ISO 3382-3: NECESSARY BUT NOT SUFFICIENT. A NEW APPROACH TO ACOUSTIC DESIGN FOR ACTIVITY-BASED-WORKING OFFICES

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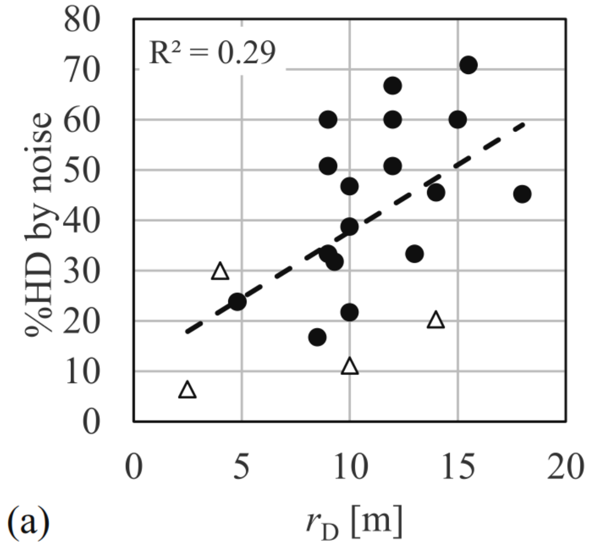
1 ABSTRACT

Since the room acoustic parameters in ISO 3382-3 were published, there have been various international attempts to classify offices achieving different values. However, recent summaries of acoustic satisfaction demonstrate little correlation with the room acoustic parameters that may drive the design. A new case study illustrates significant differences in acoustic satisfaction for people on two different floor plates within the same building; these have very different workplace design, but have almost identical parameters according to ISO 3382-3.
A new approach – the Apex Method - is proposed to assess acoustic conditions within activity-based working (ABW) offices. The Liveliness term can be used to characterise suitable acoustic environments for different types of activities; background sound levels can also be attributed, by measurement or design. A matrix of signal-to-noise ratios can be postulated, to account for source level vibrancy and receiver sensitivity. This enables a design framework for the in-situ attenuation of speech between workstations, $D_{n, A, s}$. From the in-situ attenuation requirement, the layout design can be developed accordingly. This method can identify potential for conflicts between different types of use or activity where there is insufficient attenuation between them, to inform the workspace designer where enhanced in-situ attenuation can improve the acoustic conditions for occupants.

2 INTRODUCTION

The acoustic requirements for people within a workspace are strongly dependent on the workspace culture, and cannot be realistically determined without understanding how people operate within the workspace. A model originally proposed by Hongisto[1] has been followed with many studies identifying the extent of distraction by intelligible speech – the irrelevant speech effect (ISE). Laboratory experiments by many researchers including Chevret[2], Kostallari[3], Ellermeier[4], and Schlittmeier[5] demonstrate the decrease in performance that can be objectively measured when people perform tasks when subject to noise containing intelligible speech. The concept of a distance at which the intelligibility of speech at normal levels crosses a threshold for intelligibility (e.g. STI = 0.5) has informed acoustic parameters for office design. ISO 3382-3 describes the room acoustic parameters that can be measured in an open plan office; these metrics are increasingly being used to describe Classes of performance for the office.
Haapakangasa[6] concludes, on the basis of the correlation reproduced in Figure 1, that distraction distance predicts perceived disturbance by noise in open-plan offices. The data shown with a solid circle are conventional offices, while triangle symbols denote activity-based working offices. The data in Figure 1 would suggest that there are many other factors that may be more significant in determining noise annoyance or acoustic satisfaction than distraction distance alone. Indeed, the authors of that study denote activity-based offices differently, and the data indicates that noise annoyance in these offices is generally much lower than the average.

Figure 1: Extract from Haapakangasa et al 2017



Achieving lower (better) values for distraction distance has significant design implications for the height of screens between desks and the background sound level, as illustrated by Larrieu[7]. Haapakangasa et al also demonstrate that there is either even less or no correlation in general between parameters such as speech level at 4 m, $L_{p,A,S,4m}$, and spatial decay of speech, $D_{2,S}$. The design implications noted by Larrieu often do not match either the design aspirations of clients or workplace designers. Does this mean that "good acoustic design" is simply inevitably in conflict with the current workplace design aesthetics? Or is there another way to achieve good acoustic conditions in open plan offices? We start by exploring the typical practice of workplace designers, and then look at the development of a new ISO Standard for acoustics in open plan offices. The opportunities to align these activities offers benefits for designers and the future occupants of the workspaces that may be developed.

3 THE WORKPLACE DESIGN PROCESS

New workspaces may be designed by specialist interior designers, or by capable people of associated disciplines in this field such as architects or architectural technologists. The process may be informed by a more or less formal workplace strategy. The strategy for the workplace may consider the approach to working - for example, but not limited to:

- What type of workplaces are required?
- How does the type of work (eg a call centre, individual work, collaborative work) influence the layout and design of the workspace?
- Does each occupant have a fixed desk, or are desks provided at a certain ratio of potential occupants?
- How many meeting rooms or quiet working spaces are required?
- What type of amenity space is to be provided?

The workplace strategy may be developed by a professional who specialises in that type of work, or may be inferred or explicitly developed by a workplace designer, facilities manager or client. There may be a wide level of formality around the workplace strategy - it may be simply inferred from the brief for the workspace (eg "we want to fit in as many desks as we can"), or it may be systematically derived from an engagement process between the workplace strategist and client. Workplace architects and designers typically take account of acoustic considerations in their designs implicitly.

The different functions of workspace may be considered, for example, as:

- Core - traditional workplaces at desks or other settings
- Collaborate - meetings, whether formal or informal, large or small
- Concentrate - for focused activity, protected from the normal intrusions
- Amenity – for refreshment, re-creation, and restoration

Workplace designers will often consider those activities that may generate higher sound levels, and locate them in such a way as to minimise the impact on other areas. This is a traditional approach to considering the range of activities typically undertaken within an open plan office.
There can be a significant difference in expectations and tolerance to unwanted speech depending on the type of open plan office. A taxonomy of open plan offices is described by Neil Usher[8], revealing the significant variation of possibilities for workspace concept and design. Perhaps, from an acoustic perspective, the most significant difference is the extent to which people exercise choice over where they work at any particular time. Control over one's environment is a strong modifier of annoyance. While the irrelevant speech effect (ISE) can objectively impair cognitive performance, it may be that annoyance is a more significant impact. Annoyance may not be simply proportional to the ISE, because of the modifying effect of the sense of personal control.
When a traditional workspace design approach seeks input from acoustic designers, the guidance currently available describes what acoustic requirements there may be for ceilings or rafts, screen heights between desks, and potential for sound masking. As noted above, this design advice is often in conflict with the aspirations of the client and workspace designers, without offering any detailed insight into how acoustic conditions may be ameliorated. There is no guidance currently available to assess the acoustic impact or preferred requirements for one type of usage on another. For example, between an informal meeting area and an area for focused individual work, what acoustic conditions are desirable, and how can they be achieved?

4 OPPORTUNITY IN THE NEW ISO/WD 22955

The new ISO/WD 22955 will have criteria for different types of space, where these predominate across the floor plate. The new standard is inspired by the French Standard NF-S31-199[9], and takes the same approach, starting with the acoustic requirements of the workers who are the users. There are three stages of description of the acoustic environment that workers need to undertake different types of work. The open plan office is conceived in a traditional manner, comprising workstations at desks. The acoustic targets and requirements are described for:

- The acoustic conditions at the workstation - described with a target in-situ level for ambient sound from all sources, including activities within the office. The range here is a target rather than a requirement of the Standard.
- The acoustic relationship to the adjacent workstations - described as an in-situ attenuation of speech, $D_{n,A,S}$ from one workstation to another.
- The acoustic characteristics of the floorplate, described in terms of the spatial decay of speech, $D_{2,S}$, and the speech level at 4 metres, $L_{p,A,S,4m}$, as defined in ISO 3382-3.

The different types of activity currently proposed, for acoustic classification purposes, are:

- Breakout
- Phone
- Collaborative
- Non-collaborative

An additional section considers acoustic requirements between different activity types. This has led to the development of a new method proposed below.

5 A NEW APPROACH - THE APEX METHOD

A new approach is proposed to assess acoustic conditions between different types of functional areas within an open plan office. This may be particularly suitable for assessing activity-based working (ABW) offices, or for the partial remodelling of existing floor plates to introduce more varied workplace settings within an otherwise traditional layout. For example, the introduction of collaborative areas, or seating for focused activity - either individual work or phone calls, adjacent to traditional desking, can all benefit from acoustic consideration. Previously there have been no practical tools available to the acoustician to assess these adjacencies. The new approach is summarised as:

- Use Liveliness to characterise the acoustic environment for different activities - this may be measured if the environment already exists, or assumed if not. Guidance on assigning suitable values is proposed.
- Determine appropriate background noise levels - again, preferably this can be measured if the environment exists, otherwise it must be designed with a masking sound system, or assumed; examples are given.
- Adopt a suitable unwanted-speech signal-to-noise ratio (SNR) for the sensitive receptor from the source in question. A matrix of example SNRs is given.
- Assuming a standard speech signal source level determines the requirement for the in-situ attenuation of speech between workplace settings in terms of $D_{n, A, s}$.
- The requirement for in-situ attenuation, $D_{n, A, s}$, identifies the acoustic protection from one location to another, to inform the layout design.

Th Apex method can be used to identify acoustic conflicts between different types of use or activity - where the calculated $D_{n, A, s}$ falls short of the value determined for good acoustic conditions. This method can assist the workplace designer to identify where enhanced in-situ attenuation can improve the acoustic conditions for workers, or where less acoustic protection may be adequate.

5.1 Use types to consider adjacencies

Although ISO/WD 22955 contains general use types that may prevail over an area or floor plate, a few additional use types are necessary to consider adjacencies between specific functional uses. The proposed use types are shown in Table 2. These are intended to cover the main acoustic categories of use type, as examples to compare with project-specific requirements. It is acknowledged that the category “breakout” can have a plethora of meanings and variety of uses at different times.

5.2 Liveliness

The term “Liveliness” is used to characterise the in-use open plan office acoustic environment, described by Vellenga[10]. The semantic description is correlated with an objective measure, based on 5 minute sample periods. The objective measure is a combination of the A-weighted sound level, $L_{Aeq,5min}$, and the fluctuation strength. The fluctuation strength is measured as the difference between the statistical level of A-weighted sound exceeded for 5 % of the time, $L_{A5,\ 5\ min}$, and the $L_{Aeq,5min}$. Liveliness is measured by recording the sound in five minute samples at an unoccupied workstation. Liveliness is likely to vary both spatially across an office, and also temporally at any one position, as both local and more distant activities vary. The temporal variation at different places can exhibit different patterns. In an ABW office, different areas are generally designated for different types of activities. For the areas to be suitable for these different activities, the acoustic environment must also meet the expectations of the workers. Uses may be characterised by the acoustic environment that is suitable, and the Liveliness parameter is intended for this characterisation. Workers within these areas may also be considered in terms of their sensitivity to intrusive sound, and their production of sound that may be intrusive to others. The use types are described in Table 2, with comments.

5.3 Signal to noise ratio to describe intrusion and impact of unwanted speech

While ISO 3382-3 relies on STI to assess speech intelligibility, this is a complicated parameter to calculate or measure. A simpler treatment that offers the designer more insight uses signal to noise ratio. This has been correlated with other measures of intelligibility by Lazarus[11], an extract of which is reproduced in Table 1. ISO 3382-3 adopts a single target value for STI of 0.5, and evaluates the distance, r_D, at which this is achieved in general for conditions across the floor plate. There is no opportunity within this framework to consider the specific impact of one workstation on another.

Table 1: Speech Intelligibility Evaluation, from Lazarus, 1987

Parameter	Value for comparison					
STI	0.1	0.2	0.3	0.4	0.5	0.6
SNR, dB	-12	-9	-6	-3	0	3

The Apex Method is based on the impact of one workstation on another in terms of signal to noise ratio (SNR), where the "signal" is the unwanted speech. The "noise" level is based on the background sound level that includes the more distant activity noise within the office. The acoustic parameter used to describe this noise level is the statistical parameter for the A-weighted sound level exceeded for more than 90% of the time, $L_{A90,\,T}$. This parameter reflects more a measure of the "quiet" rather than the "noise", as it is only for 10% of the time that the ambient sound is below this level. Hence it may be a reliable level when considering the effect of masking unwanted speech.

This is a deliberately simplistic approach to quantifying the impact of the ISE. There are many advantages of a simplistic approach, not least the ease of understanding and accessibility to a wide range of people. The simplification means that many of the subtleties around factors governing the impact of the ISE are lost. For example, the reduced intelligibility of speech due to the reverberant characteristics of the room is not included in a simple SNR assessment. This is considered an acceptable compromise, and it is postulated that the benefits of simplicity outweigh the drawbacks.

5.4 Annoyance depends on expectations and sensitivity

The expectation for and tolerance to intrusive or distracting sounds is highly dependent on the type of activity undertaken. For example, people engaged in individual focused work are likely to be more sensitive to intrusive sounds compared to people collaborating on a task. An increase in acoustic protection from one location to another can be characterised in terms of a preference for a decreased SNR. The increase in acoustic protection that is appropriate between dissimilar uses or tasks can be related to the difference in the expected Liveliness rating between those uses.

Some types of use are similarly rated for production of sound, and sensitivity to sounds. For example, work that is mainly individual (non-collaborative) will generally not generate significant levels of sound that intrudes on others undertaking similar work. Other people in the vicinity may tolerate short durations of intrusive sound, such as from occasional phone calls, if these are intermittent and not for long durations. However, if people at adjacent workstations are continually making telephone calls, this may become more annoying to people affected by the intelligible speech from that activity.

The activity described as "focused phone" is used to describe a place for making phone calls that requires more than the normal level of attention. Such a place would preferably have lower ambient noise levels than a call centre, and a lower SNR for speech from other workers compared with a call centre. This is an example of a type of activity that does not support many workers engaging in the same activity to be grouped together within an open plan office without acoustic protection between workstations. The Liveliness rating of this activity as a source of noise differs from its rating for tolerance to noise.

5.5 Determining Liveliness ratings and background sound levels

Liveliness is a new parameter: few people are yet familiar with its use and application. Fortunately, it is simple to measure, and understanding its meaning is straight forward, as the objective rating is correlated with semantic descriptions. When remodeling an existing office, it is prudent to measure the ambient sound around the locations that will remain with their current use. The temporal distribution of Liveliness and background sound levels can be evaluated from the survey data. When designing a new office environment, assumptions must be made to determine suitable values for Liveliness and background sound level. Background sound levels can vary spatially across an open plan office, particularly if there is significant screening between different areas or zones. Depending on the type of office and type of work being undertaken, the example values shown in Table 2 may be suitable to adopt.

Table 2: Use types, example values of Liveliness and assumed background sound that may be suitable

Use type	Liveliness rating	Background sound level, dB(A)	Notes
Breakout	8	-	It is recognised that “breakout” can refer to a wide range of different types of activity. It is not considered as a receptor, therefore background sound not used for assessment. In this example, Breakout is assumed to be an amenity space where people seek refreshment, restoration, and talk about non-work-related topics.
Meetings	7	48	Meetings are collaborative in nature, hence a relatively Lively rating is assumed.
Phone (call centre)	6	48	A call centre is a type of space where the Liveliness may not suit the occupants, although they are the source of the noise. The background sound level is taken from the lower end of the target range for ambient sound from NF S31-199.
Collaborative	6	45	Likely to be more Lively than Calm, but collaboration is not continuous; the background sound level is taken from the lower end of the target range for ambient sound in NF S31-199.
Non-collaborative	5	42	Preferably Calmer than collaborative spaces. The background sound level is taken from the middle of the target range for ambient sound in NF S31-199, as in practice few offices have background sound levels that are lower than this.
Focused phone	6 / 4	42	A protected area for making phone calls, rated with a higher Liveliness as a source, but preferring a lower Liveliness rating as a receptor. A specially-protected area, enabling lower background sound levels.
Focused individual work	3	40	A specially-protected area, enabling lower background sound levels. May be in a cellular room for acoustic protection, for example, or an individual booth.

5.6 Identifying suitable SNRs

A matrix of SNRs to describe the enhanced protection from one particular activity to another would be of great use in the design process. The initial concept to grade the acoustic separation between dissimilar spaces is to use the difference in Liveliness rating between source of noise and receptor as a multiplier for the SNR requirement in decibels. A multiplier of 3 is used in the example values to determine a predicted SNR requirement, as shown in Equation 1. This predicted value is then modified by considering each adjacency pair in turn to identify a SNR that may be suitable; the modified values are shown in Table 3.

Predicted SNR requirement = (Source Liveliness rating - receptor Liveliness rating) * 3 dB Eqn 1

If suitable background sound levels are assumed for each type of space, as noted in Table 2, the in-situ level difference, $D_{n,A,s}$ can be determined between different types of spaces, based on the potential enhanced SNR requirement, and a standard speech source level of 57 dB(A) @ 1m as described in ISO 3382-3. The calculation for $D_{n,A,s}$ is shown in Equation 2, with potential values illustrated in Table 4.

$$D_{n,A,s} = 57 - SNR - L_b \qquad \text{Eqn 2}$$

Where, from Table 3:
SNR is the potential enhanced signal to noise ratio required
L_b is the background sound level as described in Table 2.

Table 3: Potential enhanced SNR ratings between increasingly disparate activities, and associated background sound levels

Source / receiver space type	**Liveliness rating**	**Meetings**	**Phone (call centre)**	**Collaborative**	**Non-collaborative**	**Focused phone**	**Focused individual work**
Liveliness rating		**7**	**6**	**6**	**5**	**4**	**3**
Assumed L_b		**48**	**48**	**45**	**45**	**42**	**40**
Breakout	**8**	-6	-6	-6	-9	-12	-15
Meetings	**7**	-6	-3	-3	-3	-6	-12
Phone (contact centre)	**6**		0	0	-3	-6	-9
Collaborative	**6**			0	-3	-6	-9
Non-collaborative	**5**				0	-3	-6
Focused phone	**4**					-6	-9
Focused individual work	**3**						0

Table 4: Potential $D_{n,A,S}$ requirements between different types of spaces

Source / receiver space type	**Meetings**	**Phone (call centre)**	**Collaborative**	**Non-collaborative**	**Focused phone**	**Focused individual work**
Breakout	15	15	18	24	27	32
Meetings	15	12	15	18	21	29
Phone (call centre)			12	18	21	26
Collaborative				18	21	26
Non-collaborative					18	23
Focused phone					21	26

6 DESIGN IMPLICATIONS

The primary requirement for achieving acoustic satisfaction is to enable the set of project-specific SNRs within an overall ambient noise environment that is also appropriate and conducive to the type of work undertaken. As the SNR is achieved with the combination of attenuation between source and receiver, and the background sound level, an appropriate balance is required between these two otherwise separate aspects of the acoustic design to facilitate effective functioning of the workspace. At one extreme, cellular offices traditionally achieved the SNRs without any need for consideration of background sound level. At the other extreme, some people enjoy working in a busy environment such as a cafe, where high general background sound levels may mask any particular source.

6.1 Managing the background sound level

A raised background noise environment, if sufficiently loud, can mask any particular intrusive sound. Sound masking systems may provide some assistance by avoiding the problem of offices being so quiet that speech from greater distances becomes distracting. Workers often report this type of office to be "too noisy", when the acoustician may consider it to be "too quiet". The use of masking sound systems is controversial; the level and type of sounds that may be acceptable to most people are often too quiet to provide much effective masking, according to Martin[12]. Martin also notes that annoyance at the level of masking sound may not preclude its benefits in reducing distraction and improving task performance. Background sound levels that are found to be acceptable may depend strongly on the size of the office, as well as the type of work being undertaken. In larger offices there is likely to be more sound from greater distances, whereas in smaller offices there is a greater risk of lower background sound levels. The German VDI 2569: 2016 makes a distinction between "small" and "large" multi-person offices where the maximum distance between workstations is 8 m. When considering background sound levels, a larger size may be required in order to rely on the background sound from more distant activities.

There are very few studies in the literature where masking sound is added successfully to an existing workspace. However, it is understood that in North America it is normal for masking sound systems to be installed in new offices; there is an acceptance of the sound levels there. In Europe, there is a greater suspicion of masking sound systems, which are not universally accepted by workers. When suitable and reliable background sound levels and SNRs are identified, the attenuation requirements between different uses can be determined using the process illustrated above.

An alternative solution to achieving freedom from acoustic distraction at the personal level is the use of either a personal ambient sound masking system or headphones. The addition of personal control over an ambient sound masking system (i.e. playing masking sounds locally to the worker) may increase its acceptance by the worker, but it may also adversely impact on adjacent colleagues. Headphones may block intrusive sounds as well as add masking sound, depending on the type. Some designers may see this personal solution to opt out of the shared acoustic environment as a failure of the workspace design, as the collaboration benefits are lost.

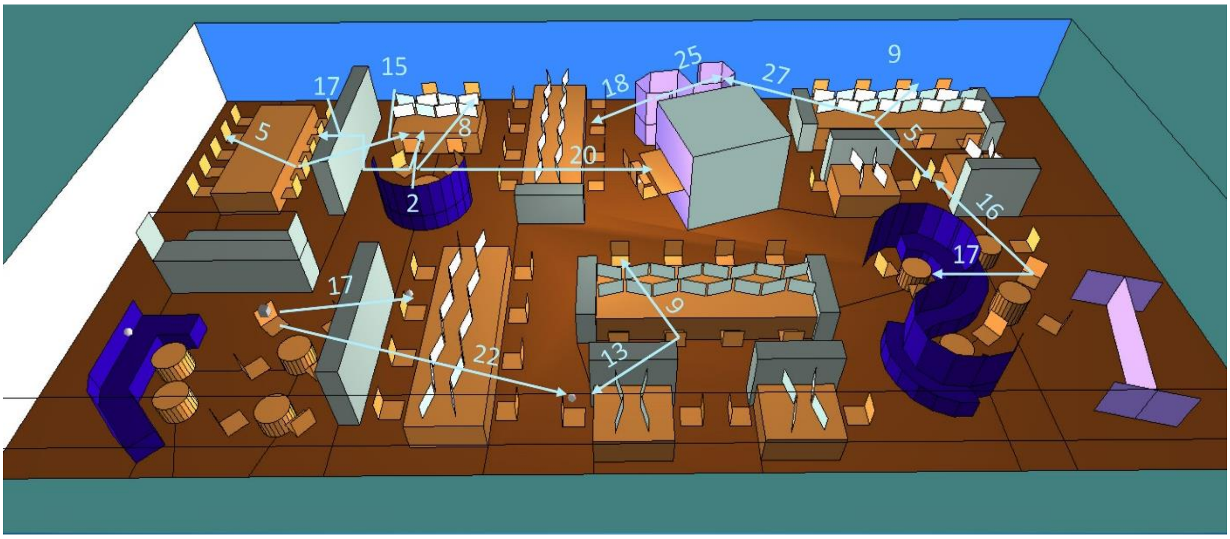
6.2 Managing attenuation between workstations

The in-situ attenuation of speech, $D_{n,A,s}$ is likely to be an unfamiliar parameter to many practitioners. It is important to gain some feeling for the implications of the values described in Table 4 – to understand the design implications. Are the values proposed feasible to achieve, or do they mean that separate activities must be separated by walls and doors? As currently described in the French Standard NF S31-199, the parameter $D_{n,A,s}$ is measured between the positions of a seated talker and seated listener, unless otherwise noted, with source and microphone positions 1.2 m above floor level. NF S31-199 does not describe A-weighted attenuation based on the speech source spectrum – this additional detail is added in ISO/WD 22955. Table 5 indicates the potential design application between different work areas, within an office where reflections from nearby surfaces are effectively minimized by suitable absorbent treatment. This may comprise, for example, a Class A absorbent soffit and absorbent wall panels on side walls if adjacent. The attenuation can, in theory, be achieved simply by allowing enough distance between disparate activities, but this is wasteful of space. Distance of separation has a significant effect such that screen height is dependent on the distance between source and receiver to achieve the desired in-situ attenuation, $D_{n,A,S}$. Figure 2 illustrates an extract from a CATT acoustic model, with the values of $D_{n,A,S}$ indicated between selected positions. These calculated values are interpreted as a little higher than values that may be measured in practice. The assessment cannot practically be made between every source-receiver position pair; nor does it need to be. An experienced eye can quickly identify on plans the adjacencies with the highest potential for conflict.

Table 5: Potential design solution within an office containing suitable absorbent treatment

$D_{n,A,s}$ / dB	Screen height between source and receiver, from floor level between adjacent desk, m	Notes
6	1.3 m high	2.5 - 3 m distance between source and receiver.
12	1.5 m high	Approx. distance 2.5 m
18	1.8 m high	Approx. distance 3.5 m. Screen height may be achieved with large furniture, cabinet filing, or simple screens etc
21	Semi-enclosure	E.g. a focus work booth with sound absorbent surfaces internally, or a pod with closed side towards the source
> 21	Full height to soffit	Floor to ceiling screen (e.g. partition) likely to be required for adjacent positions, or fully enclosed pod with door

Figure 2: Calculated values for $D_{n,A,S}$ between particular positions from a CATT Acoustic model of a workplace.



7 CONCLUSION

The theory that reducing the intelligibility of unwanted speech can improve acoustic satisfaction is well established and demonstrated in laboratory studies. However, acoustic satisfaction in real workplaces is only loosely correlated with the radius of distraction, r_D, measured over the floor plate. If acoustic designers are only motivated and equipped to propose features in the pursuit of achieving lower values of r_D, the inferred design requirements may be in conflict with other aesthetic aspirations for the accommodation and internal environmental conditions; more importantly, the overall goal of acoustic satisfaction and workplace efficacy may be missed entirely.
Control over one's environment is likely to be a stronger indicator for worker's acoustic satisfaction than any technical acoustic features. As the nature of the workplace changes to become more fluid and less based on assigned workstations, people's tolerance to intrusive sounds may well also adapt. The Apex Method is proposed to extend the concept of the impact of unwanted speech and intrusive sounds; these preferences can be used to determine in-situ attenuation requirements between specific workstations. This can be most effectively achieved within an environment that has appropriate treatment for sound absorption. The Apex Method supports, rather than conflicts, the work of the workplace designer.

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