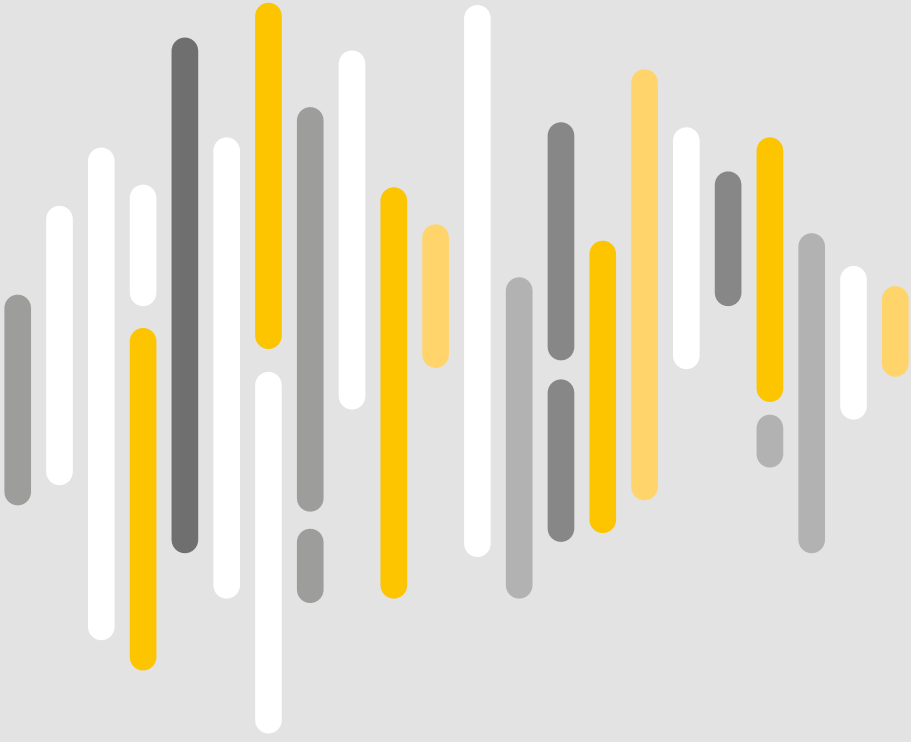
Acoustics in Aged Care

Optimising environments for older people and people with dementia



Richard Pollock

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Important: Dementia care knowledge and research is continually changing and as new understanding develops, so to does the support provided for people with dementia. All care has been taken by the authors and publishers, as far as possible at time of publication, to ensure information is accurate and up-to-date. You can contribute to future editions of this book by going to dementiacentre.com

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The Dementia Centre HammondCare is committed to providing excellence in dementia care. Older and younger people living with dementia deserve services that are designed and delivered based on evidence and practice knowledge of what works. This is achieved through providing research, training and education, publications and information, consultancy and conferences.

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FOREWORD

Noise is a part of life. I love the hustle and bustle of good conversation and company, but when I was diagnosed with young onset dementia everything changed. The everyday noise of life became unbearable. For a sociable person like me this has had a profound impact on my life. This book is a perfect companion guide to my book *Talking Sense: Living with Sensory Changes and Dementia*, written with Dr Julie Christie. It provides a technical but accessible insight into hearing and noise. There is a helpful introduction to the subject of acoustics, and sources of noise and acoustic intrusion are discussed. Importantly, the effects of both on people with dementia are explored and the author gives a fascinating insight into this subject. There are guidelines for managing acoustic intrusion and more detailed technical design solutions. This makes the book meaningful for carers, designers, planners and anyone with an interest in this area of work.

I have spoken to many people with sensitivity to noise and hyperacusis. Living with this sensitivity is hard as many activities such as going shopping on a busy street or meeting friends in a café become impossible. People with dementia can be overcome with emotions and stress responses, and noise as the reason isn't always obvious to us or the people around us. This book provides the science behind the issue and more importantly offers practical solutions to reduce noise intrusions in the lives of people with dementia. We need to pay attention to this important subject or, quite simply, we need to listen.

Agnes Houston MBE, Churchill Fellow

> ***Multiple sources of noise such as the washing machine, vacuum cleaner, radio, TV and loud conversation – all at the same time – will be very distressing to someone with a hearing impairment and worse still for someone with dementia.***
>
> Agnes Houston

For me, living with dementia means that I can only think about one thing at a time. If I want to have a conversation and I'm also expected to perhaps eat, and/or listen to music or other background noise, I have to choose from minute to minute what I will focus on. It's so stressful, it feels like being on a noisy fairground ride that you can't get off.

Eating is no longer a social activity for me. It's either eat or listen, I can't do both, and I actually don't want to do both at the same time anymore. It's exhausting. This seems to be a very hard concept for others to understand.

All my life, sound was usually an indicator for action required – a baby crying meant I had to get up and tend to the child. Dishes clattering meant that it was time for me to wash up. So, after years of being accustomed to moving in response to certain everyday sounds, even though my circumstances have changed, my body still responds to the sounds in the same way – prompting action. When I'm prevented from fulfilling the actions that my body is trying to do, the feeling of unfinished business remains. This can be interpreted as restlessness, and will present as pacing, wandering, agitation etc. Acoustic intrusion is the most disabling factor in the external environment. Inside my brain, I can't control what my ears hear. Most people can 'filter' and 'prioritise' the sounds that they wish to listen to and fade the rest of the noise into the 'background' I can't do that anymore. I can only do one thing at a time in my brain, and if I try to focus on a voice, for example, the louder sounds will intrude and take precedence, so I have to start the whole process of choosing what sound to focus on all over again. It's frustrating, particularly when people get impatient and assume that you can't be bothered. I might look like a nice calm duck sailing across the pond and ignoring you, but underneath I'm paddling furiously just to stay afloat. The anxiety that accompanies this effort is extraordinary, and it's hard not to just give up trying.

Theresa Flavin, lived experience consultant

INTRODUCTION

BACKGROUND

Many commissioners of buildings, designers and care staff do not appreciate how problematic the impact of noise can be on many people and particularly older people and those with dementia. Our aim in writing this book is to provide guidance for these groups – as well as the carers of older people and those with dementia who remain in their own homes.

By making people aware of the causes and detrimental effects of noise, we hope that they will be more able to minimise this by design and management – and so enable residents in care homes or in their own homes to achieve optimal health.

This European report, produced in 2020,[1] notes that:

Long-term exposure to environmental noise is estimated to cause 12,000 premature deaths and contribute to 48,000 new cases of ischaemic heart disease per year in the European territory.

It is estimated that 22 million people suffer chronic high annoyance and 6.5 million people suffer chronic high sleep disturbance.

In light of this, it is vital that we address noise at the source, if possible, to mitigate the damaging health effects on our populations and especially on the most vulnerable.

Acoustics in Aged Care covers the basic characteristics of sound, noise and hearing. The book also focuses on the growing research evidence demonstrating how the acoustic environment can profoundly affect the quality of life and wellbeing of people living with dementia.

Finally, very basic examples are given of forms of construction and material details that can be used to modify and influence the quality of the acoustic environment.

> ***Unnecessary noise is the most cruel abuse of care which can be inflicted on either the sick or the well.***
>
> Florence Nightingale

DEMENTIA EXPLAINED

Designing buildings that enable people with dementia to remain as independent and as stress free as possible is a challenge, but one that can be achieved. It is a challenge because we are usually designing for older people who have many impairments as a result of their age, combined with the symptoms of dementia.

As you get older it is normal to acquire impairments, often several of them. Most older people cope with these with help. One of the most likely is muscular skeletal changes where joints and muscles work less well. This affects mobility, reach, grip etc. The muscles that are often not thought about are those of the neck, hands and lungs. Older people tend to stoop. They often find pressing buttons, opening things and holding onto things difficult. When lung muscles work less well, it is really crucial that air that is breathed in is as good as possible.

Another common impairment is impaired sight. Most of us need reading glasses from our middle age. Sight continues to deteriorate, affecting the ability to see items clearly unless there is good contrast, and to see colours in the same way as younger people. Colour tones seem a lot more muted, especially those at the blue and purple end of the spectrum, and glare becomes increasingly difficult to manage.

This book is about hearing. Most older people have some degree of impaired hearing, even if it is just the loss of ability to hear high frequencies. This means that sound at lower frequencies can become overwhelming and, for example, separating speech from background noise is difficult. Many older people have hyperacusis, which means that they are very sensitive to noise, often particular noises such as the clatter of cutlery.

Dementia is an umbrella term that describes a set of conditions of the brain. Dementia is not a normal part of ageing but is increasingly common as we age – indeed there is an exponential rise in the proportion of people with dementia as they age.

According to Alzheimer's Research UK:[2]

> ***The biggest risk factor for dementia is age – the older you are the more likely you are to develop the condition, but it is not an inevitable part of ageing. About two in 100 people aged between 65 to 69 have dementia, and this figure rises to one in five for those aged between 85 to 89.***

There are over one hundred kinds of dementia, but the most common forms are Alzheimer's disease, vascular dementia and Lewy body disease. As far as design is concerned, the most significant impairments resulting from dementia are:

- **Impaired memory,** which means that people often interpret what they are seeing in terms of the past. So, things need to be familiar. Closing a window because of the noise outside might be difficult because the window design or mechanism is unfamiliar or difficult to operate.
- **Impaired learning,** which means that people with dementia often find it challenging to remember where they are or what things are, even if they have been told many times. They may want the quiet lounge but be unable to find it.
- **Impaired problem solving,** which means that they often experience difficulties in understanding a problem and responding to it. So, for example, they may be overwhelmed by a noise but unable to work out that they need to turn off the TV.

Impairments related to the senses are receiving increasing and necessary attention.[3] All the senses work by taking in stimulation, for example, hearing through the ear. The stimulation goes to a particular part of the brain for interpretation, but often this process is impacted because of dementia. People may not be able to interpret what they are hearing or may interpret it wrongly.

When these impairments are combined with those related to ageing, life can become very stressful. If you do not understand why you cannot see a chair (because there is insufficient contrast) you are likely to trip over it. If there is a great deal of noise and you cannot understand why, you may become very agitated.

With empathy and knowledge, we can design environments that reduce stress, and enable people to live full and happy lives as much as possible.

Spaces designed to suit people with dementia tend to work well for all of us and especially older people generally.

> ***Mrs Obafemi was said to be a 'wanderer' in her care home. She was very confused and had little idea where she was. Staff would seat her in the lounge/dining room and she would quickly become very agitated and start to walk. She walked round and round the lounge/dining room, going out of any door that was open and then getting totally lost. This was a particular problem at mealtimes when she seemed unable to sit still. Following some advice, the home purchased some acoustic screens to ensure that there were quiet areas in the room. Mrs Obafemi was a great deal calmer in the quiet spaces created and would eat her lunch without getting up.***

SOUND

Sound can be defined as the reception of molecular vibrations that travel through the air (or another medium) and are perceived by the brain upon reaching the ear.[4] It can also be described as the sensation produced by a certain range of rapid fluctuations of air pressure affecting the ear mechanism.

Sound is propagated by means of vibrating pressure waves travelling through a medium possessing inertia and elasticity.[5] For the purposes of the book it will be assumed to be travelling through air, which is at a rate of approximately 343 metres per second at a room temperature of 20°C.

Sound dissipates over distance.

> ***Many of us will have experienced the curious effect that the speed of sound has on attempts to synchronise the singing of national anthems in a large, enclosed arena. Different sections of the crowd end up singing out of sync with different periods of delay due to the range of distances from the coordinating source.***

SOUND SOURCE

There are two basic sources of sound: airborne and impact.

1. **Airborne** – examples are speech, music, loudspeakers, birdsong and alarm tones.
2. **Impact –** examples are footsteps, moving furniture, and slamming shut doors and bin lids.

Sources can often be visible (vibrating tuning fork) as well as felt.

Credit: Mary Marshall

MEASURING SOUND

Sound wave vibrations have two characteristics that can be measured: intensity and frequency.

1. **Intensity** – This is described in terms of decibels (dB), a logarithmic scale used to measure the volume of the sound. Because the sensitivity of the human ear is not consistent over the whole of the hearing range, a slightly modified weighted scale (dB[A]) is often used.

Some examples of sound levels of normal activities in dB(A)	
Threshold of human hearing	0 dB(A)
Sound of breathing @ 1 m	20 dB(A)
Noise of normal living	45 dB(A)
Bird twitter outside @ 15 m	45 dB(A)
Noisy vacuum cleaner @ 10 m	55 dB(A)
Passing car @ 7.5 m	75 dB(A)
Loud WC flush @ 1 m	85 dB(A)
Food processor	85 dB(A)
Electric drill	93 dB(A)
Airplane take-off @ 100 m	115 dB(A)
Loud hand clapping @ 1 m	130 dB(A)

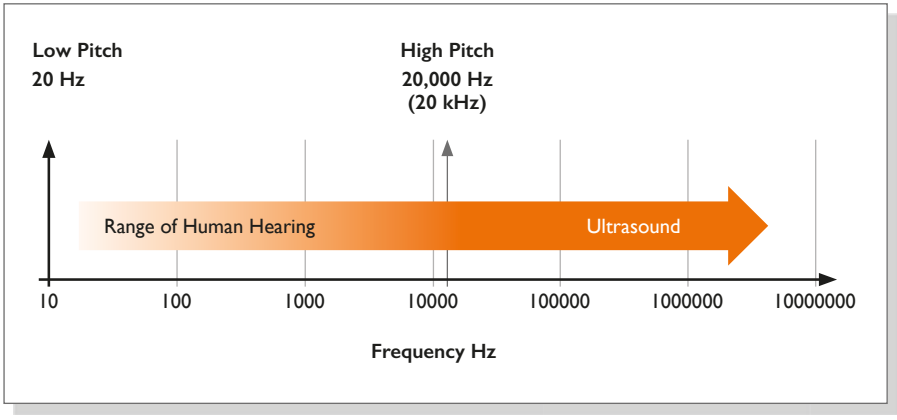
Since the Decibel scale is logarithmic, it should be noted that every increase of 3 dB (or dB[A]) in sound intensity equates to a doubling of the volume.

There is a huge range of scale of the ear's pressure sensitivity, from the threshold of human Hearing at 0 dB to the threshold of pain at around 120 dB. There is a higher risk of heart disease with long term exposure to noise levels above 65 dB and permanent damage to hearing with levels above 85 dB.

Unless a person is in an anechoic chamber (an echo-free room), there is always background or ambient sound of around 10 dB.

2. **Frequency –** This is measured in Hertz (Hz) and describes the number of times that the sound waves peaks and troughs repeat themselves in a second. Being a physical phenomenon, frequency can be accurately measured by meters and instruments.

Figure 1



Sounds at the lower end of the human hearing range can be felt by the body as much as be heard.

SOUND WAVES

In addition to frequency and intensity, sound can also be described in terms of waveforms with minute fluctuations of air molecules.

DIRECTIONALITY OF SOUND SOURCES

In the absence of enclosing reflective surfaces, an important characteristic of sound is its directionality. Longer wavelengths tend to spread in all directions, whereas shorter wavelengths tend to be focused as a beam.

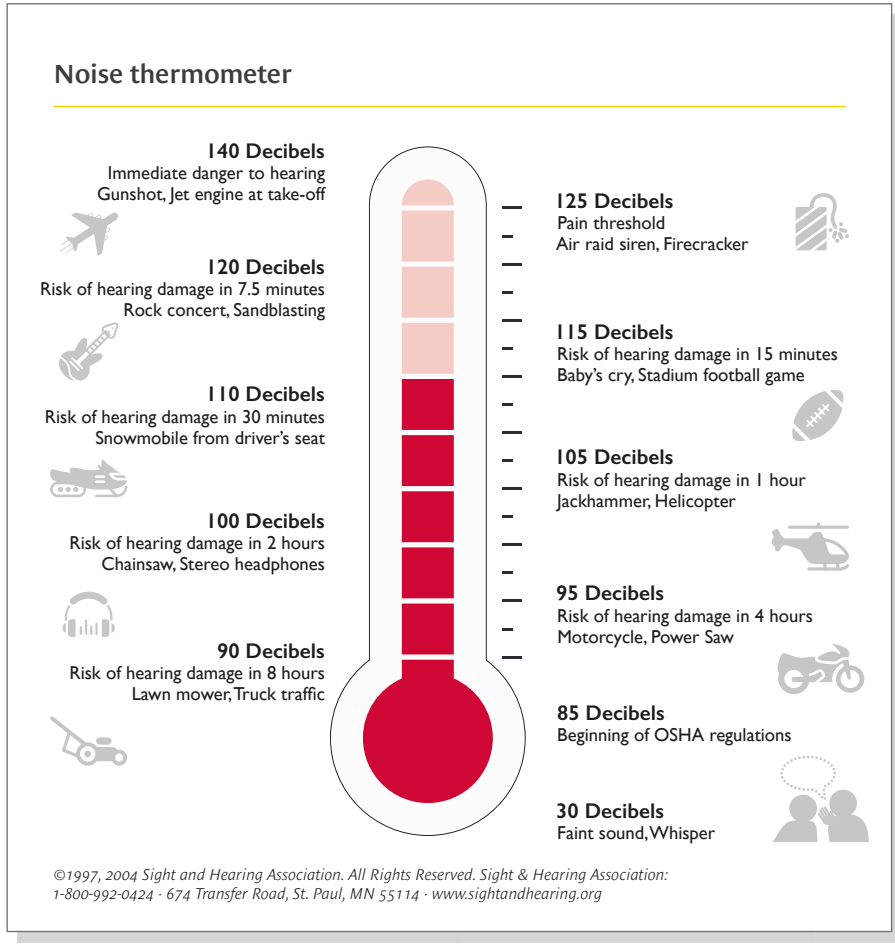
NOISE

Noise can be described as unwanted, harmful or disturbingly loud sound. Even pleasant sounds can be noise if the person hearing them is wanting peace and quiet.

'Acoustic Intrusion' refers to the experience of sound that bears detrimental effects on one's physical and psychological functioning, wellbeing and competence.

The impact of acoustic intrusion is an often-neglected issue, which can have significant impact on one's quality of life, regardless of age or wellness. Background noise is known to affect cognitive functioning in individuals without dementia,[6] and evidence indicates that children's learning ability in school is adversely affected by unwanted noise.[7]

Figure 2

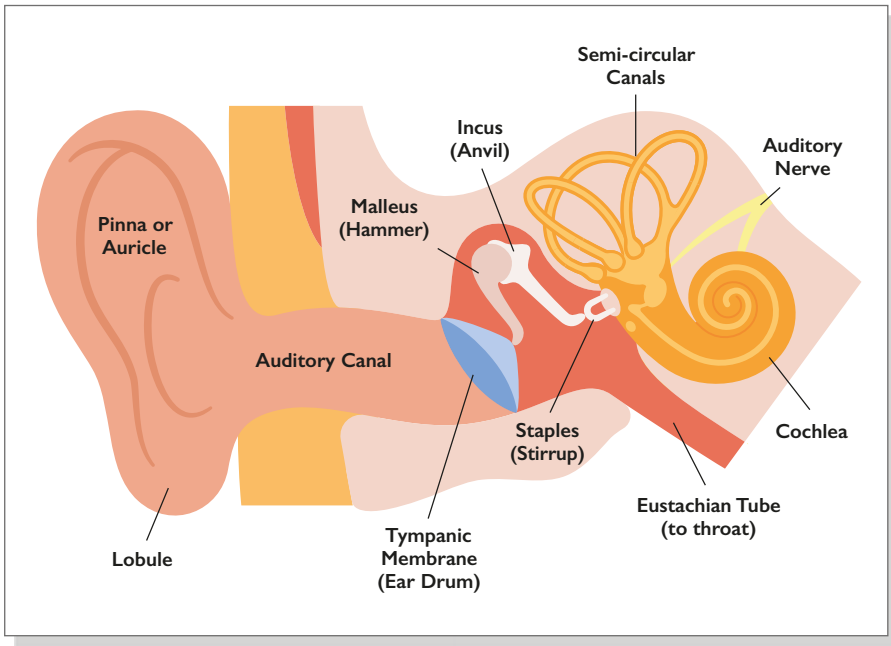


HEARING

THE HUMAN EAR

There are three parts to the human ear: the outer ear, the middle ear and the inner ear. The outer ear has the pinna, which operates as a funnel to direct the sound vibrations through the auditory canal towards the ear drum. The middle ear consists of three small bones or ossicles: the hammer (malleus), the anvil (incus) and the stirrup (stapes). These further transmit the sound vibrations to the oval window of the inner ear. The oval window is much smaller than the ear drum, so this mechanism serves to amplify the pressure of the vibrations and transfers the sound to the liquid content of the inner ear.

Figure 3

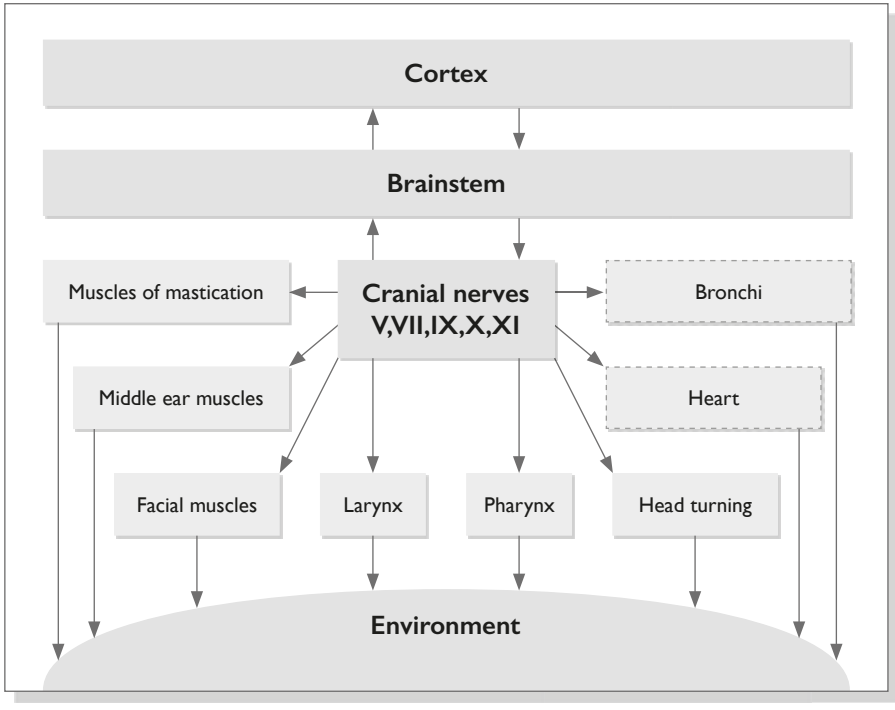


The inner ear serves two purposes; firstly, to control the body's sense of balance and secondly, to convey the perception of sound through the cochlea with its tiny, delicate hair-like receptors to the auditory nerve. The auditory or cochlea nerve carries auditory sensory information to the auditory cortex in the brain.

For a person with dementia with normally functioning hearing, damage to the part of the brain that receives and interprets the nerve signals can make their hearing unintelligible or lead to auditory hallucinations.[8]

According to research (Porges and Lewis 2010), when people feel uncertain or over-stressed, muscles in the inner ear are affected in a way that makes them unable to hear calming, considerate voices. Conversely, when people feel cherished and safe, these same muscles respond by shutting out background sound and enabling them to focus better on the frequencies of normal human speech.

Figure 4



The basic mechanism is shown in the following diagram taken from the research paper by Porges and Lewis.[9]

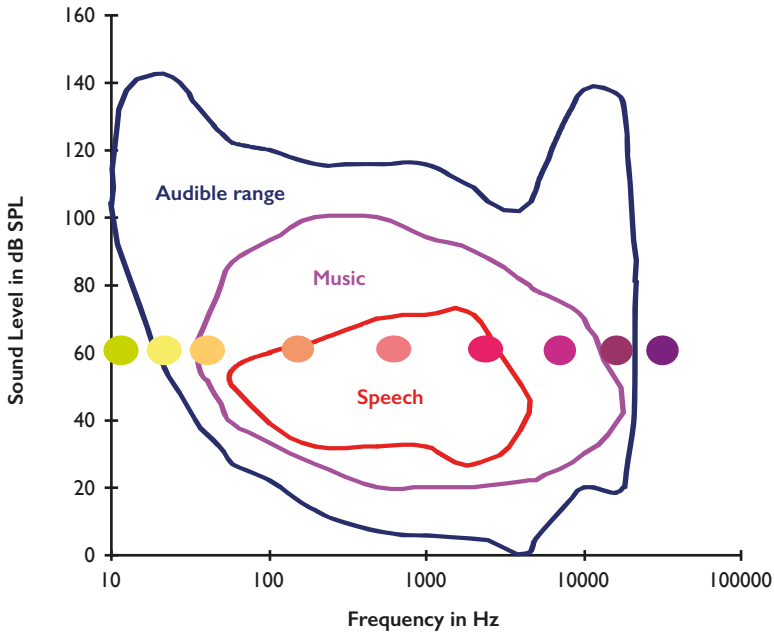
There are three stages of hearing:[10]

1. **Detection** – this first stage concerns the actual detection of sound. Can a sound be heard?
2. **Resolution –** secondly, can we identify the source or origin of the sound?
3. **Identification –** the last stage of the process is the ability to understand and name the sound.

Despite the wonders of the brain and what we may think, we cannot process two separate sounds simultaneously. We have to focus on one.

Figure 5

Threshold of hearing



Credit: Ecophon

HEARING LOSS

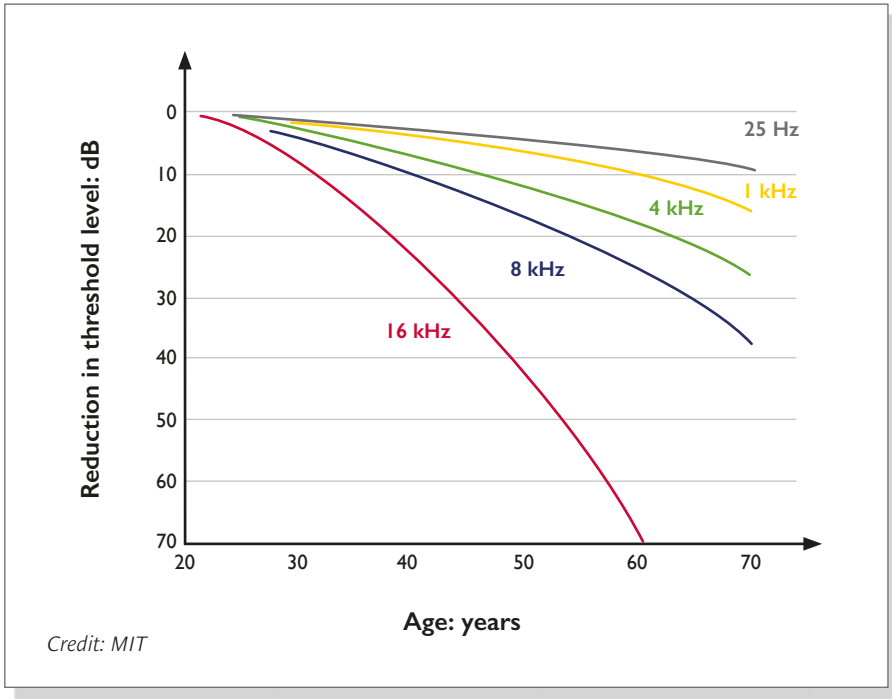
Hearing loss can affect people of all ages simply because of the build-up of natural wax around the ear drum in the auditory canal (see fig 3). This wax provides an essential measure of protection against infection but can build up to levels where hearing is seriously impaired. Care staff need to be aware of this issue when dealing with patients/residents who appear to be inattentive.

Forty per cent of people age 50+ suffer from hearing loss.[11]

The following link has useful, informative statistics on hearing loss in the general population for those who are interested:

https://www.hearinglink.org/your-hearing/about-hearing/facts-about-deafness-hearing-loss/

Figure 6



Credit: MIT

Most older people will have impaired hearing such as presbycusis which is a normal hearing impairment of ageing. Hearing loss – especially of higher frequencies – is increasingly common with age,[12] whilst it also becomes more difficult to differentiate between lower frequency sounds.

Thus, hearing speech when there is a lot of other sound is problematic – and people with dementia can easily become overwhelmed by low frequency sound, especially if they cannot understand where it is coming from.

Many older people also have a hearing impairment for other reasons – some may have had it for all or most of their lives.

Tinnitus (persistent noises in the ear) is fairly common and whilst most people can work out how to cope with it, people with dementia may not be able to and can find it very unpleasant. Some people with dementia may have blocked ear canals; this is especially common in people with Down syndrome, who may struggle to hear and appear more confused than they really are. Others may have hearing aids, which are problematic because they require adjustment and maintenance.

Healthy adults experiencing hearing loss learn to manage by adopting one or more of the following coping strategies:

- avoiding conflicting noises
- lip-reading
- interpreting body language
- paying close attention in conversations then extrapolating from what they hear.

However, these coping mechanisms can be impaired by cognitive changes resulting from dementia. Acoustic intrusion is particularly damaging to people who live with dementia since it may also lead to worry, irritation, unpleasant memories, distraction, confusion and/or increased agitation.[13,14]

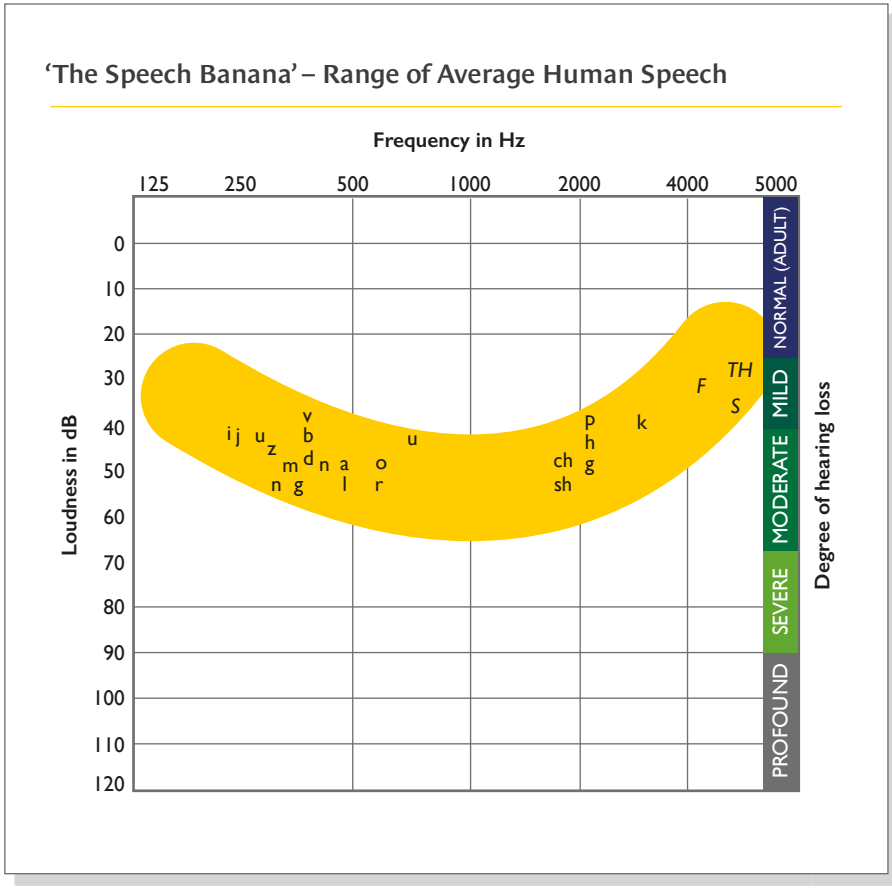
Even people with dementia who have normal hearing, are known to lose the ability to accurately interpret sounds. According to Hayne and Fleming,[15] 'the amount, type and variety of noise a person with dementia is exposed to needs to be carefully regulated, as over or under exposure to noise can cause confusion, illusions, frustration and agitation'. Excess noise within the environment can lead to overstimulation in a person who is living with dementia and associated changes in behaviour.

With hearing loss, the sounds of letters in speech, known as phonemes, are affected differently:

- 'S' is high frequency
- 'J' is low frequency
- 'K', 'L', 'F', 'S' and 'Th' are all difficult to hear with age-related hearing loss.

(see Figure 7)

Figure 7



A series of studies[16,17] has shown an association between hearing loss in older adults and dementia.

- The study was carried out by researchers from the John Hopkins School of Medicine and other research institutions in the US.
- For every 10 dB of hearing loss, there was a 27% increase in the risk of developing dementia over the follow-up period.

Another study[18] by Arthur Wingfield found that impaired hearing hinders people's ability to remember information they have just heard.

> ***I used to enjoy going to parties, but I prefer to give them a miss now because I feel that not hearing anything makes me look stupid.***

SOURCES OF NOISE AND ACOUSTIC INTRUSION

To effectively manage acoustic intrusion, its sources must first be identified. In aged care homes, Hayne and Fleming[19] reported that the overstimulation for people with dementia (measured by agitation levels) is prevalent in common areas, bathrooms, nursing stations, other residents' bedrooms and corridors. Auditory overstimulation may emanate from myriad sources (as noted in Table 1[20] below):

Source Category	Examples of Unwanted Noise Sources
Built Environment	External factors including location and position of building, construction works, structural features, physical layout and interior fit-out
Human-Generated Impact	Footfall, washing machines, dryers, doors closing, furniture movement
Residential Activities	TV, radio, music, conversation, resident vocalisations, medical equipment, clattering dishes/cutlery
Staff Operations	Photocopiers, trolley wheels, phones, vacuum cleaners, staff conversation, dishwashers, food preparation
Communications	Phones, paging systems, intercom systems, call bells
Safety Systems	Medical emergency alarms, fire alarms, nurse-call
External Activities	Traffic, aircraft, industrial processes, dogs barking, construction and grounds-maintenance activities
Mechanical Plant and Services	Air-conditioning systems, ventilation, lifts, waste/stormwater flow, hydraulic pipework

The masking effect of background music is often employed in places such as dining rooms, cafés and restaurants to ensure privacy of conversations when there are fewer customers. Whilst some background music can be shown to improve the dining experience,[21] it can cause an uncomfortable environment if used continuously and is not reduced in volume according to an increasing number of customers.

EFFECTS OF NOISE AND ACOUSTIC INTRUSION

> *Freedom from the harassing effects of noise is one of the finest qualities a building can possess.*[22]

The effects of acoustic intrusion can be of significant detriment to anyone, and further exacerbated for people living with dementia. The effects of acoustic intrusion impact social, psychological, physiological and physical functioning and are outlined as follows:

1. SOCIAL EFFECTS

Acoustic intrusion can make communication unnecessarily difficult, which can lead to feelings of social isolation.

Firstly, conspicuous noise is confusing and distracting for people with dementia, making it hard to concentrate.

Secondly, sitting in a long line either around the edges of a room or at a table, means that the person with dementia cannot easily see the person next to them and lip reading, which we all do subconsciously, is not possible.

Credit: Annie Pollock

2. PSYCHOLOGICAL EFFECTS

Cognitive changes make it difficult for a person living with dementia to discern the source of sound and filter it accordingly. Acoustic intrusion can therefore result in a person feeling overwhelmed and distressed, which can be expressed in their behaviour. Psychological implications of acoustic intrusion include confusion, anxiety and agitation.[23,24] High noise levels are also associated with aggressive and disruptive behaviours.[25] Auditory overstimulation is further known to disorientate people with dementia, which can lead to frustration and an increased risk of falls.[26] The psychological symptoms arising as a result of acoustic intrusion can result in additional strain on staff, relatives and friends, as well as the person with dementia.

Conversely, a complete lack of sound can be unsettling. People with dementia can be reassured and prompted by the sounds of normal daily life – boiling kettles, the rattle of cutlery drawers, the chinking of china cups on saucers, when neither too loud nor startling, as pointed out by Theresa Flavin in the Foreword to this book.[27]

3. PHYSIOLOGICAL AND PHYSICAL EFFECTS

Acoustic intrusion can cause a wide range of health problems for people living with dementia. It is correlated with increased blood pressure,[28] heart rate[29] and increased risk of stroke.[30] High auditory stimulation may also cause fatigue and exhaustion in people generally.[31]

Credit: thodonal

Other physiological implications of excess noise include delays in wound healing and impaired weight gain[32] – both of which can be harmful for frail older people.

When the acoustic environment impacts on sleep, immune function can be inhibited as well.[33] This is particularly dangerous for frail older people.

Difficulties interpreting sounds accurately can result in a greater risk of falls in people with dementia, due to either a loss of balance or an increased sense of disorientation.[34] Furthermore, the person with dementia may appear restless and try to escape excess noise by walking excessively. This can incorrectly be labelled 'wandering', where in fact the walking is purposeful.

KEY POINTS

- The indisputable benefits of a healthy sound environment.[35]
- A good sound environment contributes positively towards:
  - reducing risk of high blood pressure[36]
  - preventing an increase in heart rate, respiration rate and blood cholesterol[37]
  - improving quality of sleep[38]
  - reducing intake of pain medication[39]
  - reducing the number of readmissions[40]
  - improved wellbeing among staff and improved perceived performance[41]
  - being able to engage and communicate[42]
  - improving concentration and coordination.[43]

I love to have my bedroom window open at night for fresh air but can't because of the incessant noise from the street.

UNDERSTANDING BASIC ACOUSTICS

As has been mentioned, the normal process of ageing leads to a natural deterioration in human hearing ability. To compensate for this and the additional complications resulting from having dementia, it is necessary to gain an understanding of the basic principles of acoustic design.

TRANSMISSION

Transmission occurs when sound is carried from one space to another directly through the materials of construction that enclose the spaces. A sound source in one room or area sets up vibrations in the air around it and these vibrations are transferred to the separating construction materials, which, in turn, set up sound vibrations in the receiving room or space.

Transmission can result in sound, for example from a plant room, lift or stairway, being heard in nearby rooms if the form of construction of the separating wall does not include adequate sound insulation. If the next-door room is a quiet room such as a bedroom, this could be very disturbing to sleep and rest.

Materials with higher mass such as dense blockwork are more effective in reducing sound transmission. Discontinuous methods of detailing, as shown in the technical section, are also an effective means of preventing or significantly reducing sound transmission through a building structure.

From *The Guinness Book of Records*

Highest absorption/insulation

A specially constructed anechoic chamber is hidden in the depths of Building 87 at Microsoft's headquarters in Redmond, Washington, where the firm's hardware laboratories are based. In 2015, it set the official world record for silence when the background noise level inside was measured at an ear-straining -20.6 decibels.

Longest echo

In 2014, acoustics expert Trevor Cox crawled through a narrow pipe into a subterranean wartime emergency oil tank in Inchindown, Scotland. One gunshot and 75 seconds later, he had set a new world record for the longest echo in a man-made structure – 112 seconds.

Both of these extreme acoustic conditions have proven to be a highly unpleasant experience for the majority of people who have experienced the sensations!

Visit Building 87 at: https://news.microsoft.com/stories/building87/

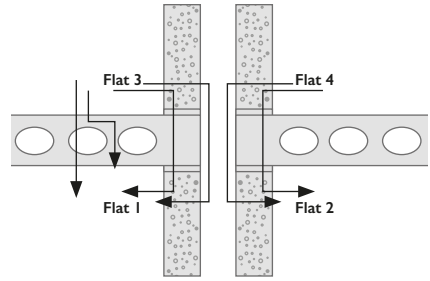
Figure 8

Flanking sound transmission

Flanking sound transmission occurs via indirect paths. The diagram shows the principal sound transmission paths (direct and indirect) in a typical floor arrangement.

Careful design and good workmanship are key to overcome this complex issue.

Diagram: Separating floor/wall junction



Flanking transmission occurs by way of indirect paths and most effectively when sound is less directional and more evenly spread.

Air passages through forms of construction are a major weak point – sound will always find the weakest path through.

ABSORPTION

Absorption is the ability of any material to dampen and reduce sound vibrations. All surfaces both reflect and absorb sound waves and the proportion of sound absorbed to the total landing on a surface is known as the absorption coefficient. The higher the number, the greater the absorption.

Harder and denser materials reflect much of the sound energy and tend to have a low absorption coefficient, while softer, porous and less dense materials have higher coefficients. The table below shows typical values for a range of common building materials.

Absorption coefficients of some commonly used materials:

Material	125 Hz	250 Hz	500 Hz	1000 Hz
Plasterboard	0.03	0.03	0.02	0.04
Laminate flooring	0.15	0.1	0.1	0.1
Thin carpet	0.1	0.15	0.25	0.3
Thick carpet	0.2	0.25	0.35	0.4
Suspended ceiling	0.1	0.25	0.70	0.85
Wall panel (board)	0.3	0.3	0.35	0.4

A common problem with materials and components that are good at absorbing sound is ensuring that, at the same time as being open textured and porous, they are equally effective in being cleaned and not prone to spreading or harbouring infection agents.

INSULATION

All walls, floors and ceilings reduce the volume of sound passing through them. The extent to which the sound transmission is reduced is described as the insulation value, which is expressed in decibels (dB).

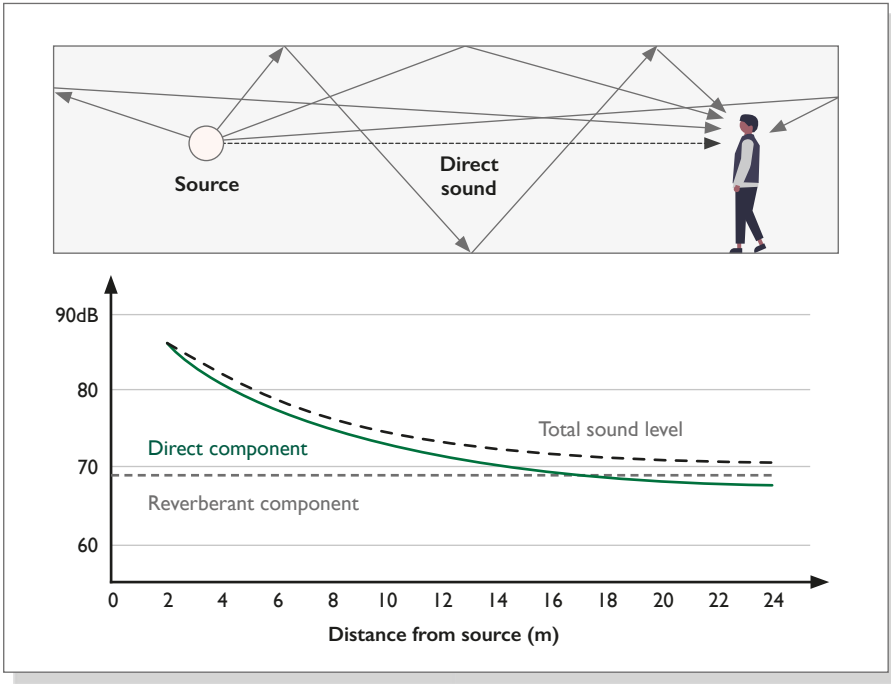
Sound vibrations passing through air have less of an effect on materials with greater mass or higher density. Lighter and less dense materials respond more elastically to sound vibrations and allow more sound energy to pass through them.

REVERBERATION

Sound travels much more slowly through air than through liquids and solid materials. This leads to echoes and reverberations becoming a potentially serious problem affecting a person's ability to hear clearly in various rooms and spaces.

Reverberation time is the standard measure of the time required for a particular sound to die away to one thousandth of its initial pressure, which equates to a drop in sound pressure level of 60 dB.

Figure 9



Reverberation time (RT) can be calculated using Sabine's formula (see panel). It is one of the most important measures of the acoustic environment and has a profound influence on the ability to hear. RT is related to the volume of the space and the extent and proportions of reflective or absorptive surfaces that enclose the space. Larger spaces tend to have longer reverberation times and need more absorptive surfaces to achieve a similar RT to smaller spaces.

Hard reflective surfaces reflect sound and absorb very little, thus increasing the reverberation time. Soft and porous surfaces absorb most of the sound, reflecting little, thereby reducing the reverberation time in a room.

Listening to speech works best in an acoustically dampened, absorptive environment in which the sound level dies down quickly. Music is best appreciated in a more reverberant environment in which the sound lingers longer.

When reflected sounds reach an observer after a delay of 0.06 of a second relative to direct sound they are perceived as echoes, which disrupt intelligibility. Similarly, If the reflected sound from one syllable is still heard when the next syllable is spoken, it may also be made more difficult to understand what was said.[44]

Sabine's formula

$$RT_{60} = \frac{24\,(\ln 10)\,V}{c_{20}\,S_a}$$

Where

RT_{60} is the reverberation time (to drop 60 dB)

V is the volume of the room

c_{20} is the speed of sound at 20°C (room temperature)

Sa is the total absorption in sabins

Since the air temperature in normal living environments is likely to be around 20°C, the speed of sound will be 343 m/s, so the formula can be simplified to:

$$RT_{60} \cong \frac{0.161\text{s/m}\;V}{S_a}$$

Optimum reverberation times for some different rooms:

Room	Reverberation Time (RT) in seconds
Bedroom	0.5
Lounge	0.9
Dining	0.7–0.8
Activity	0.4–0.6
Music	0.9–1.2

Bathrooms and toilets present particular problems due to the need for hard cleanable surfaces for moisture and infection control. In these rooms, reverberation times need to be minimised as much as possible, by using sound absorbent materials, e.g. stacks of towels, acoustic panels.

An example of how reverberation times can be calculated is given in the Appendix. An alternative is to use a proprietary method such as the 'acoustic calculator'[45] produced for free use by Saint-Gobain Ecophon, a manufacturer of acoustic building products including ceiling tiles.

GUIDELINES FOR MANAGING ACOUSTIC INTRUSION

The following are suggested guidelines for effectively controlling and managing acoustic intrusion for people living with dementia. These guidelines have been written specifically for use in residential aged care homes. However, a number of these suggestions are applicable to homes, hospitals and public spaces too.

1. SITE AND BUILDING LAYOUT CONSIDERATIONS

A site assessment, whether for a new build or for a refurbishment, is essential to shape the best way a building is laid out.

Similarly, the placement and juxtaposition of rooms and spaces within a building can have a significant influence on the quality of the acoustic environment. The following bullet points cover the general considerations and more technical solutions are covered in the section on 'Technical Design Solutions'.

Some common sounds and their decibel ratings at source	
Unsilenced pneumatic drill (at 7 m distance)	95 dB(A)
Heavy diesel lorry (40 km/h at 7 m distance)	83 dB(A)
Modern twin-engine jet (at take-off at 152 m distance)	81 dB(A)
Passenger car (60 km/h at 7 m distance)	70 db(A)
Office environment	60 dB(A)
Ordinary conversation	50 dB(A)
Quiet bedroom	35 dB(A)

- **Proximity to noise**. The proposed site/building should not be located near external sources of noise which cannot be avoided (e.g. busy roads, flight paths). *(Refer to Design features – acoustic windows/glazing in technical section.)*
- **Planning**. Arrange the layout of the rooms in a building so that quiet areas, bedrooms, quiet lounges, small wards or sitting areas are located well away from plant rooms, stairs, lifts, sluices, laundries etc.
- **Structural noise insulation**. The form of construction should be designed to facilitate effective noise insulation, e.g. through discontinuous construction and appropriate window positioning. *(Refer to sample details in technical section.)*

- **Size of residential units**. It has been found that residents in small-scale and home-like environments experience fewer changes in behaviour[46] as small generally means quieter. Residents should also have a choice of small rooms for quiet conversation or reflection.
- **Reverberation levels**. Different spaces and room shapes have different reverberation level requirements and should be assessed for appropriateness.
- **Access to outdoors**. Residents should have easy access to visible outside spaces. These are often quieter and more calming than public indoor areas.
- **Landscaping**. Planting beds and other soft landscaping located close to windows will help to absorb external noise which would otherwise be reflected off hard surfaces into the building.

As she got older, Mrs Suarez began to trouble the neighbours in her block of flats increasingly. She was a widow who had lived in the small block of flats for a long time. She did not trouble them at night but during the day they were aware that she was agitated and constantly going in and out of the flat – often heading for the small garden at the back whatever the weather. A careful assessment revealed that it was the noise of the increasingly busy road (a new distribution depot had been built nearby) outside her flat that was distressing her. Double glazing solved the problem.

2. INTERIOR DESIGN CONSIDERATIONS

The interior design and fit-out can determine the success or failure of an acoustic environment in a building for people with dementia.

- **Soft-furnishings**. Use soft-furnishings and sound absorptive finishes to control reverberation and noise (e.g. cushioned floorings, curtains, table mats). Hard surfaces (e.g. tiles) should be used only when essential, to minimise noise reflection.[47]
- **Doors**. Consider installing sound insulated doors so that noise from circulation areas is minimised.
- **Living areas**. Separate different activities so that one does not overwhelm another. Use more sound absorbent flooring. Optimised lighting will help with lip-reading.
- **Dining areas**. Smaller dining tables and seating arrangements will enable face-to-face communication and ease of hearing. Ensuring adequate lighting levels to enable lip-reading will also be of assistance.
- **Bathrooms/toilets**. Assisted bathrooms tend to have hard interior surfaces for hygiene reasons. Additional sound absorbency by such means as acoustic panels can be incorporated to reduce harsh reverberation.
- **Artwork**. Consider the use of sound absorbent panels/pictures that can be designed to look like paintings.
- **Lighting**.[48] Make good use of natural daylight and avoid glare so that people with hearing impairments can see as clearly as possible. People with hearing loss use visual cues to try to establish sources of sound such as speech.

3. ELIMINATE UNNECESSARY STIMULI

It has been established that excessive and meaningless stimulation can be detrimental to people living with dementia.[49,50] As such, the quality of life of people with dementia can be positively affected by reducing unnecessary stimuli.

- **Walking areas**. Provide space and opportunities for people to walk and move about freely so they can choose quieter locations to sit and relax. This especially includes having access to outdoor spaces.
- **Alarms and appliances**. Avoid noisy alarm systems by using vibrating or visual alarms and silent bell alarm systems.
- **Appliances**. Sound generated by different household appliances should also be considered (e.g. kettles, hair/hand dryers, TVs, radios). 'Airblade' type hand dryers with a potential noise level of around 85 dB(A) are a particular problem for vulnerable groups of people.[51]

> ***A day centre had worked hard to make their premises as enabling as possible for people with dementia. They had a lounge area, several activity spaces and a dining area adjacent to a kitchen with a counter and steel roller blind which was closed except at mealtimes. Several members became very agitated at lunchtime. The explanation turned out to be the catering staff banging the big spoon they used to serve the mashed potato on the side of the large saucepan.***

4. PROMOTE POSITIVE STIMULI

There is evidence that a total absence of sound might not have the desired effect in reducing the aggressive and disruptive behaviour that high noise levels can trigger. Rather, 'a pleasant level of noise might be beneficial to stimulate residents and to help them to avoid boredom'.[52]

- **Social interaction**. Provide a range of spaces for quiet social interactions and activities to facilitate meaningful social connection.
- **Music**. Be mindful that 'playing unwanted or interrupting pleasurable music can lead to more agitation in people with dementia'.[53] However, residents may enjoy individualised, meaningful music playlists.
- **Mealtime cues**. Sounds of staff cooking or setting tables can cue people with dementia that a meal is approaching and promote feelings of comfort and familiarity.
- **Outdoor access**. Easy access to the outdoors, for exposure to natural sounds (e.g. birdsong, wind rustling branches, water feature).

> ***Mr McDonald was very withdrawn in the lounge of his care home. He sat to one side in silence and refused to participate. The staff always had music in the lounge and they had chosen several types of music they thought residents would enjoy: music hall, barn dancing, crooners of the 1950s etc. One day the radio played some classical music and Mr McDonald came alive. He sat up and smiled at everyone.***

5. STAFF AWARENESS, TRAINING AND EDUCATION

Staff awareness is integral to promoting a good acoustic environment. Be sure to consider:

- **Mealtimes**. Staff should be made aware of the value of quiet mealtimes and kitchen tasks (e.g. loading and emptying dishwashers).
- **Dining**. Space should be available for staff to be able to assist some residents with eating, without impinging upon or disrupting other residents.
- **Cleaning schedules**. Cleaning routines should be developed to produce minimum impact on residents.
- **Maintenance**. Regular maintenance schedules for mechanical ventilation systems will help minimise draughts and noise emissions.
- **Garden maintenance**. Routines should be developed to produce minimum impact on residents.
- **Phones**. Limit phone use to staff areas or special areas for use by residents and visitors.
- **Entertainment media**. Operation of radio, television and communal music should be carefully managed to suit the residents' interests.

- **Staff conversations**. Limit the number of simultaneous staff conversations, especially during times of heightened levels of noise such as mealtimes. In busy and noisy environments staff may attempt to talk over existing levels of noise, thereby creating yet another layer of noise.
- **Monitor**. Use monitoring devices such as a 'YackerTracker' (see section on apps and meters) to alert staff to the presence of unwelcome levels of noise.
- **Night-time**. Staff should understand the need for a quiet ambience, especially during the night when background sounds are more easily heard.

> *Mr O'Brien was very agitated and aggressive at night. He would wake up shouting and he was aggressive towards staff who came to his room. It was only when a staff member sat with him that they realised that the exit gate for staff was attached to the wall of Mr O'Brien's room and every time a member of staff went out of the gate, it made a loud squeak and bang which he was interpreting as people coming to attack him.*

TECHNICAL DESIGN SOLUTIONS

This is a huge subject that cannot be dealt with in any degree of detail in this book. The following are some examples to illustrate the main issues and provide guidance towards appropriate solutions for individual circumstances.

The illustrated details in this section are taken from the UK Building Regulations, 'accredited' details in Scotland and 'robust' details in England and Wales.[54]

For developments in Australia, refer to Standards Australia (AS/NZS 2107:2016 and AS/NZS ISO 717.1:2004) for national standards for acoustics.[55]

In the UK, the recommendations for acoustic design given in BS8233:2014[56] and BS EN 12354[57] should be followed in order to choose an appropriate acoustic absorbency for each surface.

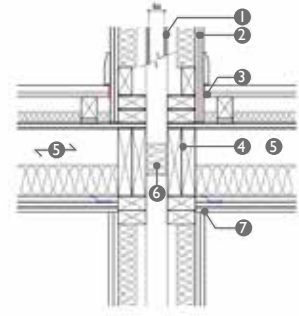
WALLS

- High mass/density to increase insulation and reduce transmission.
- Discontinuous construction to increase insulation and reduce transmission.
- Softer, more porous linings to increase absorption and reduce reverberation.
- Use of decorative panels to increase absorption and reduce reverberation.
- Seal all construction gaps to increase insulation and reduce airborne transmission.
- Use flexible and more malleable waterproof lining materials instead of ceramic tiling in wet rooms to reduce reverberation.

Figure 10

Separating floor junction: with Floor Type 3A using solid timber joists

1. Separating wall may have sheathing board to cavity side provided that minimum 50 mm cavity is maintained
2. Two layers gypsum based board total minimum mass per unit area 22 kg/m² both sides
3. 5 mm (min) resilient flanking strip
4. Close spaces between floor joists with full depth timber blocking or continuous header joist where joists are at right angles to the wall
5. Separating floor type 3A joists
   - ◇ must not be continuous between dwellings
   - ◇ may be parallel or perpendicular to the wall
   - ◇ separating floor joists must be built in and should not be mounted on hangers
6. Close cavity with cavity barrier
7. Seal all perimeter joints with tape or caulk with sealant



Credit: Scottish Building Standards Agency

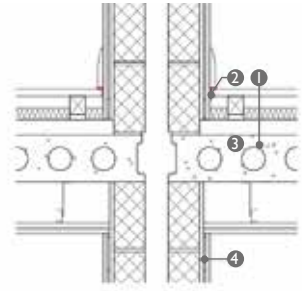
FLOORS

- High mass/density to increase insulation and reduce impact transmission.
- Discontinuous construction to increase insulation and reduce impact transmission.
- Floating floors reduce impact sound transmission.
- Cushioned or softer floor finishes to increase absorption and reduce reverberation and impact transmission.
- Seal all construction gaps to increase insulation and reduce airborne transmission.

Figure 11

Separating floor junction: with Floor Type 2B

1. Separating floor type 2B
2. 5 mm (minimum) resilient flanking strip
3. Concrete slabs to be built into wall:
   - precast concrete slab must not be continuous between dwellings
   - 75 mm cavity to be maintained between precast concrete slab
   - wall must not be continuous between storeys
   - slabs must not abut separating wall
   - all voids between slabs and blockwork must be filled with mortar or flexible sealant
4. Continuous ribbon of adhesive



Credit: Scottish Building Standards Agency

CEILINGS

- Acoustic suspended ceiling tiles increase absorption and reduce reverberation.
- Acoustic panels, rafts and baffles increase absorption and reduce reverberation.
- Enclose noise generating services such as air handling ducts and fans.
- Ensure ceiling finishes are not compromised by the installation of light fittings and ventilation grilles.

DOORS

- Minimise gaps around door frames to reduce airborne transmission around doors.
- Higher mass, solid core doors more effectively reduce transmission.
- Where possible, use doors with higher specified insulation values.
- Where appropriate, fit automatic closers to reduce airborne sound transmission when open.
- Carefully design threshold details to reduce air passage under doors.

WINDOWS

- Where appropriate, keep windows to neighbouring rooms as far apart as possible to reduce flanking transmission.
- Where noise nuisance is anticipated, use windows with higher acoustic insulation values.
- If there is noise outside, keep windows closed as much as possible when ventilation is not required.
- Curtains, and to a lesser extent, blinds increase the absorption of sound and reduce reverberation. Choose materials that reduce light levels only where appropriate.

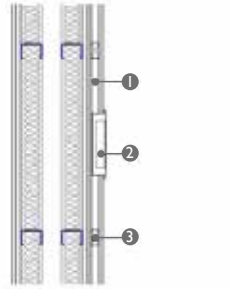
PLANT/SERVICES

- Locate plant rooms, laundries and commercial kitchens as far away as possible from quiet areas requiring acoustic comfort.
- Carefully maintain sound generating mechanical equipment such as fans and pumps to avoid unnecessary noise intrusion.
- Seal all gaps around services, such as plumbing pipework and wiring conduits, where they pass through sound separating walls and floors.
- Acoustically insulate services in floor and ceiling voids.
- Avoid penetration of separating walls when installing services.
- Lifts, especially with audible voice announcements, must be located well away from quiet areas.
- Ensure light fittings do not penetrate acoustic ceiling construction.

Figure 12

Services and sockets

1. Provide a service void on surface of separating wall
2. Services should not puncture the separating wall
3. Studs or battens used to create the service zone should be securely fixed back to the separating wall structure

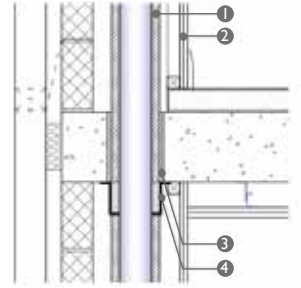


Credit: Scottish Building Standards Agency

Figure 13

Services – vertical soil vent pipes (SVPs) through separating floors

1. SVP to be fully wrapped with 25 mm (min) mineral wool quilt (min 10 kg/m^3)
2. Pipe boxed in with two layers gypsum based board, each layer minimum 8 kg/m^2
3. All voids around pipe to be sealed
4. Fire Stop



Credit: Scottish Building Standards Agency

STAIRWELLS

Provide effective sound control construction to isolate quiet areas from the airborne and impact noise expected to be generated.

APPS AND METERS

There are accurate but often costly meters for measuring the various characteristics of sound.

These can be complex to set up and operate and are generally intended for professional acousticians. There are, however, many apps for smart phones, which can provide a reasonable indication of sound levels and frequency ranges. These are perfectly adequate to demonstrate where there may be problems of noise and acoustic intrusion in any healthcare or domestic environment. Organisations should encourage training in the use of these devices.

ALARMS AND ALERTS

Silent is best!

Select alarms and alerts to suit the general situation regarding the different audibility ranges of younger staff/carers and older residents/patients. This means:

- starting at high pitch, progressively lowering
- starting at low volume, progressively rising
- linking to a mobile phone app where not used at a normally fixed location.

EQUIPMENT AND HEARING AID SYSTEMS

For most common forms of hearing loss, the most effective hearing aids are those that amplify the frequencies that the ears are least sensitive to.

KEY POINTS

- Plan building layouts to keep noise sources apart from quiet areas.
- Specify building components and elements that are effective in reducing sound transmission.
- Design in detail forms of construction that adequately reduce sound transmission.
- Use interior design features that modify sound reverberation.
- Provide staff training in understanding the importance of acoustic comfort.
- Enable staff to monitor, measure and deal with issues where acoustic intrusion is impacting on the health and wellbeing of those they are responsible for, including their own colleagues.

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GLOSSARY

Decibel (dB or dB[A])	A unit of measurement used to express the ratio of one value of a power or field quantity to another on a logarithmic scale. It can be used to measure the intensity of a sound.
Flanking transmission	Transmission of sound via adjoining elements and air paths through or round a building element.
Hertz (Hz)	The international unit for the frequency of sound in cycles per second.
Reverberation time (RT)	Time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

"This book provides the science behind the issue (of acoustics in aged care) and more importantly offers practical solutions to reduce noise intrusions in the lives of people with dementia."

Agnes Houston MBE, Churchill fellow and dementia advocate

The impact of noise on older people and people living with dementia is easily overlooked, but the acoustic environment can profoundly affect our quality of life and wellbeing. *Acoustics in Aged Care* is a practical guide to sound, noise and hearing that will help the reader understand the problem of acoustic intrusions.

Written for anyone planning, designing, building homes or caring for older people, *Acoustics in Aged Care* is an important resource with practical strategies that can be taken to reduce intrusive noise at home or in the care environment.

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