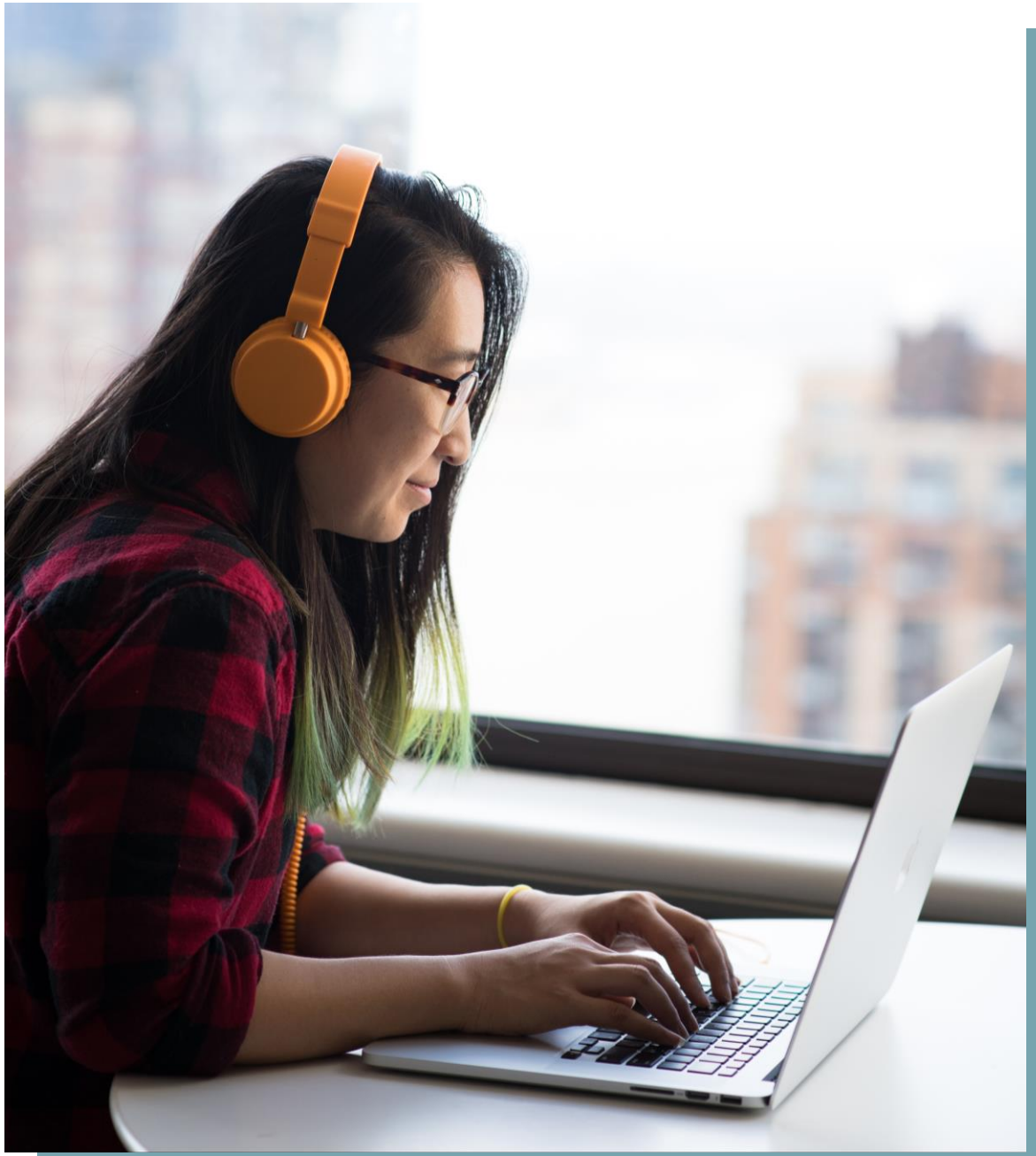
SOUND

SOUND

ISSUE

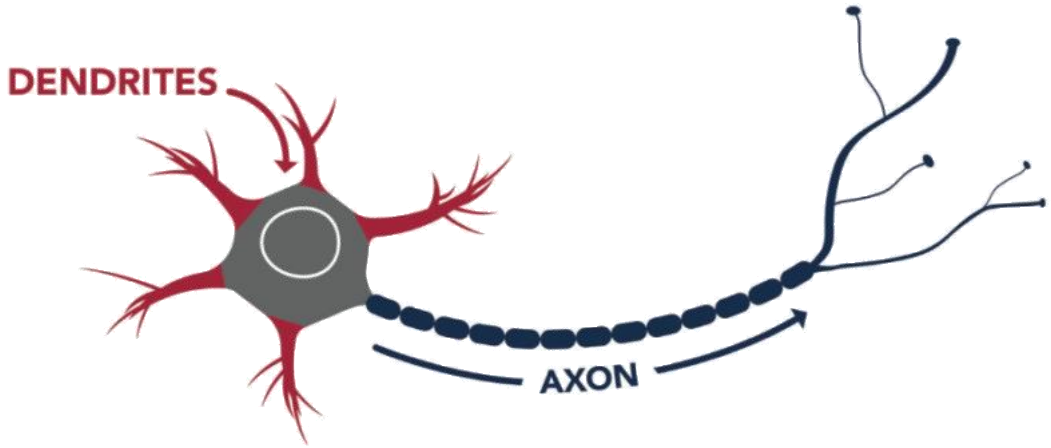
Sound within an enclosed space from sources such as HVAC equipment, appliances and other people has been shown to hinder productivity, focus, memory retention and mental arithmetic.[1-7]



A SINGLE HUMAN NERVE CELL

STIMULI SUCH AS LIGHT, SOUND AND PRESSURE CAN TRIGGER A NERVE IMPULSE IN A NEURON.

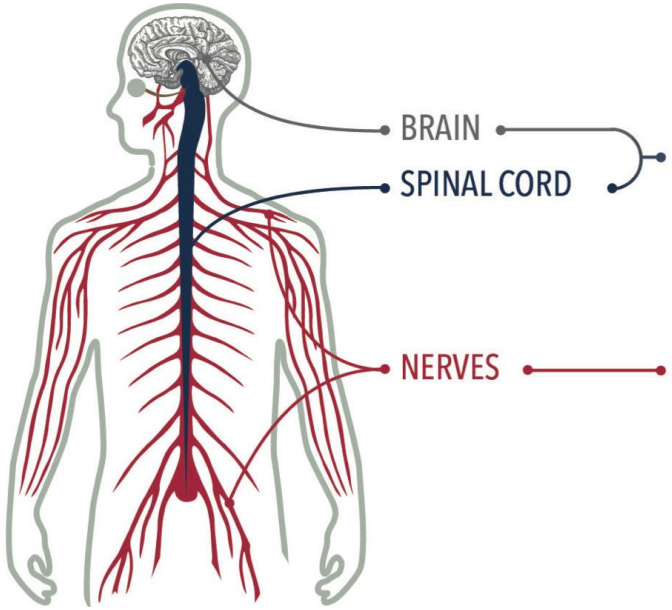
THE COMPLEXITY OF THE NEURONAL INTERCONNECTIONS CARRIES THE INFORMATION TO THE VARIOUS BODY SYSTEMS.

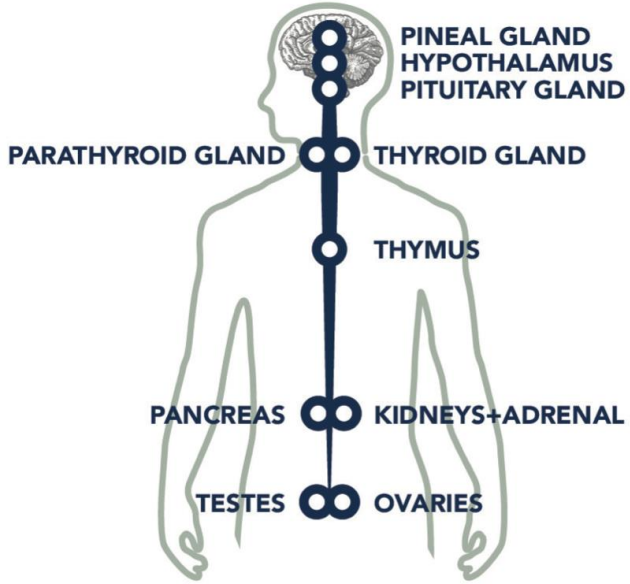


GOALS + INTENTS

REDUCE NEGATIVE STIMULI

HUMAN BRAIN: 100 BILLION NEURONS. CONNECTING WITH 10,000 OTHER NEURONS. RESULTING IN APPROXIMENTLY A QUADRILLION SYNAPSES





ENDOCRINE SYSTEM

GOALS + INTENTS

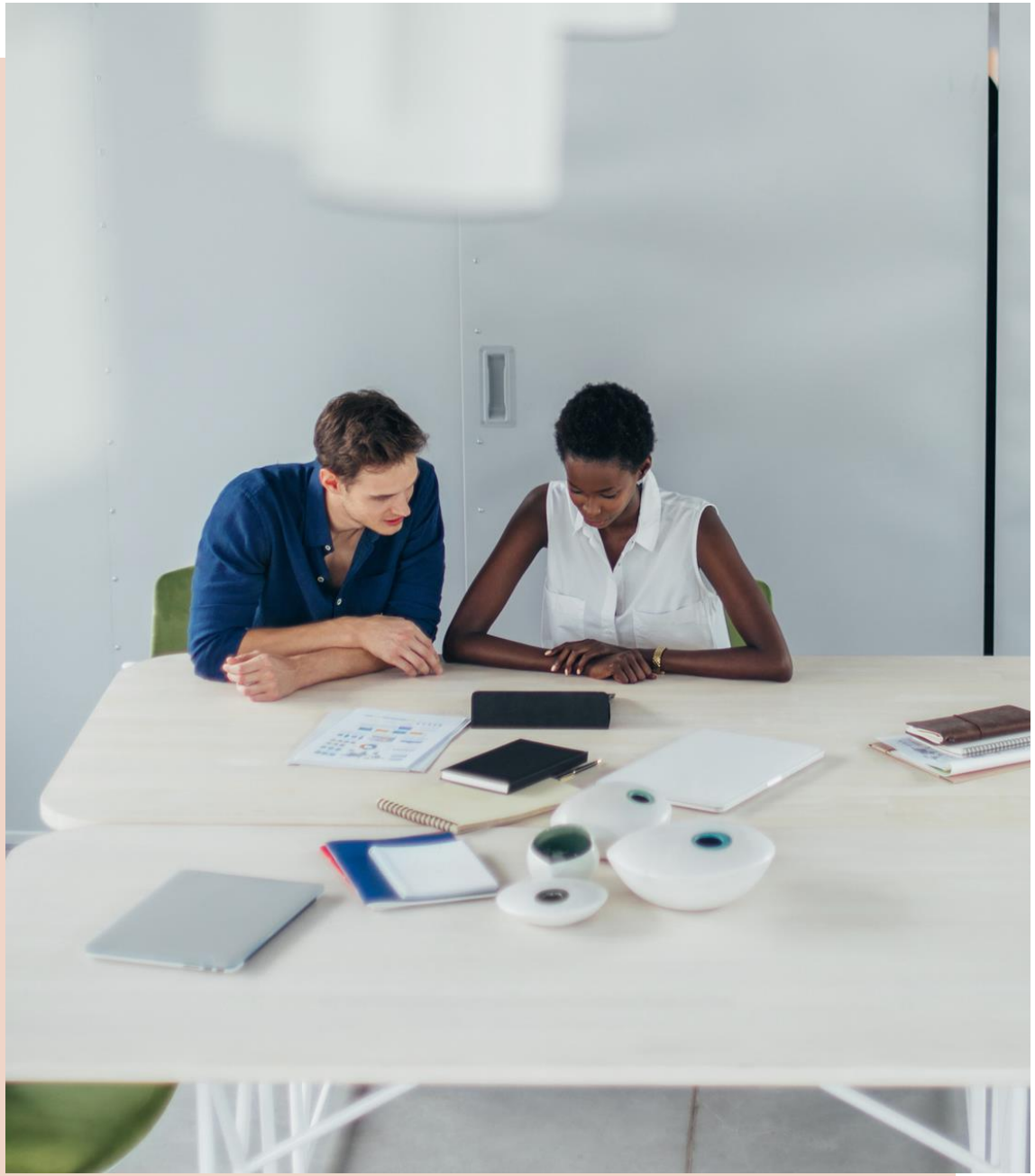
REDUCE IMPACT FROM ENVIRONMENTAL NOISE.

ACOUSTIC COMFORT

ACOUSTIC CONSIDERATIONS

66% DROP IN PERFORMANCE WHEN EXPOSED TO DISTRACTING NOISE.

Banbury SP. and Berry DC. (1998) Disruption of Office-related Tasks by Speech and Office Noise. British Journal of Psychology 89:3, pp. 499–517.



SOUND

IMPACT

Research on the effects of best-practice acoustical design within a space suggests that a holistic approach to addressing the issue of acoustical comfort in the built environment is achievable.[14,16,27]

SOUND

Improve your experience with optimal acoustical comfort parameters.

- S01 Sound Mapping*
- S02 Maximum Noise Levels
- S03 Sound Barriers
- S04 Reverberation Time
- S05 Sound Reducing Services
- S06 Minimum Background Sound
- S07 β Impact Noise Management
- S09 β Enhanced Audio Devices

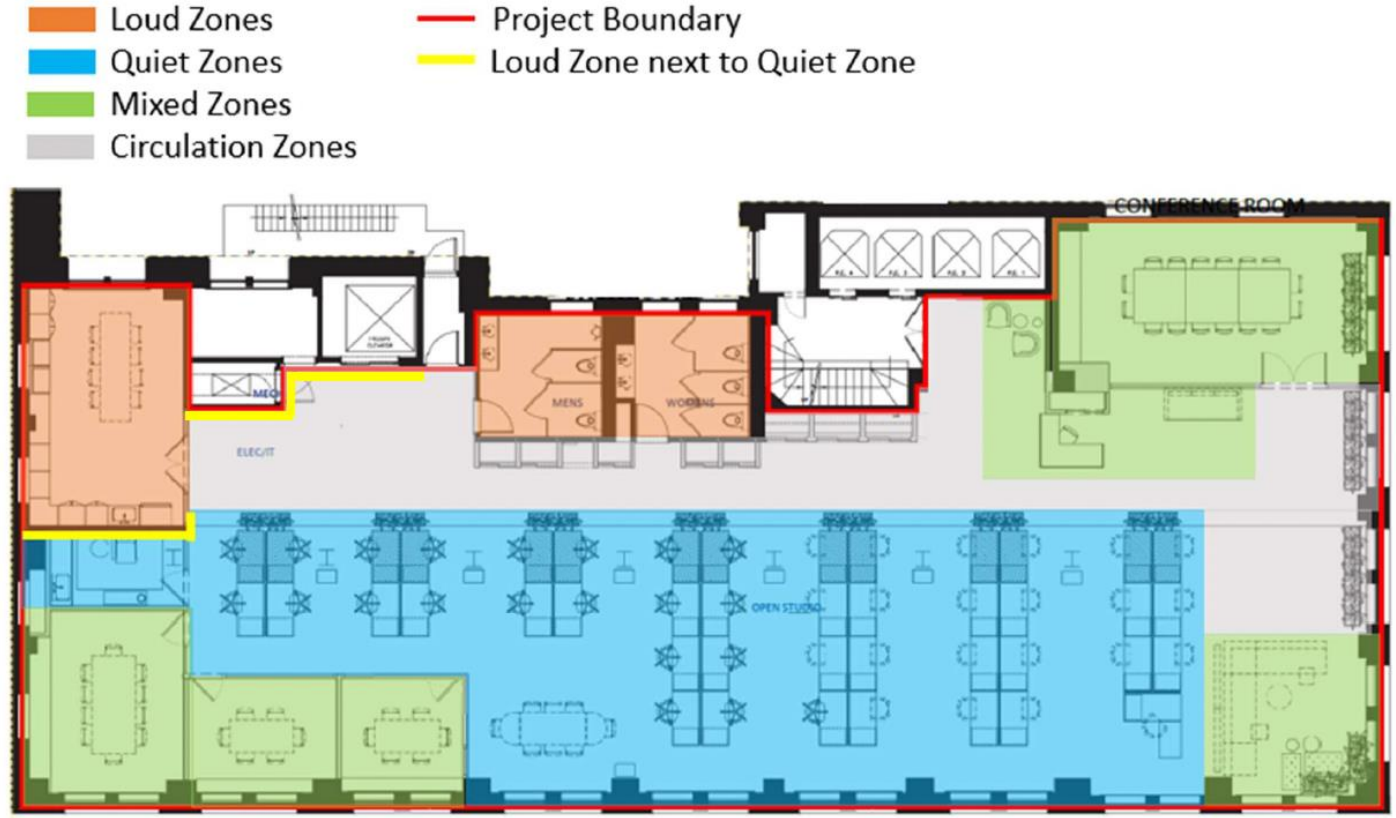
S01 SOUND MAPPING

PRECONDITION

Incorporate strategic planning required to prevent issues of acoustic disturbance from various sources of noise.

1. Label Acoustic Zones
    1. Spaces designated as loud, quiet and mixed spaces
2. Provide Acoustic Design Plan
    1. Spaces designated as loud, quiet and mixed spaces

S01.1 Label Acoustic Zones



Part 1.b Plan for Mitigating Sound Transmission between Loud Zones and Quiet Zones:

There are Loud Zones (e.g., kitchen with social space for eating, mechanical and IDF rooms) adjacent to Quiet Zones (wellness room and quiet open office space). It was not possible to reprogram the space in this existing interiors project, so the following strategies have been implemented ***(intent-stage: will be implemented)*** to mitigate sound transmission:

- ✓ The wall highlighted in yellow in the annotated architectural drawing above has a sound transmission class (STC) of 60 (as recommended in WELL S03 Part 1: Design for Sound Isolation at Walls and Doors.)
- ✓ The doors to the kitchen have the following attributes to mitigate sound transmission:
  - Self-closing
  - Non-hollow core
  - STC of 30
  - Seals at the head, jamb and base

S02 MAXIMUM NOISE LEVELS

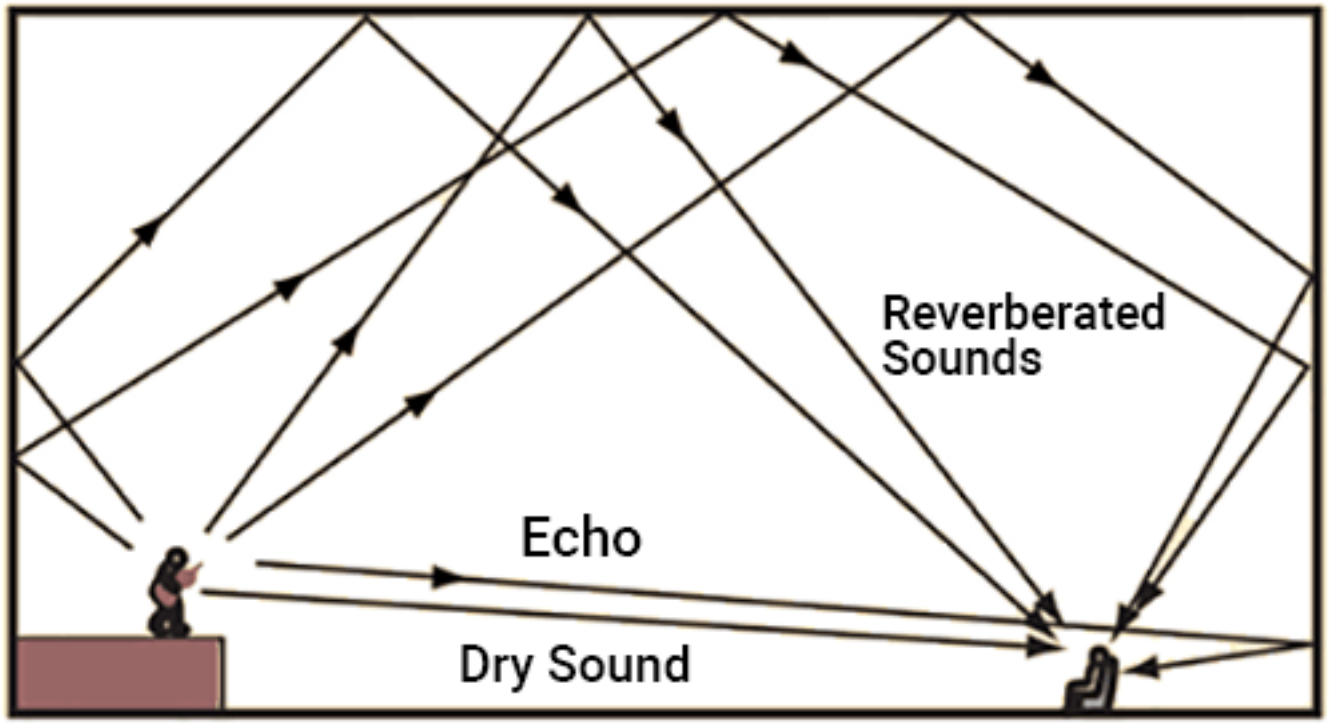
S04 REVERBERATION TIME

S02 MAXIMUM NOISE LEVELS

Tier	Sound Pressure Level (SPL)		Category 4	Category 3	Category 2	Category 1	Points:
1	Average SPL (Leq)	dBA	55	50	45	40	1
		dBC	75	70	65	60	
	Max SPL (LMax)	dBA	65	60	55	50	
		dBC	85	80	75	70	
2	Average SPL (Leq)	dBA	50	45	40	35	3
		dBC	70	65	60	55	
	Max SPL (LMax)	dBA	60	55	50	45	
		dBC	80	75	70	65	

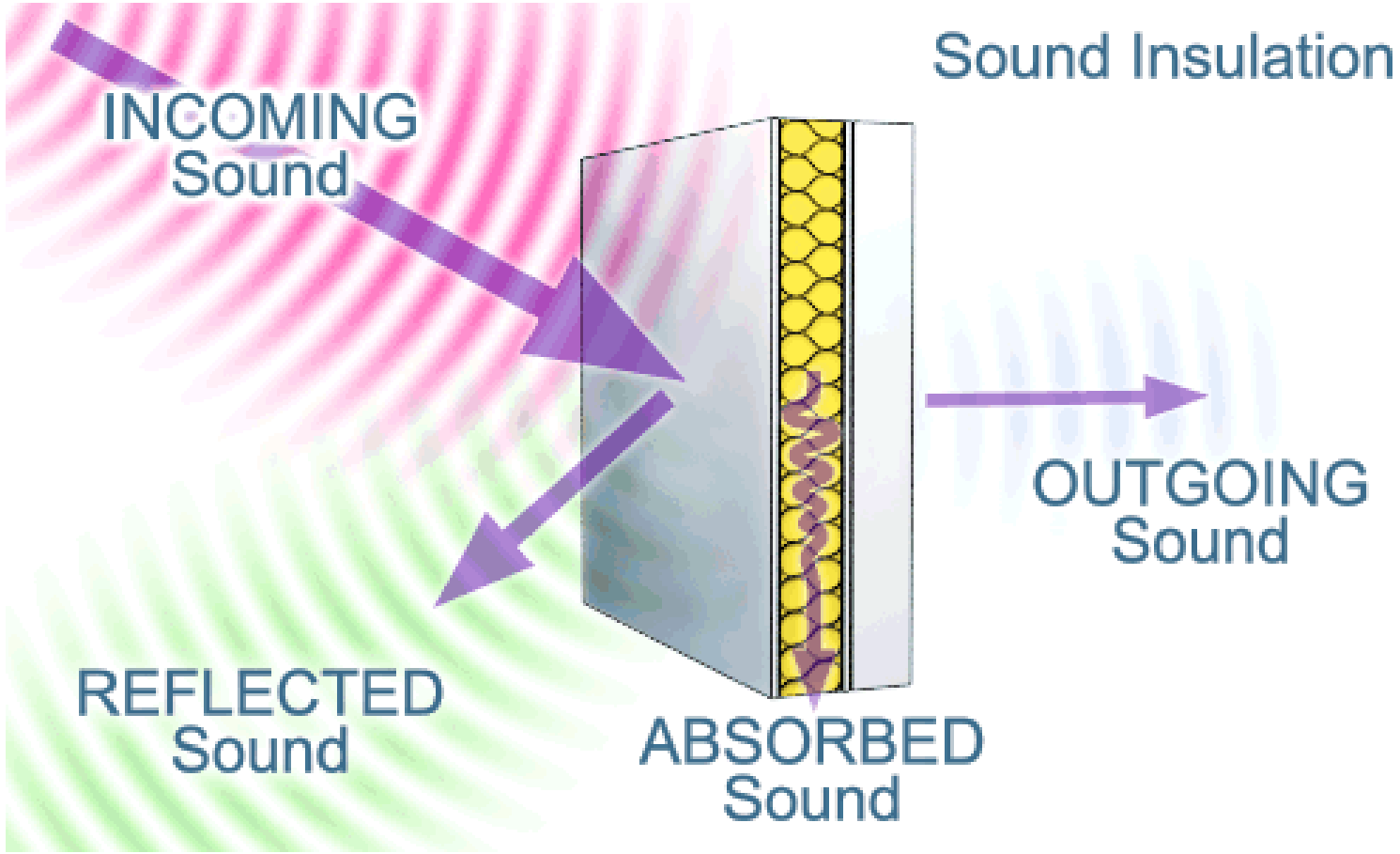
- **Category 1 Room Types:**
  - Areas for conferencing
  - Areas for learning
  - Areas for speaking
- **Category 2 Room Types:**
  - Enclosed areas for concentration
- **Category 3 Room Types:**
  - Open areas for concentration
  - Areas with regularly used PA systems
  - Areas for dining (excluding office kitchenettes)
- **Category 4 Room Types:**
  - Areas with machinery and appliances used by occupants (e.g., baggage handling areas, security, commercial kitchens, labs where spoken lectures do not take place)

S04 REVERBERATION TIME



Reverberation time is the length of time taken for a sound to decay by 60 dB from an initial impulse level.

DESIGN + SOUND



Reflective

vs

Absorptive

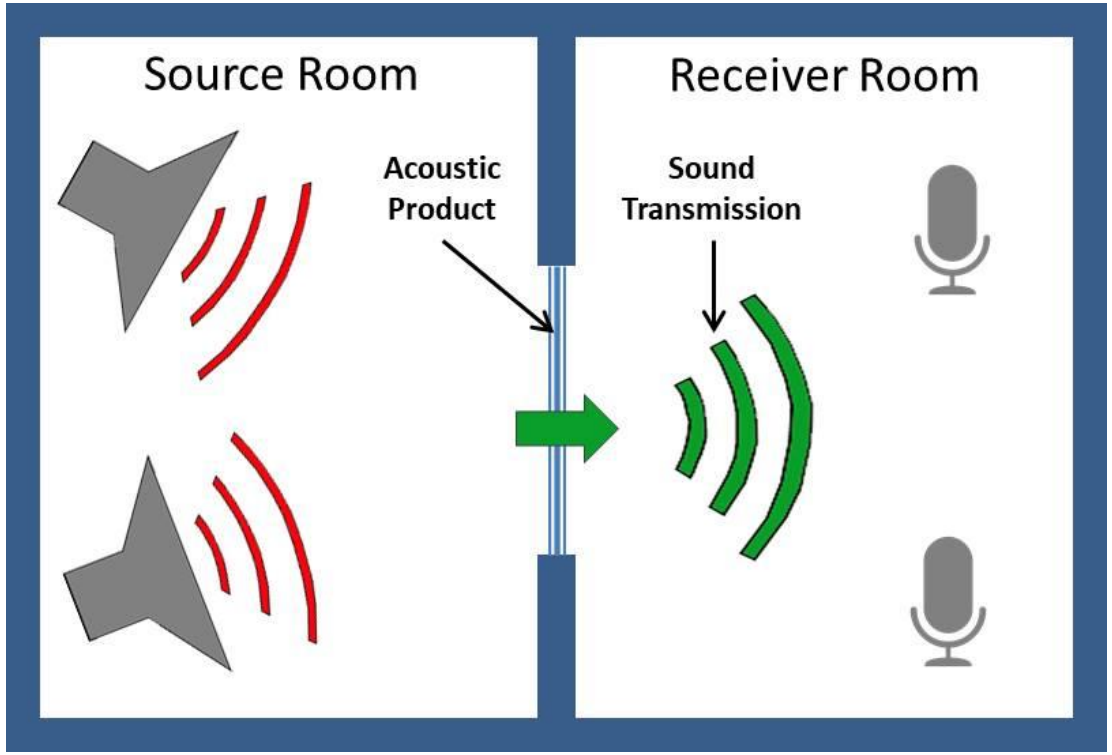
materials

S03 SOUND BARRIERS

S05 SOUND REDUCING SURFACES

S07 β IMPACT NOISE MANAGEMENT

DESIGN + SOUND



BUILDING SURFACE	STC RATING	SOUNDS LIKE
Single-Pane Window	25	Normal speech is clear
Double-Pane Window	33-35	Loud speech is clear
Indow Insert & Single-Pane Window*	39	Loud speech sounds like a hum
Indow Insert & Double-Pane Window**	42-45	Loud speech/music mostly blocked except for bass
8" slab	45	Loud speech cannot be heard
10" Masonry Wall	50	Loud music barely heard
	65+	"Soundproof"

* Acoustic Grade insert with 3" gap ** Acoustic Grade insert

WELL IN PRACTICE

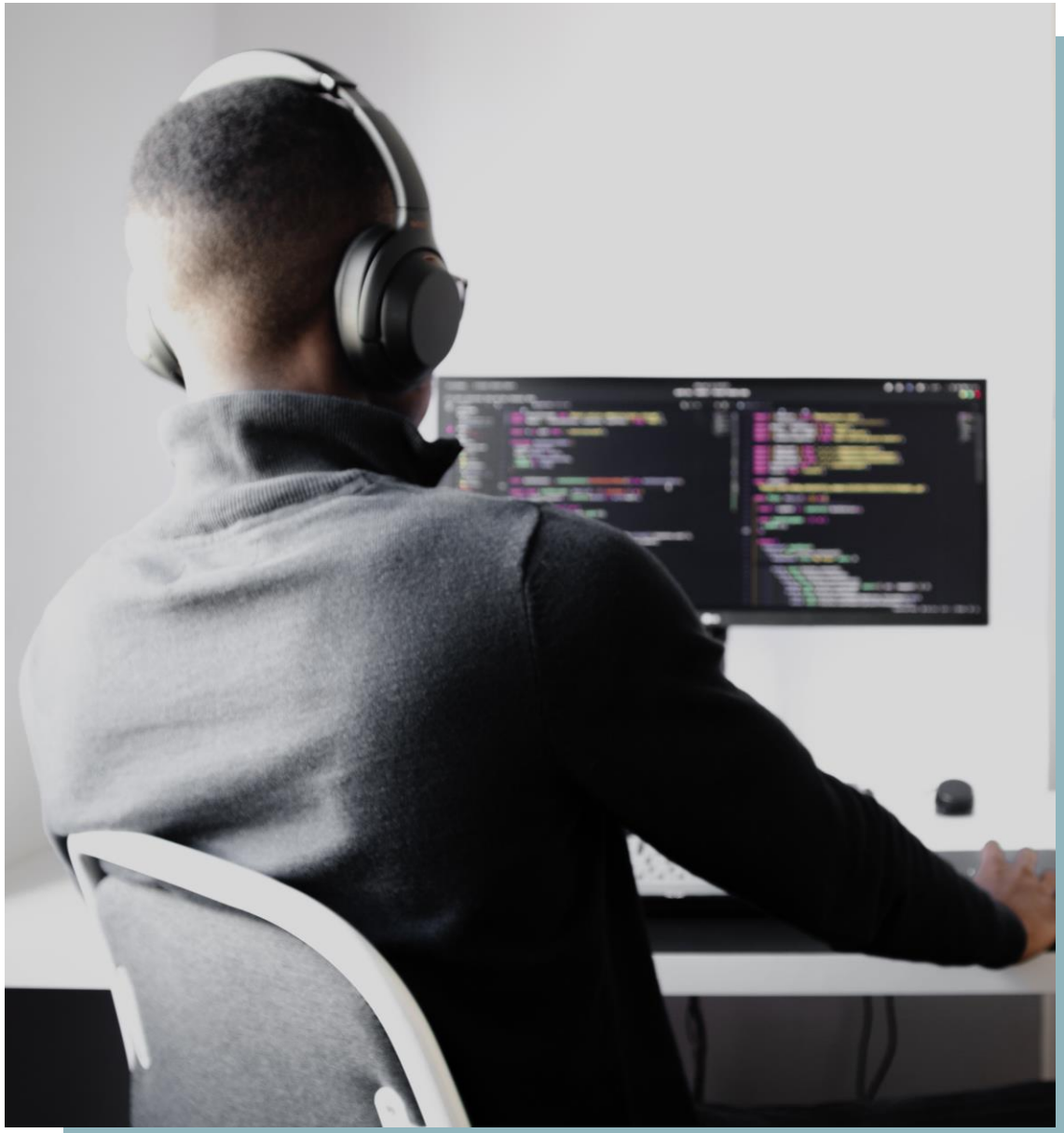
SOUND BARRIERS

WORKSAFE VICTORIA – GEELONG, AUSTRALIA

S06 MINIMUM BACKGROUND SOUND

Increase acoustical privacy within and between occupied spaces.

1. Provide Minimum Background Sound
2. Provide Enhanced Speech Reduction



WE ARE **WELL**

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INTERNATIONAL WELL BUILDING INSTITUTE

Project Name:
Paya Lebar Quarter

Owner Name:
Lendlease

Location:
Singapore

Size:
981,708 sqf

Typology:
WELL Core (Office)

- *WELL project owners usually proceed to register more and more projects, such as Lendlease in Singapore after Sydney.*
- *Paya Lebar is a large redevelopment incorporating offices, apartments, a retail mall and a public precinct adjoining a prominent metro station.*

IMAGE: Westpac Bank Perth – WELL Certified at the Silver level, 2020

REFRENCES:

1. Belojević G, Öhrström E, Rylander R. Effects of noise on mental performance with regard to subjective noise sensitivity. Int Arch Occup Environ Health. 1992;64(4):293-301. doi:10.1007/BF00378288
2. Hedge A. The open-plan office: A Systematic Investigation of Employee Reactions to Their Work Environment. Environ Behav. 1982;14(5):519-542. doi:10.1177/0013916582145002
3. Gensler. What we've learned about focus in the workplace. 2012.
4. The American Society of Heating Refrigerating and Air-Conditioning Engineers. Chapter 48 . Noise and Vibration Control. ASHRAE Handb HVAC Appl. 09;(1):1-28.
5. Jones DM, Miles C, Page J. Disruption of proofreading by irrelevant speech: Effects of attention, arousal or memory? Appl Cogn Psychol. 1990;4(2):89-108. doi:10.1002/acp.2350040203
6. Söderlund, Göran BW, Sverker Sikström, Jan M Loftesnes EJS-B. Behavioral and Brain Functions The effects of background white noise on memory performance in inattentive school children. Behav Brain Funct. 2010:1-10. doi:10.1186/1744-9081-6-55
7. Lercher P, Evans GW, Meis M. Ambient noise and cognitive
8. Fyhri A, Aasvang GM. Noise, sleep and poor health: Modeling the relationship between road traffic noise and cardiovascular problems. Sci Total Environ. 2010;408(21):4935-4942. doi:10.1016/j.scitotenv.2010.06.057
9. Jarup L, Babisch W, Houthuijs D, et al. Hypertension and exposure to noise near airports: the HYENA study. Env Heal Perspect. 2008;116(3):329-333. doi:10.1289/ehp.10775
10. Hansell AL, Blangiardo M, Fortunato L, et al. Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study. Bmj. 2013;347:f5432. doi:10.1136/bmj.f5432
11. .Klatte M, Bergström K, Lachmann T. Does noise affect learning? A short review on noise effects on cognitive performance in children. Front Psychol. 2013;4(August):1-6. doi:10.3389/fpsyg.2013.00578
12. Trimmel K, Schätzer J, Trimmel M. Acoustic noise alters selective attention processes as indicated by direct current (DC) brain potential changes. Int J Environ Res Public Health. 2014;11(10):9938-9953. doi:10.3390/ijerph111009938
13. Kaltenbach M, Maschke C, Klinke R. Health Consequences of Aircraft Noise. Dtsch Aerzteblatt Online. 2008;105(31-32):548-556. doi:10.3238/arztebl.2008.0548
14. Solet J, Buxton O, Ellenbogen J, Wang W, Carballiera A. Validating Acoustic Guidelines for Healthcare Facilities: Evidence-based design meets Evidence-based medicine: The Sound Sleep Study. Presented at the: 2010.
15. .Goines L, Hagler L. Noise Pollution: A Modern Plague: Adverse Health Effects of Noise. South Med J. 2007;100(3):287-294. http://www.medscape.com/viewarticle/554566_3.
16. The Physics Classroom. Sound Waves and Music. In. The Physics Classroom: Physics Tutorialsn.d.:http://www.physicsclassroom.com/class/sound.
17. Kaarlela-Tuomaala A, Helenius R, Keskinen E, Hongisto V. Effects of acoustic environment on work in private office rooms and open-plan offices - Longitudinal study during relocation. Ergonomics. 2009;52(11):1423-1444. doi:10.1080/00140130903154579
18. Kim J, de Dear R. Workspace satisfaction: The privacy-communication trade-off inopen-plan offices. J Environ Psychol. 2013;36:18-26. doi:10.1016/j.jenvp.2013.06.007
19. Banbury SP, Berry DC. Office noise and employee concentration: Identifying causes of disruption and potential improvements. Ergonomics. 2005;48(1):25-37. doi:10.1080/00140130412331311390
20. Hedge A. The open-plan office: A Systematic Investigation of Employee Reactions to Their Work Environment. Environ Behav. 1982;14(5):519-542. doi:10.1177/0013916582145002
21. Brammer A, Laroche C. Noise and communication: A three-year update. Noise Heal. 2012;14(61):281. doi:10.4103/1463-1741.104894
22. Jahncke H, Hygge S, Halin N, Green AM, Dimberg K. Open-plan office noise: Cognitive performance and restoration. J Environ Psychol. 2011;31(4):373-382. doi:10.1016/j.jenvp.2011.07.002
23. Evans GW, Johnson D. Stress and open-office noise. J Appl Psychol. 2000;85(5):779-783. doi:10.1037/0021-9010.85.5.779
24. Pierrette M, Parizet E, Chevret P, Chatillon J. Noise effect on comfort in open-space offices: development of an assessment questionnaire. Ergonomics. 2015;58(1):96-106. doi:10.1080/00140139.2014.961972
25. Navai M, Veitch J a. Acoustic Satisfaction in Open-Plan Offices: Review and Recommendations. 2003:23. doi:http://doi.org/10.4224/20386513
26. Banbury S, Berry DC. Habituation and dishabituation to speech and office noise. J Exp Psychol Appl. 1997;3(3):181-195. doi:10.1037/1076-898X.3.3.181
27. Hongisto V, Oliva D, Keränen J. Subjective and objective rating of airborne sound insulation - living sounds. Acta Acust united with Acust. 2014;100(5):848-863. doi:10.3813/AAA.918765
28. Park HK, Bradley JS, Grover BN. Rating Airborne Sound Insulation in Terms of the Annoyance and Loudness of Transmitted Speech and Music Sounds.; 2008.
29. 3Xie H, Kang J, Mills GH. Clinical review: The impact of noise on patients' sleep and the effectiveness of noise reduction strategies in intensive care units. Crit Care. 2009;13(2):208. doi:10.1186/cc7154
30. Strauch C, Brandt S, Edwards-Beckett J. Implementation of a quiet hour: effect on noise levels and infant sleep states. Neonatal Netw. 1993;12(2):31-35.
31. Parthasarathy S, Tobin MJ. Sleep in the intensive care unit. Instensive Care Med. 2004;30:197-206.
32. Jensen HAR, Rasmussen B, Ekholm O. Neighbour noise annoyance is associated with various mental and physical health symptoms: results from a nationwide study among individuals living in multi-storey housing. BMC Public Health. 2019;19(1):1508. doi:10.1186/s12889-019-7893-8
33. Klatte M, Bergström K, Lachmann T. Does noise affect learning? A short review on noise effects on cognitive performance in children. Front Psychol. 2013;4(August):1-6. doi:10.3389/fpsyg.2013.00578
34. Klatte M, Hellbrück J, Seidel J, Leistner P. Effects of Classroom Acoustics on Performance and Well-Being in Elementary School Children: A Field Study. Environ Behav. 2010;42(5):659-692. doi:10.1177/0013916509336813

REFRENCES

35. Belojević G, Öhrström E, Rylander R. Effects of noise on mental performance with regard to subjective noise sensitivity. Int Arch Occup Environ Health. 1992;64(4):293-301. doi:10.1007/BF00378288
36. Architectural Joint Technical Committee AV-004 Acoustical. AS/NZS 2107:2016. 2016:24.
37. General Services Administration. Sound Matters: How to Achieve Acoustic Comfort in the Contemporary Office. 2011. https://www.wbdg.org/FFC/GSA/gsa_soundmatters.pdf.
38. General Services Administration, Service PB. PBS-P100 Facilities Standards for the Public Buildings Service. 2016;(March):333. doi:10.1017/CBO9781107415324.004
39. General Services Administration. Sound Matters: How to Achieve Acoustic Comfort in the Contemporary Office. 2011. https://www.wbdg.org/FFC/GSA/gsa_soundmatters.pdf.
40. Bradley. Speech Intelligibility Studies in Classrooms. J Acoust Soc Am. 1986.
41. Bradley JS. The acoustical design of conventional open plan offices. Can Acoust. 2003;27(3):23-31. doi:NRCC-46274 A
42. Venetjoki N, Kaarlela-Tuomaala A, Keskinen E, Hongisto V. The effect of speech and speech intelligibility on task performance. Ergonomics. 2006;49(11):1068-1091. doi:10.1080/00140130600679142
43. Jensen KL, Arens E, Zagreus L. Acoustical Quality in Office Workstations , As Assessed By Occupant Surveys. Indoor Air 10th Int Conf indoor air Qual Clim. 2005:2401-2405. doi:10.1111/j.1600-0668.2011.00745.x
44. Kim J, de Dear R. Workspace satisfaction: The privacy-communication trade-off inopen-plan offices. J Environ Psychol. 2013;36:18-26. doi:10.1016/j.jenvp.2013.06.007
45. Hongisto V. Effects of sound masking on workers - a case study in a landscaped office. 9th Int Congr Noise as a Public Heal Probl. 2008;(1979):1-8.
46. Larm P, Keränen J, Helenius R, Hakala J, Hongisto V. Acoustics in open-plan offices -- A laboratory study. Forum Acusticum. 2005;(Figure 1):2021-2025.
47. LoVerde J, Miller E, Nash AP, et al. ICC G2-2010 Guideline for Acoustics. 2010:29.
48. Joen J, Lee P, Kim P, Yoo S. Subjective evaluation of heavy-weight floor impact sounds in relation to spatial characteristics. J Acoust Soc Am. 2009;125(5):2987-2994.
49. Ljunggren, Fredrik; Simmons, Christian; Hagberg K. Correlation between sound insulation and occupants' perception – Proposal of alternative single number rating of impact sound. Appl Acoust. 2014;85:57-68.
50. Crandell CC. Effects of Sound Field FM Amplification on the Speech Perception of ESL Children.pdf.
51. Edwards C, Harold G. DeafSpace and the principles of universal design. Disabil Rehabil. 2014;36(16):1350-1359.
52. Hintermair M. Health-Related Quality of Life and Classroom Participation of Deaf and Hard-of-Hearing Students in General Schools. 2010. doi:10.1093/deafed/enq045
53. Klatte M, Hellbrück J, Seidel J, Leistner P. Effects of Classroom Acoustics on Performance and Well-Being in Elementary School Children: A Field Study. Environ Behav. 2010;42(5):659-692. doi:10.1177/0013916509336813
54. Bennetts L, Flynn M. Improving the classroom listening skills of children with Down syndrome by using sound-field amplification. Downs Syndr Res Pract. 2002;8(1):19-24.
55. Jennings MB. Universal Design for Hearing: Considerations for Examining Hearing Demands and Developing Hearing Friendly Workplaces. AudiologyOnline. 2009.
56. Cheesman MF, Jennings MB, Klinger L. Assessing communication accessibility in the university classroom: Towards a goal of universal hearing accessibility. Work. 2013;46(2):139-150.
57. Heylighen A, Rychtarikova M, Vermeir G. Designing Spaces for Every Listener. Univers Access Inf Soc. 2010;9(3):283-292.
58. Renel W. Sonic Accessibility: Increasing Social Equity Through the Inclusive Design of Sound in Museums and Heritage Sites. Curator Museum J. 2019;62(3

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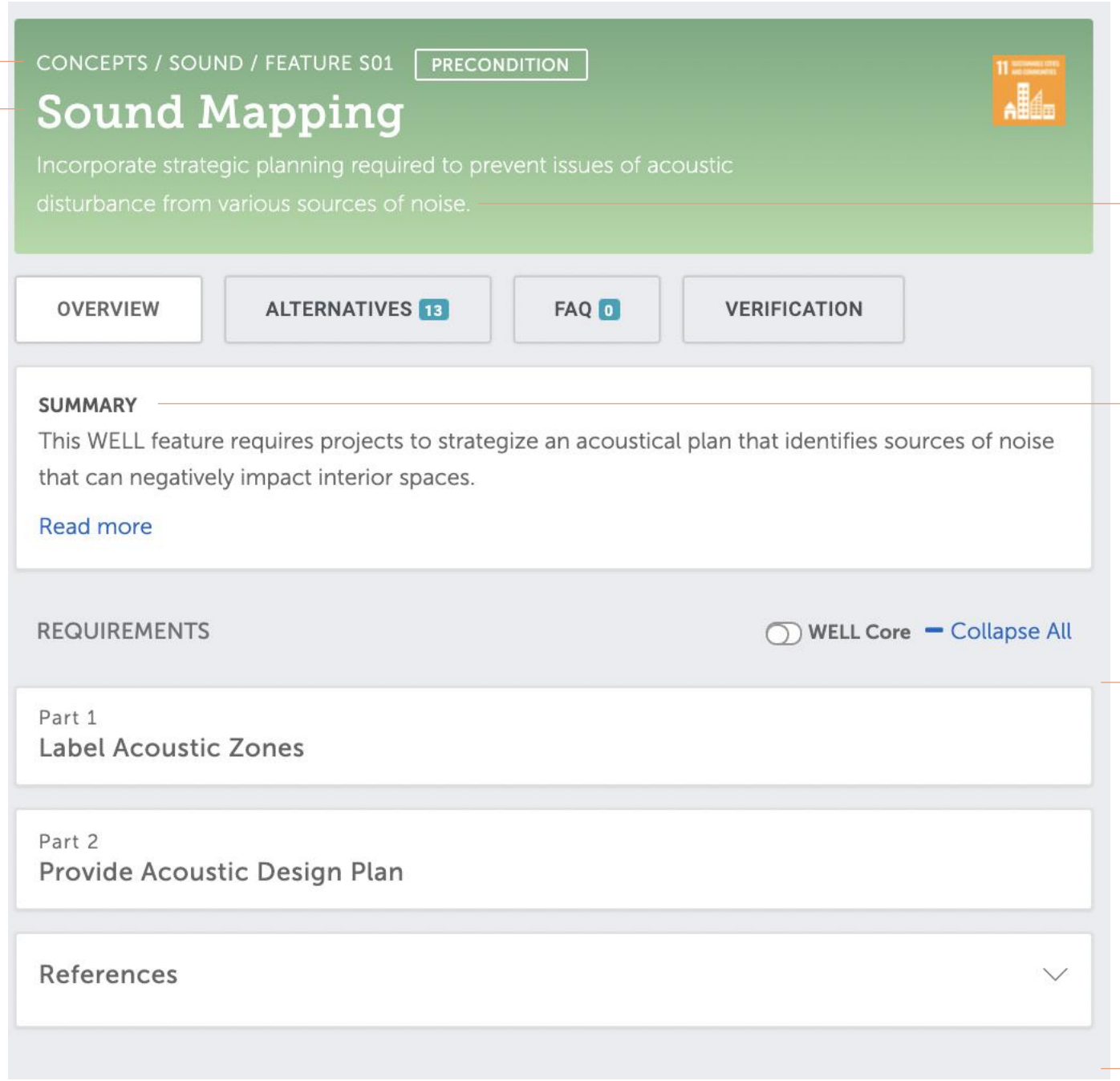
ANATOMY OF A WELL FEATURE



Feature name

Concept name / feature number / mandatory (precondition) or optional (optimization) feature

Health intent

Summary of the health issues, impacts and key strategies

Parts (requirements)

S02 MAXIMUM NOISE LEVELS

ISSUE

Employees are unable to habituate to noise in office environments over time and office noise, with or without speech, can create stress and disrupt performance on more complex cognitive tasks (e.g., memory of prose, mental arithmetic).[23-27]

SOLUTIONS

- Select HVAC equipment with lower sound ratings and design the system to reduce sound within duct
- Provide sound reduction at the building façade, windows and any exterior penetrations

S03 SOUND BARRIERS

ISSUE

Sound that transmits from one room to another through walls or doors can be distracting or annoying and also disturb sleep.[27-31] There is evidence that links noise annoyance in multi-story housing to poor mental health and perceived stress in residents.[32]

SOLUTIONS

- Use of walls with high sound transmission class ratings
- Doors can be fitted with gaskets and seals to reduce sound transmission
- Rooms that require high speech privacy can use sound masking systems

S04 REVERBERATION TIME

Design spaces in accordance with comfortable reverberation times that support speech intelligibility, vocal effort and are conducive to concentration

1. Achieve Reverberation Time Thresholds

S04 REVERBRATION TIME

ISSUE

Spaces with high reverberation may have increased ambient noise levels and reduce speech intelligibility (e.g., public address, speech reinforcement and unamplified speech). Studies have shown that high reverberation times in classrooms increase auditory workload in students and reduce cognition, memory retention and concentration.[33-36]

SOLUTIONS

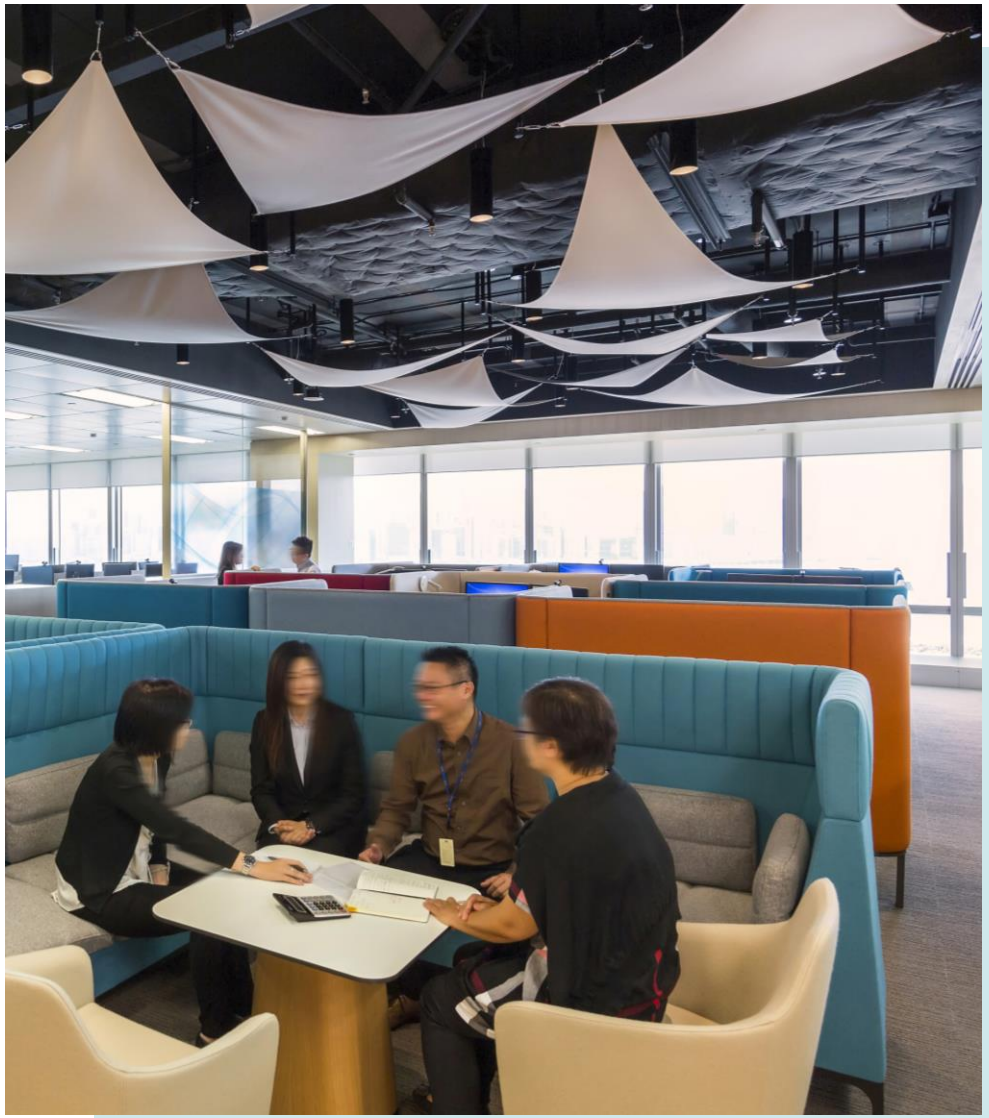
- Avoiding the use of glass or other hard surfaces in areas where speech is critical (i.e. conference rooms, distance learning)
- Adding absorptive surface finishes at ceilings, walls and furniture.[37-39]
- In design, control of room volume and geometry can help target lower reverberation times

S05 SOUND

REDUCING SURFACES

Design spaces with sound reducing surfaces to minimize the buildup of speech or other unwanted sound.

1. Implement Sound Reducing Surfaces



S05 SOUND REDUCING SURFACES

ISSUE

When spaces lack acoustical absorption at ceilings or partial height barriers, individuals can become distracted by reflected sound.[3–6] Reverberation can also impair a listener's comprehension of speech, especially when listeners are hard of hearing, expending a greater auditory workload to process speech, resulting in reduced task performance.[7–12]

SOLUTIONS

- Providing acoustical treatment that significantly reduces sound across human speech frequencies[40]

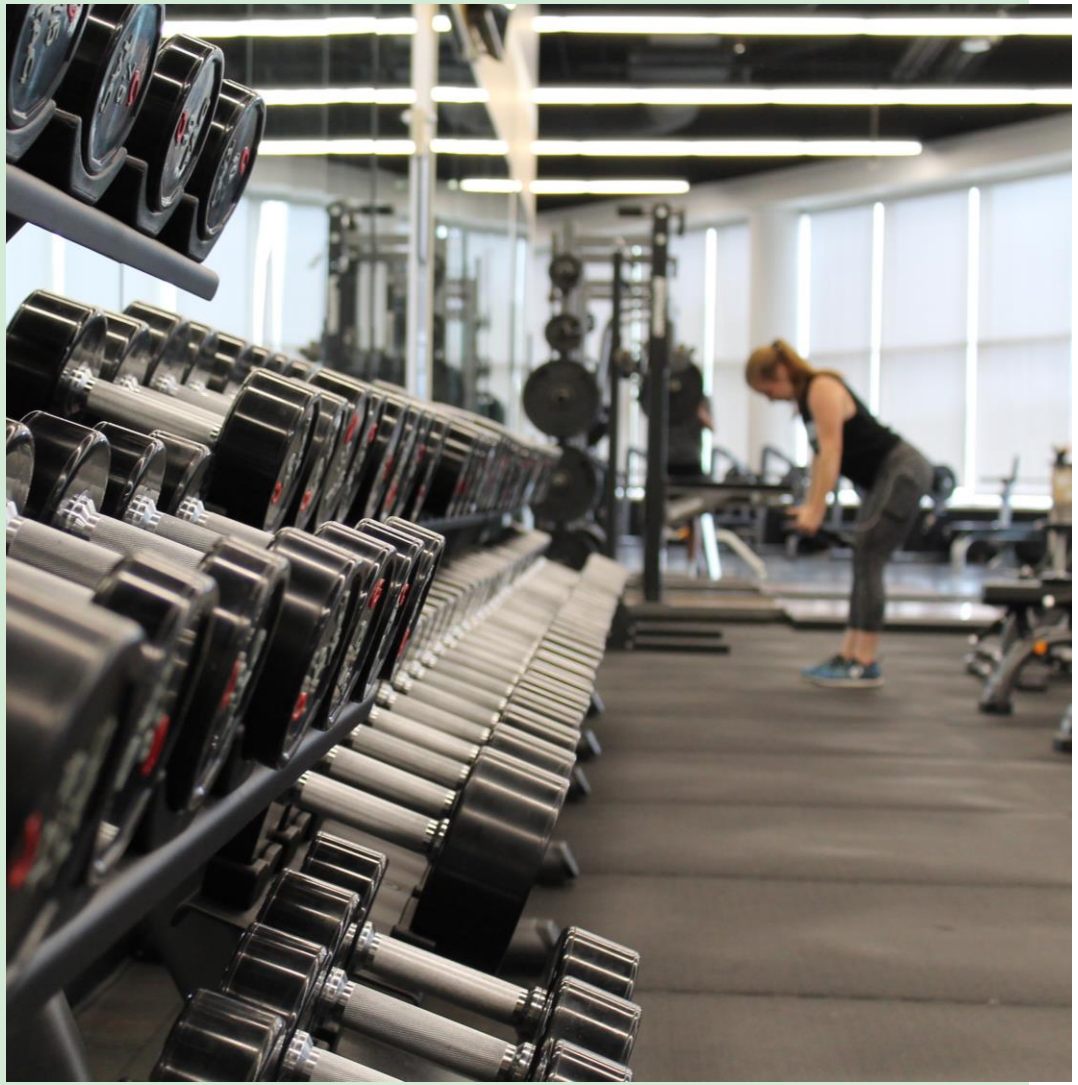
S06 MINIMUM BACKGROUND SOUND

ISSUE

Many issues come from a lack of speech privacy. Ambient background sound, which can include artificial sound sources, can increase speech privacy to comfortable levels.[46,47]

SOLUTIONS

- Use an adjustable array of loudspeakers located such that sound is uniformly distributed
- Use systems programmed to output a sound source similar to the sound of air flowing through HVAC
- Implement sound reducing sources



S07 β IMPACT NOISE MANAGEMENT

Reduce the level of impact noise radiation by designing resilient floors.

1. Specify Impact Noise Reducing Flooring
2. Meet Thresholds for Impact Noise Rating

S07 β IMPACT NOISE MANAGEMENT

ISSUE

Sound can transmit between rooms within a building as structure-borne impact noise. This impact noise travels through structures (e.g., walls, floors, columns, piping) as vibrations that are then radiated as airborne noise to a listener, which can result in workplace distractions, sleep disturbance or disrupted focus.[48,49,50]

SOLUTIONS

- Construct buildings with resilient, composite floor-ceiling construction (e.g., thick concrete slab, suspended ceiling, floor with an underlayment)

TERMINOLOGY

ACOUSTIC COMFORT

The subjective human perception of the sonic environment in any given space, including enclosures and open environments.

ACOUSTIC PRESSURE

The difference between the pressure produced by emanating sounds and the average ambient or atmospheric pressure, measured in decibels (dB).[16]

REVERBERATION TIME (RT60)

The length of time (in seconds) required for the average sound pressure level in a space to decay 60 decibels (dB) from its initial level once its source has stopped producing sound.[16]

LOUDNESS

The amplitude or change in atmospheric pressure created as energy travels from one particle to another in a sound wave.[16]

METRICS

SOUND PRESSURE

Measured in units of Pascals (Pa).The smallest sound pressure that the human ear can detect is 20 micropascals or 2.0×10^{-5} Pa.

SOUND PRESSURE LEVEL (SPL)

Converts sound pressure (Pa) into a logarithmic scale that expresses the ratio between the sound pressure of a given sound and a reference sound pressure (typically the threshold of human hearing), measured in decibels (dB).

SOUND TRANSMISSION COEFFICIENT

A single-number rating given to a material or structure based on laboratory testing that represents the sound insulating properties of a partition/barrier, or the effectiveness of the partition in reducing sound transmission. Higher STC ratings correspond to better sound insulation.

S08 β ENHANCED AUDIO DEVICES

ISSUE

The ability for people to comprehend speech is a fundamental consideration of universal design. Reduced or low speech intelligibility can negatively impact occupant satisfaction and well-being, especially for non-native speakers, individuals with hearing loss or neurodiverse populations.[51-58]

SOLUTIONS

- Implement audio systems such as teleconferencing equipment in offices, speech reinforcement systems in classrooms and public address systems