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User Comfort in Unexpected Acoustic Environments

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ABSTRACT

This paper investigates the efficacy of sound masking in non-traditional settings to enhance occupant wellbeing. Through three diverse case studies—a warehouse impacted by industrial noise in Perth, a government building impacted by road traffic noise in Adelaide, and a home impacted by road construction noise in Melbourne—we evaluate the impact of sound masking interventions. Using pre- and post-installation measurements, the study demonstrates significant improvements in perceived comfort from end users. Findings suggest that prioritising user experience leads to superior environmental satisfaction in complex, real-world acoustic landscapes.

1. INTRODUCTION

Sound masking is traditionally used in open plan offices, medical facilities, and professional suites to reduce the impact of intrusive noise and improve speech privacy. While there have been many successful installations of sound masking in non-traditional settings, these are less well researched. Furthermore, the sound level recommended for these settings can be non-existent, unclear, or unsuitable for real world user comfort. Balancing the practical need for an objective standard with the subjective experience of the user is difficult. However, a slavish adherence to existing recommended shapes and levels can unnecessarily limit the use and effectiveness of this technology. Indeed, some specifications may inadvertently exclude off-the-shelf sound masking products, even if they would improve user comfort. This is particularly true in the case of low frequency environmental noise, which has a significant negative impact upon human health. This paper explores some of the opportunities for sound masking to be implemented, in particular using three case studies where sound masking would not typically be recommended. Our hope is that this paper will prompt more user experience-focused academic research in the field.

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2. THE HUMAN IMPACT OF NOISE

The importance of technological solutions to environmental noise cannot be overstated. The acute negative physiological, psychological, and cognitive impacts of environmental noise have been studied at length. There is a consensus among academic researchers that when noise moves beyond annoyance, the impacts on human health are significant. Indeed, noise is a stressor that impacts the entire body, not just hearing. Often when workplace noise is considered, hearing loss is the major risk criteria. For example, according to Safe Work Australia:

> Noise can damage your hearing if it's too loud. Both sudden, loud noises, like an explosion, and constant, loud noise, like working near industrial machinery, can damage your hearing. Hearing damage includes permanent or temporary hearing loss and tinnitus (ringing in the ears). [7]

This is all true. However, it fails to account for the activation of the stress response, which contributes to cardiovascular disease. This has been studied in detail in relation to rail, airplane, and road traffic noise—which roughly half of people in urban environments around the world must contend with and is one of the biggest challenges facing urban planners. In fact, a recent review [1] of road traffic noise and its impact on health found that there is a growing body of high-quality evidence revealing that prolonged exposure to road traffic noise causes cardiovascular disease, cerebrovascular dysfunction, age-related degenerative diseases, as well as mental health disorders. Furthermore, road traffic noise exposure leads to the continuous release of the stress hormones like cortisol and catecholamines, which in turn negatively impact the human microbiome and metabolism leading to type-2 diabetes and neurodegenerative disorders. This can be due to the presence of the noise itself, or due to disrupted sleep. Given that around 48% [6] of urban populations in major Australian cities are exposed to road traffic noise that exceed the World Health Organization's (WHO) recommendations, this is a very real problem. Traditional methods of mitigation, like blocking and insulation, are often used to improve the impact of environmental noise. But sometimes these may be too costly to implement or might be unsuitable. Further, these traditional methods may fail to address the stress response triggered by intermittent or low-frequency environmental noise.

3. APPLICABLE STANDARDS AND GUIDELINES

One challenge when measuring the impact of noise is the wide range of available standards and guidelines. In Australia, the AS/NZS 2107:2016 [9] is typically used to measure sound masking within buildings. However, reference might also be made to AS/NZS 2702:1984 [10] which provides guidelines for road traffic noise. Outside of Australia, much of the research into environmental noise uses other parameters—for example, the widely-used WHO guidelines [12] use the European Union Directive [5]. The subjective experience of how people experience noise is not necessarily captured by any of these standards, especially when guidelines are assuming an average of ambient background sounds that encompasses a wide variation. To take one example, the recent attempt to designate and zone urban noise by the Victorian Environmental Protection Authority [4] demonstrates the complexity of the task, and it is understandable that standards can fall short for the residents. For the purposes of user comfort and onsite measurement, we have used A-weighted decibels (dBA) and used AS/NZS 2107:2016 [9] as a comparison tool.

4. INDUSTRIAL NOISE

High impact, intermittent sounds are one of the most challenging acoustic scenarios to ameliorate. These kinds of sounds also cause a startle response on people subjected to them which over time can become particularly damaging for physical and mental health. During a recent Australian inquiry into the impact of airline noise, for example, these kinds of high impact noises were described by community members as causing palpitations, panic, stress, and even “an assault on the mental and physical health and well-being” [8]. An example of such a situation in the workplace occurred in IREAUS Construction’s head office is in outer Perth. Located within a typical industrial precinct, surrounded by trade-based businesses, the site is positioned approximately 25 metres from a main road. This results in constant traffic noise. Plus, the site is directly opposite a scrap metal facility. This facility operates a large lifting magnet, generating frequent but erratic noise events from dropping scrap metal of varying sizes. These two types of intrusive noise impacted the office occupants in different ways. The continuous background sound of road traffic noise, within an average level of around 45dBA, created an underlying stress level. However, the noise of scrap metal drops was the reason the office considered sound masking. The scrap metal drops produce sharp, high-energy impact sounds with irregular timing and varying intensity. These loud “bangs” and “crashes” create a disruptive contrast between the ambient background sound levels, with sudden peaks of around 70dBA. As a result, the occupants suffered from a noticeable disruption to concentration, an increased startle response, and reduced consistency for phone calls and office tasks. Upstairs, the acoustic tiles (Figure 1) assisted in some sound absorption. But the downstairs office had an even worse experience due to the reflective concrete ceiling, which increased perceived sharpness and reverberation. This also meant that although the offices were in the same building, and theoretically required the same sound masking levels, the user experience would be different for each space.

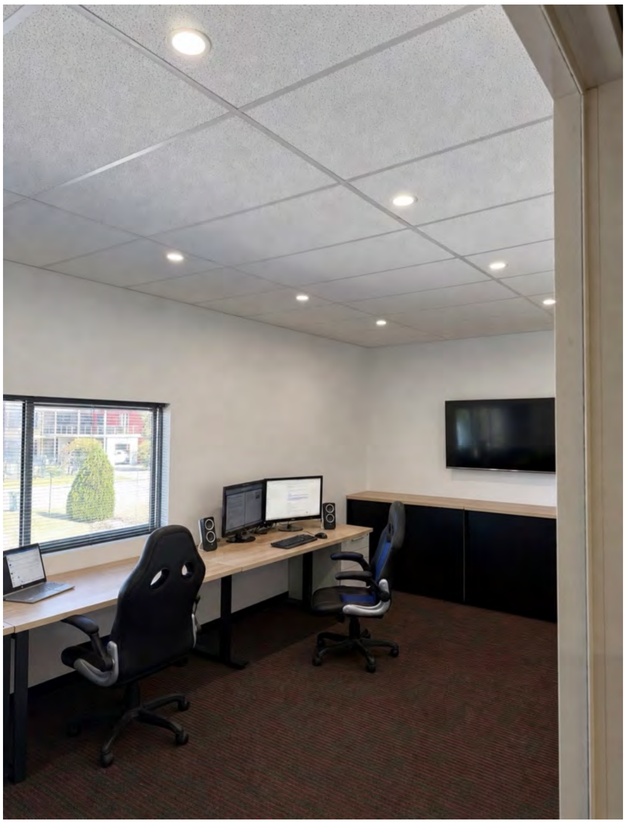

Figure 1: Acoustic tiles absorb some of the noise.

We added a zoned sound masking system, with the objectives of reducing the contrast between background noise and the scrap metal drops and improve day-to-day communication. A secondary objective was to reduce overall stress levels caused by noise. The zoning allowed fine tuning of both the sound levels and spectral balance. Upstairs, the sound distribution was easy to achieve with a lower output level of around 42dBA. Downstairs, the reflective surfaces required more careful turning, with a greater sensitivity to the frequency balance. The average sound levels were set to around 44dBA in that space, with an exposed ceiling speaker (Figure 2).

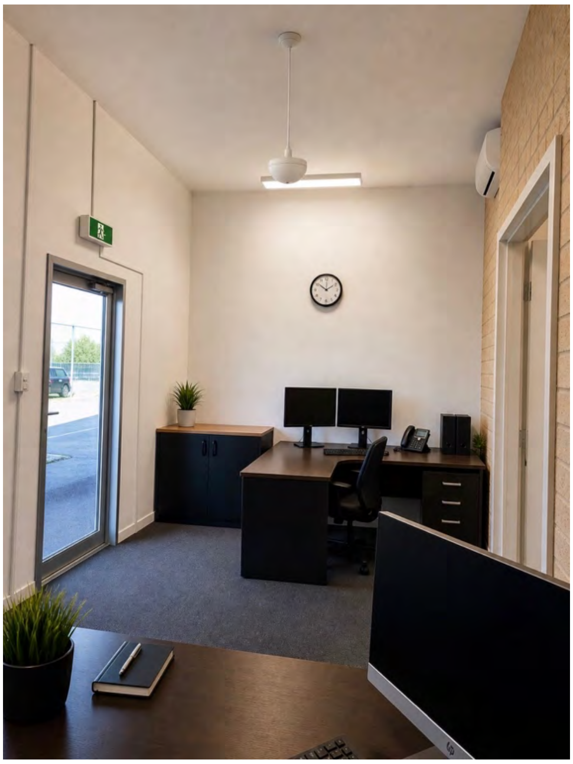

Figure 2: Reverberative concrete ceiling with exposed ceiling speaker.

We tuned the system using a practical, in-field approach combining listening and measurement. System levels and tonal balance were adjusted during normal site operation, focusing on reduction in the perceived impact of scrap metal drops, avoiding over-masking or introducing distraction, and achieving a consistent background sound across the space. Attention was given to mid-frequency content affecting speech and high-frequency control in the downstairs reflective environment. Once the system was performing as intended, we took sound pressure level (SPL) measurements to record the final operating levels and to check for consistency across both zones. This ensured the system was operating within expected ranges, while still being set based on real-world performance. As is usually the case, we observed that identical SPL readings upstairs and downstairs did not produce the same perceived outcome. Room construction and acoustic behaviour had a significant impact on how the masking was experienced. This highlighted the limitation of relying purely on standardised level setting without considering the space itself. Introducing a sound masking system into the office had a positive impact on the occupants. Following installation and tuning, the occupants reported reduced perceived impact of scrap metal drops, a lower frequency of startle response, and improved concentration and task continuity. Overall, the system has delivered a more consistent and controlled acoustic environment, supporting both concentration and general workplace comfort.

5. ROAD TRAFFIC NOISE

The stress of road traffic noise can be exacerbated when it interferes with the ability of workers to do their jobs. This frustration can elevate stress further. An example of this occurred at a government agency, Centrelink, located in Adelaide. The agency had a service office facing a main arterial road that carried very high volumes of traffic including heavy haulage trucks. The property was situated less than thirty metres from the road with no trees, bushes, or barriers to reduce traffic noise. The agency had previously installed two sets of automatic doors with an air lock to try to reduce traffic noise. The service counter was situated eight metres inside the main doors in line with the doors. This air lock ameliorated the noise to some extent—when it was closed. However, Centrelink is a customer-facing agency, and the doors are opening and closing constantly. When the doors opened, the traffic noise was so loud the staff and clients could not hear each other at the counter. We took sound measurements over a full working day. The results made the assessment challenging as the noise levels were much higher in morning and afternoon peak hour traffic as well as between 12pm and 2pm. The office was situated on a slight hill with traffic lights fifty metres from the office. The noise level also increased when the lights changed, and the traffic decelerated and accelerated particularly in the case of semi-trailers. The sound levels ranged from 55dBA to 85dBA, with peak hour traffic creating the highest levels. These values could peak over 95dBA. This is well above the WHO guidelines of 45-55dBA. While sound masking is not normally used in their type of application, due to the loud sound levels, the client was willing to try because other options like sound absorption screens and other physical options were unsuitable due to the need for disability access to the building. Sound masking transducers were installed directly above and in front of the reception counter, and in the adjacent areas using separate zones for ease of adjustment. The plan was to create a more consistent level over the whole area, so not to add to the noise problem but to increase the background noise slightly to average the sound levels and reduce hot spots. In other words, to reduce the difference between high and low traffic noise. The staff would become accustomed to the more constant levels. Initial levels were set at 47dBA (after hours) to get a clear reading. This was ultimately raised slightly during implementation. After the system was installed and over the following few weeks, we made small gradual changes to the system. This was done when staff were not present, so it did not draw attention to the adjustments. As with all sound masking, there is an acclimatization period. After several weeks the feedback was positive, and it did improve the issues.

6. BIG BUILD NOISE

At present in Melbourne, there are numerous large scale building works, including railway, road, and tunnelling works. Some have been ongoing for years. Often these involve twenty-four-hour works, including night works, which are temporary but impactful for residents. The Level Crossing Removal works were where we first discovered the effectiveness of sound masking in night works. The residence in this case was located a little under 400 metres from the works, with dense residential housing in between. The masking levels were set around 30dBA, whereas the usual nighttime ambient background sound levels without the works is 23dBA. With loud intermittent sounds and low frequency, a sound masking system with a sub-woofer speaker and specific bands would be specified. However, we wanted to work with what we had and see what happened. Over a two-week period, twenty-four-hour works included pile driving, saw cutting and other noisy works using heavy equipment. Figure 3 shows an example of the kinds of equipment used.

Figure 3: Example of pile driving equipment used in the construction works [2].

Using a sound specially shaped for road noise, we used the natural experiment to compare the two week long night works impact on the sleep patterns of residents. Those without sound masking slept badly. Those with sound masking slept as usual. These findings were anecdotal, but suggestive. The sub-woofer and low frequency bands might not be necessary. From 27-29 March 2026, North East Link works were undertaken within 175 metres of another residence. We decided to measure the performance of the sound masking system in a more controlled way. The works included intermittent “bangs” and “crashes” associated with works including concrete works, piling, installation of underground cables, saw cutting and removing asphalt, and so on. Due to the proximity to the Eastern freeway, the residence usually has traffic noise, with an ambient background sound on average of around 41-43dBA. There is minimal sleep disturbance at night due to the evenness of the ambient background sound. In contrast, during the works, levels were measured in the range of between 40-60dBA, with an average of around 42-43dBA. The peaks were due to the intermittent crashes and bangs of the works that were perceived as disruptive. These sounds were consistent throughout each nighttime during the works. On the first night, without sound masking, the intermittent sound was disturbing and sleep was difficult for residents. The second night was divided into two parts. Firstly, masking the sound so that no noise was audible. The levels were set at 42-43dBA. This masked all sound, but the relatively loud masking levels resulted in disturbed sleep–which was expected, because recommended background sound levels for sleep are around 30-35dBA [8]. For the second half of the night, as the works continued, the masking levels were adjusted to 30dBA. While some construction sounds were audible at this level, they were no longer distracting or disturbing to sleep. The distance between the works and the residence at 175 metres was not as close as some works. There were trees and parkland between the works, so the sound absorption of these may have had an impact. The residence did not have double glazing but did have blackout blinds to mitigate the extreme light pollution (see Figure 4).

Figure 4: Extreme light pollution from the works during an otherwise dark night.

7. CONCLUSIONS

There is evidence that even in challenging environments, a well-designed sound masking system can positively impact the comfort and wellbeing of occupants in non-traditional acoustic envrionments. However, there are barriers to the implementation of sound masking systems where unusual situations arise. In Table 1 below, the measured sound levels are well above the AS/NZS 2107:2016 recommendations, and the sound masking levels are well below the measured sound levels. Theoretically, masking should not work in these circumstances. However, in each case, the end users experienced significant subjective improvement in their situations.

Table 1: Sound level comparison.

Case Study	Setting Type	Design sound level ($L_{Aeq,t}$) range [9]	Measured Sound Levels (dBA)	Average Masking Sound Levels (dBA)
Industrial noise - Perth	Industrial/ Occupational	40-45	40-70	42-44
Road traffic noise - Adelaide	Commercial/ Office	40-45	55-95	47-48
Big Build noise - Melbourne	Residential/ Construction	30-35 (Night)	40-60	30 (42)

There is nuance in each scenario, and the reduction of the stress response in residents or workers is necessarily subjective. However, these three case studies are a good basis to explore the inclusion of a more flexible and user comfort-based focus in future noise standards and guidelines. More research is needed to explore possible applications and adjust the range of recommended sound levels and shapes to accommodate novel applications. We recommend prioritising the end user experience and exploring how to flexibly include masking sounds to protect public health in an increasingly dense and noisy urban and industrial acoustic landscape.

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