, < 0.2 STI between adjacent groups.

These similarities should not come as surprising, as similar tasks are being carried out and the physiological factors are very similar (although children may be more sensitive to acoustic factors in terms of what they can cope with, adults in offices may be more aware of what is acceptable or unacceptable).

Although comparitively little research has been carried out into open plan teaching and learning, there are obvious lessons to be learnt from office environments.

7. THE SOLUTION?

As soon as the partitions are removed, it is not logical or reasonable to expect that the same conditions can be replicated. Yes, measures can be put in place with the aim of attaining to cellular performance, but can only ever get so close.

But does this matter? What are open plan offices actually used for? Are they purely meant for people to work autonomously in without interaction with others? It would appear that this is not the case and that there is much to be gained from groups of office workers being able to interact with each other as a team, whilst having a reasonable degree of privacy between adjacent teams.

Immediately the similarities between open plan teaching and learning become apparent. The evidence suggests that a single set of parameters for open plan offices may not be appropriate, but that variation may be required across a floor plate. Evidence also suggests that different tasks vary in their sensitivity to acoustic conditions.

The procurement routes currently employed do not make this situation any better, especially when most of the ceilings are in place prior to a tenant being involved, resulting in high levels of wastage and compromise.

The most sustainable and practicable solution in offices would seem to be for finishes to only be specified once the end user and their respective requirements has been assessed.

The following criteria are suggested for fully fitted-out open plan offices:

Factor	**Within a working cluster**	**Between work clusters**
Background noise level	NR40 / 46 dBA (L_{90})	NR40 / 46 dBA (L_{90})
STI	≥ 0.60	≤ 0.20
Absorption per m^3	≤ 0.21	≥ 0.36
Physical factors	▪ Ceiling αw ≥ 0.6 across speech frequencies ▪ Soft floor covering	▪ Ceiling αw ≥ 0.9 across speech frequencies ▪ Absorbent screens 1.4 to 1.6 m high ▪ Soft floor covering ▪ Lower ceiling height between clusters to break up skimming across the ceiling

Consideration also needs to be given to tasks people are performing. Evidence suggests that some tasks, such as proof reading, meetings or confidential conversations, are just not suited to open plan offices. Any flexible space has its limitations and these need to be realized, with cellular spaces being provided.

8. CONCLUSIONS

The similarities between acoustic effects and requirements of open plan offices and teaching and learning spaces are many and unmistakable.

One of the key benefits of both types of space is flexibility. However, flexibility brings with it limitation and consideration needs to be given to which tasks and room uses can afford to be subject to these limitations.

It is evident that not all office activities can be appropriately accommodated in an open plan environment. in these cases, enclosed spaces should be provided. Conversely though, there are many types of office activities, such as team working (where clear communication is required between a number of people working together) where open plan is most appropriate. Unfortunately, most office research is not applicable to such situations, as it relates to the quest for privacy rather than promotion of communication.

This is where lessons learnt by open plan teaching and learning spaces can be implemented, where a single open space has a number of differing requirements.

Ultimately, the use of any type of space is only as effective as its management. Even cellular offices do not work effectively when people talk too loudly or leave door open. Etiquette is therefore required, with users being sensitive of the limitations, and benefits, or their environment, and working or learning in them appropriately. There is a definite role and responsibility for acoustic designers in this process, making sure that environments are designed and ultimately constructed around the end users; end users also need to be informed and taught how to get the most of their environment otherwise the spaces will effectively not be fit for purpose.

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