The ceiling as an acoustic instrument

for cultivating healthy and productive interior climates

in healthcare
in education
in open offices
in public spaces

Contents

I. INTRODUCTION

Acoustics: taking a back seat
Acoustics are at least as important in creating a pleasant interior climate as colour and light. It is a proven fact that good acoustics contribute to better school performance, quicker recovery, higher labour productivity and more satisfied customers. In practice, however, it turns out that for budgetary reasons acoustics are not yet seen as a top priority by contractors and commissioning parties. Either the effects of poor acoustics are underestimated or it is thought that floor covering, curtains, furniture and plants will do the job. Measurability does play a part here: it is difficult to establish a direct, data-based relation between acoustics and, say, school performance or labour productivity, as there is usually a range of factors to take into account. The result is that complaints about acoustics often do not surface until after the final stages of building. The cost of solving problems post hoc is usually higher than the cost of taking acoustic requirements and wishes into account in the design phase.

Look up first
Acoustic comfort is achieved by installing sound absorption, sound diffusion and soundproofing materials. The sensible thing to do is to look up first, as the ceiling is the largest free surface in the interior space and therefore has the greatest acoustic potential. Also, ceilings are usually easy to access, which makes them suitable for budget-friendly adaptation. The market offers a wide range of ceiling solutions with which you can 'tune' any space for optimal acoustics, taking into account every conceivable functional and aesthetic requirement or wish.

In this whitepaper, we will take a closer look at the added value of good acoustics in various sectors, while also introducing the ceiling as the ideal instrument for achieving greater acoustic comfort. A good, carefully considered acoustic ceiling is worth the investment: it is an effective, efficient and aesthetically pleasing way of cultivating healthy, productive environments for living, working, learning and caring.

II. SOFT GUIDELINES, NOT HARD ONES

As far as noise levels are concerned, regulations and requirements tend to be limited to sources of noise outside the actual interior space. They are aimed at protecting occupants and users of buildings from excess noise produced by ventilation systems and elevators, traffic noise and reverberation sound in communal corridors and stairways. Noise levels inside a living space tend to be overlooked. This is quite remarkable, to say the least. We spend a large amount of our time, after all, in our homes, schools, offices, hospitals and restaurants. And it is a known fact that interior acoustics – in addition to other environmental factors, such as light, colour, air quality and temperature – have a major influence on how we feel and perform.

Subjective experience

There is an explanation for the absence of fixed standards for interior acoustics. Acoustics centre on our highly subjective experience of indoor sound. What may be annoying to one person – such as having music on while writing a whitepaper – may stimulate the next. The acoustic parameters used in the process of establishing requirement specifications depend heavily on how the space in question is to be used. The kind of reverberation necessary in a concert hall would be highly undesirable in a classroom.

Multiple factors to take into account

The acoustic properties of an interior space are not determined by a single factor, but by multiple factors. A room with a reverberation time that meets a certain standard, may yet have poor acoustics due to annoying reflections or flutter echoes (a flutter echo is a sound that bounces back and forth between two solid, parallel walls, or between the floor and the ceiling). Countless other non-architectural factors also influence acoustics, such as furniture, floor covering and the number of people present. So, again, establishing fixed standards is a tough job. Perhaps at this point we should compare acoustics to colour. Many building codes and requirements do not include colour regulations, despite the known fact that colour has as much influence on our wellbeing as acoustics do. Fortunately, science and market players have produced some norms and target values for interior acoustics.

Finding the balance

Good interior acoustics, then, are made up of a mosaic of factors. Lining a hall with sound absorption materials will not do the job. This approach – regardless of the aesthetic objections – merely produces ‘dead space’, in which communicating requires a lot of effort. Acoustics are all about finding the balance – which can be quite a challenge in today’s architecture, with its smooth floors, hard materials and straight forms. These characteristics may look beautiful, but they also produce undesirable reverberation levels. Another point of tension is that between speech intelligibility and speech privacy. In one and the same room, it may be desirable for people to be able to understand one another at short distance, but not several metres apart. All in all, good acoustics have an impact on how people feel and function. Like light, colour, temperature and air quality, good acoustics contribute to productivity at work, learning at school and recovery from illness.

III. ACOUSTICS IN HEALTHCARE

Studies in healthcare environments have shown that good acoustics contribute to reduced blood pressure, less need for pain medication and the general wellbeing of patients and occupants. In hospitals, acoustics play a vital role in the recovery process of patients. Uninterrupted sleep is crucial to recovery, while noise can be a major cause of sleeping problems. Patients can be kept awake by other patients, staff and typical hospital sounds, such as ringing telephones, beeping cardiac monitors and respiration equipment. On top of these factors, hospital floors and walls for hygienic reasons tend to be hard and smooth, thus amplifying sound impulses.

Noise levels have doubled

Since the 1970s, noise levels in hospitals have doubled – not only when patients are asleep, but also during the day, with visitors dropping in, televisions on, food being served, cleaners at work and beds being moved around. The World Health Organisation (WHO) has stated that optimal recovery requires a maximum ambient noise level in the patient's recovery room of 35 decibels. Very few hospitals can meet this standard.

Acoustic ceilings

Swedish research has shown that adding an acoustic, sound-absorbing ceiling will significantly reduce the number of sleep disturbances in a hospital. Mounting sound-absorbing materials in the corridors also contributes. The rise of single rooms – aimed primarily at protecting patients from antibiotic-resistant infections – is also contributing to quieter, more effective environments for recovery. A disadvantage of single rooms is that they reduce patients' social contacts, which also affects recovery.

Privacy

Another aspect of acoustics in healthcare is privacy. Poor acoustics make patients feel inhibited in expressing complaints, thus hindering doctors in their diagnosis. Privacy does not just matter in consultation and treatment rooms, but also at counters and nurse stations and in waiting rooms. In drawing up acoustic requirements in the healthcare sector, it is therefore important to ask questions like these: what will the room be used for, how

many people will use it at once, and what are its measurements and shape? Careful zoning of noisier and quieter activities can also make a huge difference: placing different zones at appropriate and logistically sensible distances from one another can help patients get the rest they so badly need

Stress at work

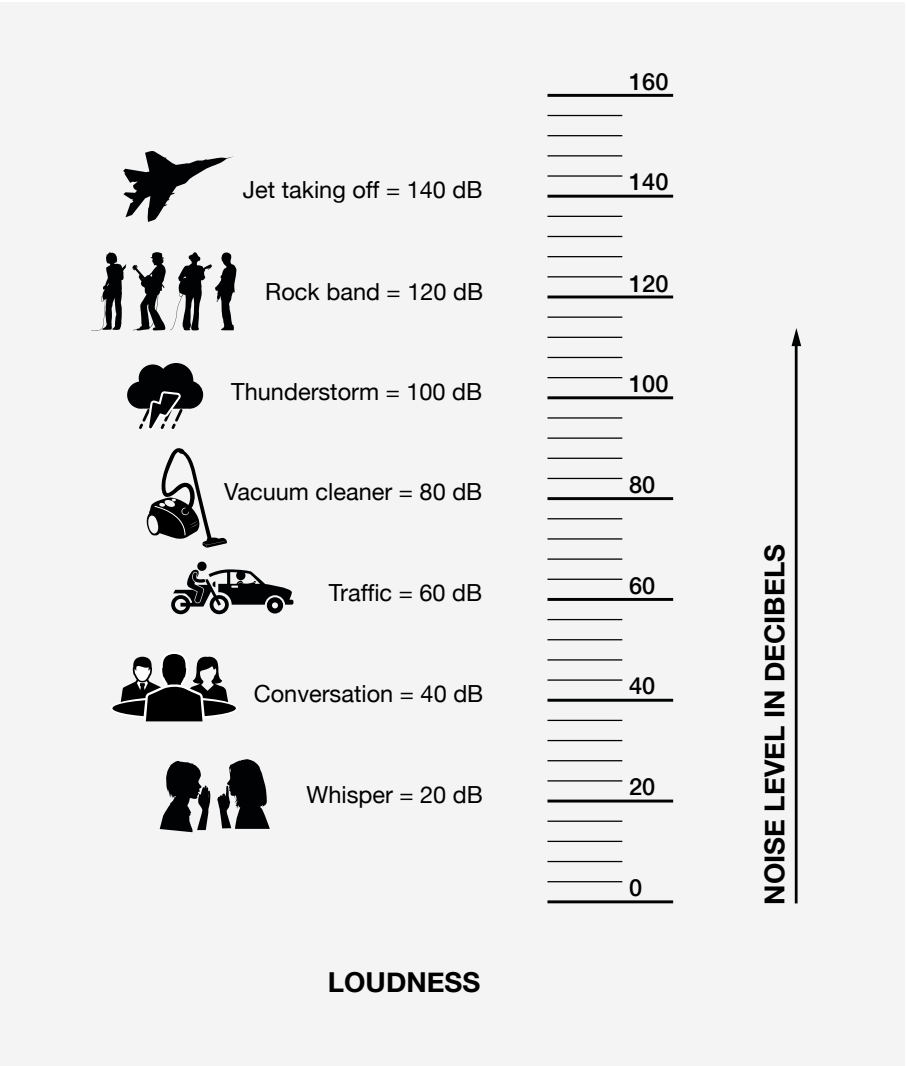
Finally, a hospital or nursing home is not just a healthcare environment, but also a working environment in which doctors and nurses are required, night and day, to deliver first-rate performances. A combination of poor acoustics and the cacophony of hospital sounds can heavily impact concentration, while increasing stress levels and raising the risk of mistakes.

In short, project developers in the healthcare sector have more than enough reasons to take acoustics seriously and to take them into account in the early stages of the building process.

Case:

A study of different ceilings for heart patients

At Sweden's Huddinge University Hospital, a study was done as to the influence of interior acoustics on the recovery of cardiac patients. A total of 94 patients participated. During the research period, the sound-reflecting ceiling tiles (poor acoustics) in the hospital's cardiology department were replaced with sound-absorbing tiles (good acoustics). The researchers monitored the effect on patients' blood pressure, pulse rate amplitude, heart rate and heart rate regularity. Patients were also requested to fill out a questionnaire on healthcare quality. After one and three months, respectively, the researchers monitored the number of rehospitalised or deceased patients. The study showed significant differences between good and poor acoustics with regard to the pulse rate amplitude of patients who had suffered cardiac arrest or heart spasms. The need for rehospitalisation occurred more frequently among patients exposed to poor acoustics. Also, patients exposed to good acoustics were more positive about healthcare quality and staff attitudes.



Sound pressure

Sound pressure levels are measured in decibels. By way of reference:

- 0 dB is the absolute threshold of hearing (ATH): the lowest sound level a human can hear
- 30 dB is the sound level in a quiet room without people
- 40 dB is the sound level in an office or class room in which quiet work is going on, without external sounds penetrating the room
- Sound levels in conversational speech start at about 55 dB, measured at a distance of 1 metre from the speaker
- 80 dB is the sound level in a very noisy restaurant without music; those present have to speak very loudly to be understood
- Anyone exposed for a longer period to sound levels above 80 dB will probably suffer hearing damage
- At a disco, sound levels easily exceed 100 dB; speech is only intelligible if the speaker shouts in the hearer's ear at a distance of less than 10 centimetres and acute hearing damage is a real possibility
- 120 dB is the highest sound pressure level a human can endure and is also referred to as the threshold of pain

IV. ACOUSTICS IN EDUCATION

In one out of five schools, acoustics are so bad that students miss much of what their teachers say. Also, they have to put a lot of effort into paying attention during classes, which leads to poor concentration and fatigue. The negative effect on their school performance is significant. Poor acoustics are usually caused by too much reverberation. In rooms for which a reverberation time of 0.8 seconds has been advised, reverberation times of over 1.2 seconds are quite common. In his 2012 TED Talk, sound expert Julian Treasure – founder of The Sound Agency and author of the book Sound Business – propagates a reverberation time of 0.4 seconds for cultivating ideal learning conditions.

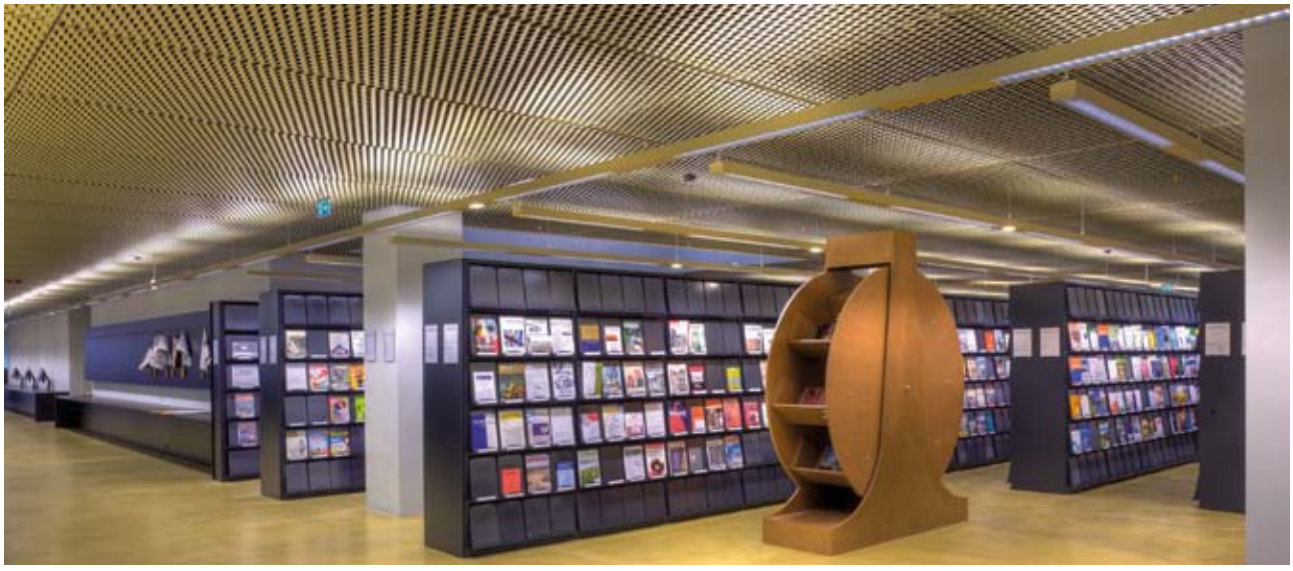
Health risks for teachers

Pupils are not the only ones who stand to benefit from good acoustics. To be sure of adequate speech intelligibility, a teacher's speech volume should be about 9 dB above the ambient noise. Considering the fact that the normal speech volume of an adult is around 50 to 55 dB, the disturbance level must be lower than 40 dB. However, the average ambient noise level in a class room is 65 dB, while even during silent activities it rarely drops below 50 dB. This means a teacher must raise his voice considerably to be properly understood, thus exposing himself to various health risks. Research by the University of Bremen in Germany has shown that rising noise levels in a class room are paralleled by the teacher's rising heart rate – an obvious sign that poor acoustics pose serious health threats. It has even been proven that daily exposure to noise levels of 65 dB or higher considerably increases the risk of a cardiac arrest.

The Lombard Effect

An added difficulty is the fact that disturbance noises are generally spread throughout the classroom equally, while a teacher's voice usually comes from one direction and sometimes has to cover as much as six metres to reach back row students. This, too, adds to the strain on the teacher's voice, while raising another barrier hindering the flow of information from reaching students.

In modern, differentiated educational methods, there is yet another challenge to take into consideration: multiple



small groups speaking amongst each other in the same room expose each other to disturbance noise. The result can be a negative chain reaction, with students compensating for reduced speech intelligibility by raising their voices, thus causing increased disturbance noise and so on. The sound level in a class room will thus steadily rise, even if the number of people present remains the same. In the field of acoustics, this phenomenon is known as the Lombard Effect. Sound absorption measures can help remove it.

Modern teaching methods

In solving acoustic problems in the classroom, it is therefore vital to consider the type of education and the communication process. While in the past the teacher's job was to keep students quiet while doing most of the talking himself, we are now seeing teaching methods based on increased interaction with the teacher and among students (project-based learning). This, quite naturally, affects noise levels. In looking at these issues, it is important not just to consider the actual measurement data, but also the context. For instance, a noise level of 65 dB is quite normal for a situation in which a text is being recited with raised voice, whereas students engaged in silent work will find an ongoing murmur of 55 dB to be a disturbance.

There is no doubt that short reverberation times contribute to clear speech intelligibility. A study called Acoustic Ergonomics at Schools has shown that the build-up of noise (the Lombard Effect) is far lower, or even nonexistent, in class rooms with good acoustics. To the contrary, the study showed that under optimal conditions the noise levels measured while students were engaged in individual work dropped below the level common to teacher-centred instruction. Overall, the basic noise level in class rooms with a reverberation time shorter than 0.5 seconds was 8 dB lower than it was in class rooms with a reverberation time between 0.6 and 0.8 seconds.

Reverberation

Reverberation sound is reflected sound that is audible after its source has stopped producing sound. Reverberation time is the amount of time that passes before the sound has decreased by 60 dB. In practice, the reverberation is no longer heard by then. All else being equal, the reverberation time in a large room is longer than in a small room. Reverberation has a huge influence on speech intelligence. In classrooms, a short reverberation time is vital. In churches, the reverberation time is usually long, which benefits organ music, if impairing speech intelligibility. The reverberation time can be reduced by taking measures aimed at sound absorption.

V. ACOUSTICS IN OPEN-PLAN OFFICES

According to FFM, the Dutch trade journal for facility managers, more than half of Dutch businesses are busy implementing Alternative Working Practices. The term refers to new work forms, flexible workplaces and open-plan offices, in which large numbers of employees work side by side. The space and cost savings employers realise with these practices, it turns out, are often undone by reduced productivity and increased absenteeism among employees.

Noise as a disturbing factor

As many as 60 per cent of people working in an open-plan office consider noise to be the most disturbing factor. It is often said that open-plan offices are conducive to better communication and knowledge transfer, but on-site scientific studies have not brought forward any evidence of this. And if the advantage does exist, it does not outweigh the disturbing effects of colleagues having a meeting on those in the same space trying to concentrate on working quietly. Ringing telephones, colleagues making calls and whirring printers add to the noise. Carefully considered interior acoustics, however, can work wonders.

Acoustics often acknowledged too late

In design practice, acoustic consultants often find that the acoustic quality of open-plan offices is taken (too) lightly. Commissioning parties and contractors tend to sacrifice acoustic measures to cutbacks, assuming that furniture, floor covering, curtains and plants will suffice. Although these soft surfaces do absorb certain high-frequency tones, the absorption of mid- to low-frequency tones indisputably requires lowered ceilings. The problem is that this fact is usually acknowledged too late, viz., when the building is already in use and the first complaints have started coming in. By that time, it is difficult to install sound-absorbing ceilings, even if only because of the height of the building's floors.

Speech intelligibility versus speech privacy

As the open-plan office concept is still relatively new, adequate (acoustic) guidelines are yet to be developed. The guidelines that do exist tend to be aimed primarily at office rooms. The focus is on reverberation times, ambient noise levels and noise levels produced by installations.

The acoustics in an open-plan office are a lot more complex. They have to provide good speech intelligibility at short distances, while ensuring speech privacy and preventing noise from spreading over larger distances, thus disturbing colleagues. This involves reverberation times of less than 0.5 seconds. Acoustic ceilings with a high absorption class can make a significant contribution in this area, as can privacy screens and (waist-) high cabinets between workplaces. Also, noise produced in open-plan offices tends to be transported from one working group to another by hard surfaces. This means it makes sense to avoid the use of hard surfaces as much as possible and to look carefully at the floor plan. Much can be accomplished by creating separate workplace zones for activities involving noise and those requiring silence.

Speech intelligibility

Until about five years ago, acoustic parameters were based entirely on reverberation times. Nowadays, speech intelligibility is playing an increasing role. Speech intelligibility is the degree to which speech can or cannot be understood in a given space. It can be measured according to the so-called STI (Speech Transmission Index), with a number between 0 and 1, with 0 standing for poor intelligibility and 1 for excellent intelligibility. Measurements are performed at varying frequencies by placing a loudspeaker in the speaker's position and a microphone in the position of the audience. In calculating the STI, the influences of both reverberation and possible ambient noise are taken into account. Poor speech intelligibility can be desirable in situations in which some of the people in the room do not wish to be disturbed by the conversations of others, or confidential conversations are held. This is called speech privacy.

VI. ACOUSTICS IN PUBLIC SPACES

Good acoustics are not only important in spaces where people work, provide healthcare or offer education. Wherever (large numbers of) people convene, acoustic comfort is vital to creating a pleasant interior climate. Let's look at a few examples below.

Hotels, restaurants and catering

In a restaurant, poor speech intelligibility or speech privacy can discourage customers from returning, no matter how good the menu. Unfortunately, the sleek lines and smooth ceilings and walls characteristic of many of today's hot venues often fall short in this respect. The combination of chairs being moved, the clatter of dishes and ambient music can produce a cacophony that is highly annoying to both customers and staff. Researchers at the TU Delft University of Technology in the Netherlands, have observed another interesting phenomenon: as conversations involving four people are difficult in a restaurant with a lot of reverberation, bilateral conversations tend to take over. This causes a further increase of volume, as there are now two conversations going on between two sets of people, rather than just one among four. In a crowded restaurant with 20 tables, the result is an acoustic nightmare. In situations like this, a sound-absorbing ceiling can work wonders.

Sports facilities

The acoustics in gyms, sports halls and swimming pools are problematic at the outset, because of the shape and size of these facilities. The high noise levels accompanying the activities for which these buildings are typically used merely add to the challenge. Squeaking shoes, bouncing balls, cheering spectators and shouting team members together create an unpleasant acoustic atmosphere, even posing safety risks as instructions or warnings go unheard. Teachers, sports instructors or lifeguards exposed to these conditions on a daily basis can develop vocal and concentration problems as well as chronic fatigue and serious hearing impairments. Sound-absorbing materials are an absolute must for cutting back reverberation times and preventing flutter

echoes in this kind of facility. According to TU Delft, the absorbing material used should cover at least 25% of the total geometric surface. Ceiling absorption alone is not enough, as reverberation is prolonged by walls, especially the shortest ones. This effect can be prevented by mounting sound absorption material on at least one of the short walls.

Atriums

Atriums in modern shopping malls and public buildings are sometimes referred to as the cathedrals of our age. The reference does not just hint at their size or architectural status, but also at their acoustic properties. The high ceilings typical of these central spaces cause considerable reverberation times, raising the levels of the noise produced by people, rolling suitcases, ambient music and climate installations. The acoustic challenge is not restricted to the central hall; the connected floors, or levels, are also affected by the noise level within the atrium, as it takes on the function of a resonance box. An additional handicap is the fact that, generally speaking, atriums are clad with large quantities of natural stone and fitted with glass ceilings – highly reflective materials that cannot be made to absorb sound. This means that other available surfaces have to be used for adding sound absorption, such as the ceilings of the corridors on the different levels connected to the atrium, high walls and parapets beneath the window frames. Another option may be to close off part of the glass roof designed to let in daylight with ceiling islands or baffles.

Church buildings

Diminishing church attendance is having a negative impact on acoustic comfort in church buildings. An empty pew, after all, absorbs less sound than a filled one. Reverberation times exceeding five seconds are no exception. In taking sound absorption measures aimed at increasing speech intelligibility, it is important not to lose sight of the natural reverberation in a church building. Without it, organ music and congregational singing can ‘go dead’. Also, many church buildings are now being used for multifunctional purposes or reallocated to entertainment venues, office spaces or exhibition halls. These new uses call for tailored acoustic solutions.

VII. THE CEILING HOLDS THE ANSWER

We have looked at the importance of good acoustics in various sectors and at some of the challenges involved. Clearly, each interior space has challenges of its own, depending on function, volume, interior decoration, ambient noise levels and the number of people present. Developing an acoustic design, therefore, is a dynamic process, in which adequate assessment of the acoustics relies on close interplay between the commissioning party, the architect and the acoustic consultant. Form influences acoustics and therefore also influences the choice of the right material for meeting acoustic and aesthetic requirements.

Functional and aesthetic requirements in one
The market offers a wide range of ceiling solutions tailored to every conceivable functional and aesthetic demand or desire. Aspects such as the accessibility of the plenum (the space between the actual ceiling and the lowered ceiling), light reflection and temperature control all play their part. Applying such solutions in the design phase means that climate, lighting and sprinkler installations can be directly integrated. But even acoustic problems arising once a building is being used can be met with many reliable and attractive ceiling systems available – even in situations in which concrete core activation has been applied

Building design choices make a difference
In new building projects, making logical design choices can contribute to a high level of acoustic comfort. Good examples are planning interior spaces with similar sound level requirements next to each other (acoustic zoning), or using acoustic insulation materials to keep out noise from other parts of the building and from outside. But shape also heavily influences acoustics. A sloped ceiling above a platform may protect audience members in the front rows from echoes, while amplifying the sound for those in the back. It has been shown that in practice the cost of acoustic design is less than one half per cent of total building costs, if the acoustic design is included in the earliest stages of the building process. In the operational phase, the gains of this investment will easily outweigh the cost in terms of increased labour productivity, decreased absenteeism and more satisfied customers.

The ceiling: the largest available surface for acoustic comfort
If architectural measures are no longer possible because the building is already in use, or if they fail to yield the desired effect, the ceiling is the first place to look for improved acoustic comfort. Ceilings can be replaced or adapted at relatively low cost. They are also the largest, uninterrupted and most accessible surface in most interior spaces. This means that even a relatively low absorption value can have a major impact. Floors and floor coverings have the disadvantage that they are often interrupted by sound-reflecting objects, such as tables and cabinets. And walls – with or without glass windows – offer little or no sound absorption, as they are usually made from dense, hard materials.

Closed, smooth ceilings
A common ceiling solution for creating a sober, smooth ceiling that stretches from wall to wall without interruption is a perforated ceiling system (the perforation being a means of absorbing noise). To many architects, however, perforated panels are an eyesore. Manufacturers have responded to this by developing ceiling panels that are smooth and evenly structured, while still offering the desired acoustic qualities. Hunter Douglas' Techstyle ceiling panels are a good example. They have the clean, smooth look of plaster panels, but their cellular structure and nonwoven material result in high levels of noise absorption, both in high and low frequencies.

Ceiling islands and baffles

Another aesthetic approach is the industrial look, with installations, pipes and cable gutters remaining in view. A common way of ensuring acoustic comfort in these conditions, while also adding aesthetic value, is to use ceiling islands and baffles. Ceiling islands are free-hanging ceiling elements with a high noise absorption capacity. Baffles are small, often rectangular panels hung from the ceiling at a vertical angle for the purpose of absorbing noise and reducing reverberation. They are often used in large, noisy environments, such as shopping malls and restaurants, but they can also be highly effective in office spaces and hospitals. The advantage of ceiling islands and baffles is that they can be used quite precisely in places with specific communication and concentration requirements. Examples include hotel reception areas, waiting room counters or workplaces in an open-plan office.

Concrete core activation

Ceiling islands and baffles are also often applied in interiors in which the temperature is regulated by means of concrete core activation. Concrete core activation is a way of heating or cooling a space by pumping water (or another liquid) through pipes integrated in the concrete ceiling system (which in most cases is also the floor of the level above). The method makes use of the large surface of the ceiling and of the thermal mass of the building. In this way, a relatively small difference in temperature between the supplied water and the ambient air can be enough to provide the required heat or cooling. However, any energy savings thus gained are lost if the ceiling is entirely covered by a closed ceiling system. In these situations, ceiling islands and baffles are a good solution, as they are open enough to allow for the radiation of heat or cold, while at the same time absorbing noise in the right places to ensure optimal acoustics.

BXD panels: ideal for concrete core activation

In some interiors in which concrete core activation has been applied, it may be desirable from an aesthetic point of view to provide the ceiling with a smooth, closed look. A solution for these situations is now available. BXD panels by Hunter Douglas are aluminium ceiling panels with extra wide spacing (30 mm). The loss of noise reduction resulting from the wide joints is offset by the panels' thickness/height (6 cm). In this way, absorption values with an α_w of 0.5 up to 0.85 can be achieved, while there is still plenty of room for the exchange of heat or cold between the concrete core and the building's interior space. Visually, however, the ceiling has the appearance of being closed. The advantage of this system over baffles is that the panels do not hang down as far from the ceiling and therefore do not hinder the view. Also, baffles leave the concrete ceiling more visible, as they can be hung at wider intervals.

‘Tuning’ an interior space

Realising ideal acoustics is always a quest for the balance between noise absorption and reflection. Too much absorption ‘deadens’ an interior. A restaurant needs some buzz to feel lively, but also to prevent people from listening in on a conversation going on two tables away. An assembly hall or meeting room does not just need sound absorption measures for cutting reverberation times, it also needs sound reflection for the sound to be transported to listeners positioned further away from the speaker. In situations like these, ceiling islands without noise absorption capacity can be placed in the middle of the room as reflective surfaces, with ceiling islands and/or baffles placed along the sides and at the far end of the room to reduce reverberation. With measures like these, you can ‘tune’ an interior space to achieve optimal acoustics.

VIII. IN CLOSING

Good acoustics, by definition, are custom-made. With acoustics depending on so many different factors, the involvement of an expert advisor is vital. Your advisor can make calculations, take measurements and propose measures tailored to the purpose of your interior. Ceilings, being easier to adapt than other parts of a building, offer the most effective and inexpensive way of improving acoustics. Naturally, the ceiling is not the only available instrument. In more complex situations, partition walls, acoustic wall panels, acoustic screens and/or other acoustic elements can be added.

Try inviting manufacturers of acoustic building solutions to your design table. As front liners, they know best what is new and worthwhile about their products. Manufacturers also have a lot of knowledge, as they are continuously engaged in researching and developing acoustic innovations.

About the author
Richard de Boer is a conceptual thinker and copywriter at Admix, a Rotterdam-based agency specialised in corporate communication. He has spent over ten years writing commercial and journalistic copy for a variety of organisations in the building and real estate sectors and in the (financial) services sector, among others

IX. WHAT YOU CAN DO

I can imagine that after reading this document you may have questions or be interested in finding out more about the possibilities offered to you (and to a variety of interior spaces) by ceilings. Naturally, you are free to consult your regular partner for ceiling systems or to use the information presented in this publication in any way you see fit. Please also be aware that as an expert I am more than happy to support you if and as necessary.
I sincerely hope that this publication will put you on the right track towards achieving optimal acoustics with your organisation.

David Harris
General Manager
d.harris@hunterdouglas.co.uk
Mobile : +44(0)7917 168759

Hunter Douglas Architectural Projects UK
Pondwood House
Pondwood Close
NN3 6RT Moulton Park
United Kingdom

Phone : +44 (0)1604 766 251

www.hunterdouglas.co.uk

X. RESOURCES CONSULTED

www.arbocataloguspo.nl
A Dutch website offering practical information on working conditions in primary education

www.bk.nijsnet.com
A Dutch website on interior acoustics by ir. L. (Lau) Nijs, lecturer in Building Physics, Faculty of Construction Engineering, TU-Delft

www.greten.nl
A Dutch website by Greten Raadgevende Ingenieurs, an independent consultancy agency specialised in acoustics and building physics, among other things

www.sonus.nl
The website of Sonus BV Raadgevende Ingenieurs

Adviesbureau Peutz, Slapen om beter te worden: akoestiek in ziekenhuizen, FMT Gezondheidszorg, September 2013

Aren Raue en Marius Roel, Akoestische Aspecten van Het Nieuwe Werken, Arbo Magazine, October 2010

Inger Hagerman a.o., Influence of intensive coronary care acoustics on the quality of care and physiological state of patients, International Journal of Cardiology, nr. 98, februari 2005

Sara Persoon and Theodoor Höngens, Het nieuwe werken en het akoestische comfort, Weekblad Facilitair, nr. 268, 2011

S. Berg, Impact of Reduced Reverberation Time on Sound-Induced Arousals During Sleep, May 2001

Dutch Building Code (Bouwbesluit) 2012

The following people contributed their expertise to this article:

Gijs van Wijk
Acoustic advisor in the field of Alternative Working Practices, Hoofddorp, the Netherlands, www.gijsvanwijk-solutions.nl

Heymen Westerveld
Architect at Benthem Crouwel, Amsterdam, www.benthemcrouwel.nl

Jos Reijnierse
Building physics advisor at EGM Adviseurs, Dordrecht, the Netherlands, www.egmadviseurs.nl

Martin van der Meijden
product manager ceilings at Hunter Douglas BV, Rotterdam, the Netherlands, www.hunterdouglas.nl

Nathalie Geebelen
Acoustic advisor at DPA Cauberg-Huygen BV, Maastricht, the Netherlands, www.chri.nl