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Indiscernible noise – a review of acoustic criteria for impulsive noise event in presence of background noise

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ABSTRACT

Discernibility in presence of background noise is a complex aural phenomenon and not explicitly defined in scientific literature. Policymakers often aim to control music and mechanical equipment noise egress by setting noise emission criteria as “inaudible” during the night period when background noise is relatively low. However, the quantification of “indiscernible” in relation to “typical” background noise is not well defined in the literature. As commonly understood by acousticians, a subject noise source will not significantly contribute to the ambient noise environment when the source level is 10 dB or more below the background noise level. Subjective perception of such noise depends on myriad of factors including the temporal and spectral content of the noise, noise sensitivity and cognitive perception of the subject and the subjective perception in context. The indiscernibility of sound in an outdoor setting becomes even more complex when the subject noise source is of impulsive character (i.e. gun shots etc.). It is of interest to investigate whether the “Background - 10 dB” rule ensures the indiscernibility to the majority of subjects in an outdoor context, when a noise source is located outside or inside of a building in the vicinity of a sensitive receptor. This paper presents a literature review on the indiscernibility noise criteria of an impulsive noise source, located at indoor or outdoor environment, in the presence of background noise. The findings will be especially of interest for defence and law enforcement building design to ensure the safe operation of the facility and address the acoustic amenity of receivers in the surrounding environment.

1 BACKGROUND

Indiscernibility of noise is often a regulatory requirement or a guideline criteria for environmental noise compliance. Noise sources for which such compliance is generally required include mechanical plant equipment (e.g. mechanical ventilation equipment), domestic air conditioning units and entertainment (music) noise. Some examples of inaudible noise requirements across Australia include the following:

- NSW Liquor and Gaming NSW (L&GNSW) requires noise from licensed premises shall not be audible within any habitable room in any residential premises between the hours of 12:00 midnight and 7:00am.
- VIC Publication 1254 – Noise Control Guideline recommends where a residential area will be impacted by noise from deliveries, then deliveries should be inaudible in a habitable room of any residential premises (regardless of whether any door or window giving access to the room is open) outside scheduled hours.
- VIC Publication 1254 – Noise Control Guideline recommends noise from any fixed domestic plant must not be audible within a habitable room of any other residence (regardless of whether any door or window giving access to the room is open) during prohibited hours prescribed by the Environment Protection (Residential Noise) Regulation 2008.
- VIC Environmental Protection Act 1970 – State Environment Protection Policy (Control of Music Noise from Public Premises) No. N-2 requires an operation of an outdoor venue take place between the hours 12 noon and 11 pm, except where the duration of the operation is greater than five hours in which case the operation may take place only between the hours 12 noon and 10 pm. The Act also requires that the Authority may allow later operations where it is satisfied that music from the premises will be inaudible within all noise sensitive areas, or where it is satisfied that the proposed operation is: a non-profit event, for charitable purpose, or is of special social significance.

- NT EPA - Northern Territory Noise Management Framework Guideline 2018 recommends where a residential area will be impacted by noise from deliveries, then deliveries should be inaudible in a habitable room of any residential premises (regardless of whether any door or window giving access to the room is open) outside scheduled hours.

From a policymaking perspective, defining “inaudibility” is one of the preferred options to ensure a noise source is not intrusive at a sensitive receiver and thus remove the possibility of noise complaint. However, from a technical point of view, the reality is “inaudibility” or “indiscernibility” in presence of background noise is a complex term, which depends on a myriad of acoustical and non-acoustical factors and not quantitatively defined currently in any scientific literature locally or internationally. As a result, the question remains – how indiscernibility is defined quantitatively? If this is not known, there will always be uncertainties in meeting the above regulatory requirements, thus more likely resulting in noise complaints.

Many researchers have found that noise with impulsive characteristics is more annoying than continuous noise of the same equivalent noise level. Miedema reported that up to a level of 60 or 65 dB(A), impulse noise is more annoying than any transportation noise and that industrial noise (non-impulsive) is more annoying than any transportation noise at equal level (Miedema 1992). A penalty or adjustment is therefore often proposed in different environmental noise regulations and standards to consider this effect, which may be equal to 5 or 12 dB in the case of regular impulsive sound sources and highly impulsive sound sources (ISO 2016). Managing impulsive noise is therefore more challenging than the steady-state environmental noise. Schomer noted that high-energy impulse such as artillery practice ranges, quarry blasting etc. can engender annoyance beyond that associated with the simple audibility of the impulse by inducing house vibrations, startle effects, or other responses, and this should be treated differently from more common sounds such as those from transportation noise sources (Schomer 1985). It is therefore important to investigate the indiscernibility criteria for impulsive noise which can be applied for control of regular impulsive noise sources (e.g. industrial noise) or highly impulsive noise sources (e.g. artillery practice range). This paper, however, focuses investigating impulsive noise associated with artillery training and shooting range etc.

Controlling noise from artillery training facilities and shooting ranges often requires noise from weapons to be within a recommended environmental noise performance criteria at nearby noise sensitive receivers. The proximity of such facilities and training areas to noise sensitive premises increases the risk of unnecessarily alerting occupants for possible emergency situations even though compliance has been achieved with these requirements. This is not a desirable outcome in the design of a facility involving the firing of weapons. It is understood that criminal, terrorist, and military actions involving firearms are of increasing concern to police, soldiers, and the public. Hence, it is thought prudent to design facilities such that the operational impulsive noise is indiscernible at nearby noise sensitive receivers and thus do not falsely alarm the nearby occupant/residents. This raises the same fundamental question of defining inaudibility, the term that we have commonly seen in our environmental noise regulations. Hence, it was the intention of this paper to review the literature on “indiscernibility” of shooting impulsive noise in the presence of background noise and establish criteria based on current best practice that would likely assure indiscernibility of a noise source at noise sensitive premises. The indiscernibility of weapon noise from a shooting range at nearby noise sensitive receivers is the key focus of this paper.

2 WHAT IS INDISCERNIBILITY

The human auditory system is sensitive to sound from 0 dB (hearing threshold) to 140 dB (threshold of pain) and frequencies between 20 Hz and 20 kHz. Absolute indiscernibility, inaudibility, or the hearing threshold is referred to as the lower limit of audibility. Along with a set of equal loudness level contours for pure tones, ISO 226:2003 (ISO 2003) include a hearing threshold curve below which a sound is considered inaudible. However, absolute inaudibility is not the focus of this paper, rather, indiscernibility of a subject noise source in presence of background sound is the key theme. In the absence of any technical definition, a subject noise source can be considered indiscernible if the sound cannot be heard or is not audible in the presence of a background sound environment. The threshold of audibility is elevated to “masked threshold” in presence of a background noise and a higher subject noise level maybe needed for audibility at a given frequency (Caley and Georgiou 2004). Interference of a subject noise by a masking background sound may decrease the perceived loudness and the audibility of that subject noise (Michael D. Proctor 2004). In reality, the indiscernibility of a sound is not only influenced by the level and characteristics of the subject sound but also depends on the ambient noise level, the masking thresholds, engagement of the listener in the context and a number of other subjective factors. These factors are discussed in the following section.

3 FACTORS AFFECTING INDISCERNIBILITY

The audibility of a sound in a context is considered a psychophysical phenomenon, which depends on the physical ability of signal detection and psychological, behavioural and contextual reactions of an individual to the sound (Skagerstrand 2018). Audibility of a sound and its recognition depends on the sound source, factors affecting the sound propagation in the environment and the listener. Factors related to the sound source include its level, dynamic range, signal to noise ratio, duration of the sound, its temporal variability and the frequency bandwidth. Factors associated with the listener include hearing acuity and memory, subject's engagement in a context, response proclivity, experience, attention, familiarity of the signal and the context, stress and expectations (Kim F Fluitt 2015).

Subjective evaluation of a sound is the collection, identification, organization, and interpretation of acoustic information arriving at the listener's ears in a context. This collective information provides the listener with an understanding of the sound and helps develop a cognitive representation of the environment. This can result in an awareness of the presence, behaviour, and meaning of a variety of sound sources operating in the surrounding environment (Kim F Fluitt 2015). The meaning of the sound can be interpreted by the listener differently which depends on the listener's well-being, noise sensitivity, cognitive perception and coping capacity to the sound in that context.

A number of psychoacoustic factors also play an important role in a listener's ability to detect or not detect a sound signal and to discriminate it from other sounds. These include hearing sensitivity, temporal integration, listening conditions, nature of target sounds and listener's efficiency (Kim F Fluitt 2015). For sounds to be audible, the level of the sound must be above the listener's hearing threshold in a spectro-temporal space. The absolute threshold of a sound is the minimum detectable level of that sound in the absence of any other external sounds. The presence of background noise has an impact on the auditory detection of a sound of interest. A sound can be considered indiscernible if it is masked by the background noise and therefore cannot be detected in the ambient soundscape. Auditory masking consists of frequency masking and temporal masking, with a weaker sound inaudible in the presence of a louder sound. Auditory masking is the decreased audibility of one sound due to the presence of another.

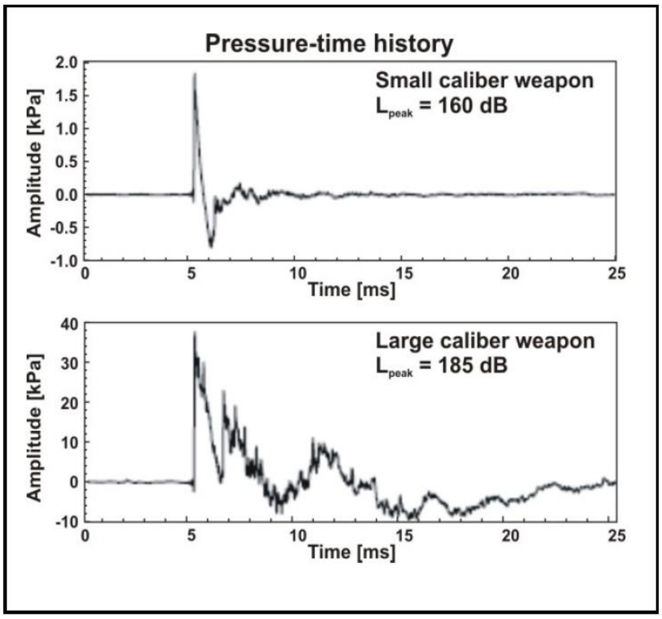
Temporal integration refers to the auditory system integration of acoustic energy. The time constant of the human auditory system is about 200 ms (Garner & Miller, 1947; Zwislocki, 1960; Price & Hodge, 1976). For sound with durations exceeding 500 ms, the sound intensity at threshold is roughly independent of duration. However, the sound intensity necessary for detection of a sound increases when the duration of a sound decreases below 200 ms (Skagerstrand 2018). If a 20 ms duration sound is just detectable, it would require the same sound of 200 ms to be just detectable at a 10 dB lower intensity. Hence, for sounds of longer duration (i.e. industrial sound), it would be detected at lower sound pressure level than very short duration impulsive sounds such as from gunshots and weapons noise (Georges R. Garinther 1985). Research has shown that sounds with very short duration (less than 200 ms) are not perceived at the same loudness as they are when the duration is increased (John C. Swallow 2007), and thus the duration of a sound also affects its audibility in presence of background noise. The background noise level at the listener's location is likely the single most important factor for determining aural non-detectability (Georges R. Garinther 1985).

Shooting noise from an indoor or outdoor shooting range is one such phenomenon, where the perception and indiscernibility of it in the presence of background noise depends on the factors discussed previously. The following section will describe the characteristics of general impulsive noise and shooting noise (the noise under investigation in this paper).

4 IMPULSIVE CHARACTER OF SHOOTING NOISE

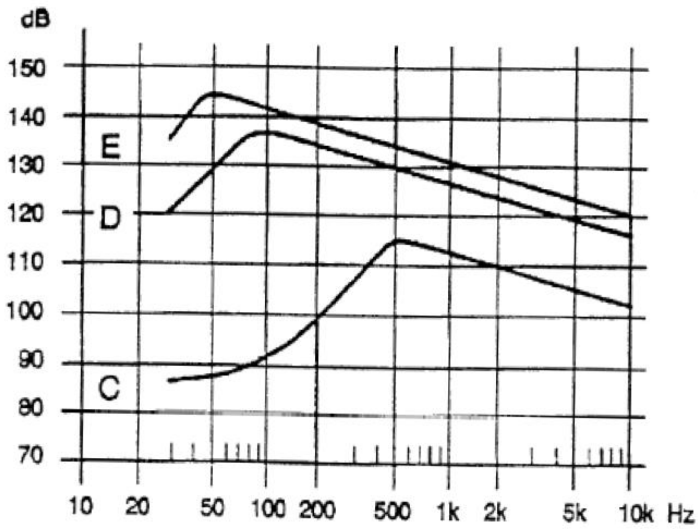
Impulsive noise is defined as the sudden onset of a sound (British Standard 2014). The onset rate is defined as the positive slope of the line between the approximate start and end of the impulsive time history where the slope is more than 10 dB/sec. Impulse noise contains rapid sound pressure transients. The characteristics and prominence of the impulse depends on the character of the noise source, the propagation path and distance from the source and on the background noise (British Standard 2014). The duration of impulsive noise in typical commercial and industrial activity varies between a few hundred milliseconds to seconds. However, characteristics of impulsive noise from firearms and shooting noise are different to industrial activity noise.

Firearms typically use an explosive charge to propel a projectile out of a gun barrel. Muzzle blast from guns and noise from explosive charges are sources of impulse noise that are commonly encountered in military service. The shock wave due to expanding propellant gases escaping from the muzzle is known as the muzzle blast. The duration of the blast ranges from 0.2 ms for small calibre weapons (less than 20mm), and up to 5 ms for large calibre weapons (greater than 20mm). It is characterized by a very rapid increase in pressure, followed by a decay to a partial vacuum, before returning to ambient pressure (Lautour 2017). Typical time profile of a small and large calibre weapon are shown in Figure 1. Higher proportions of low frequency energy is generated in large calibre weapons compared to smaller calibre weapons. Figure 2 below present's examples of the impulse sound spectra for three generic forms of weapons.



Source (Pascal Hamery 2015)

Figure 1 Typical pressure-time history of a small (upper graph) and large (lower graph) calibre weapon



Source (Southdowns Environmental Consultants 2016)

Figure 2 Impulse noise spectra summed over octave band frequencies (C: Pistol, 0.85m distance; D:7.5mm Gun, 5m distance; E: Explosion of 4kg TNT, 4m distance)

Discernibility of weapon noise from an indoor or outdoor firing range or artillery facility at an outdoor setting will depend on the type of weapon, its location relative to the receiver, level of noise, the sound insulation performance of the building shell (if enclosed), the atmospheric conditions, the propagation path, the level of the weapon noise at the listener's location, the surrounding soundscape (masking noise) and the listener's cognitive perceptions. In general, dominant low frequency blast sound produced by weapons ranges from 20 Hz to 100 Hz. For large weapons, such as heavy artillery, there are large magnitudes of low frequency energy around the 30-50 Hertz (Hz) range (Southdowns Environmental Consultants 2016) which is towards the lower end of the audible range of human hearing. The audibility of a sound might therefore be challenging to a listener if the weapon noise is low enough in relation to the background noise, in addition to its very short duration of impulse. In the following sections, criteria will be investigated in the scientific literature which could potentially be used in the design of shooting ranges to achieve indiscernibility in presence of background noise in an outdoor setting.

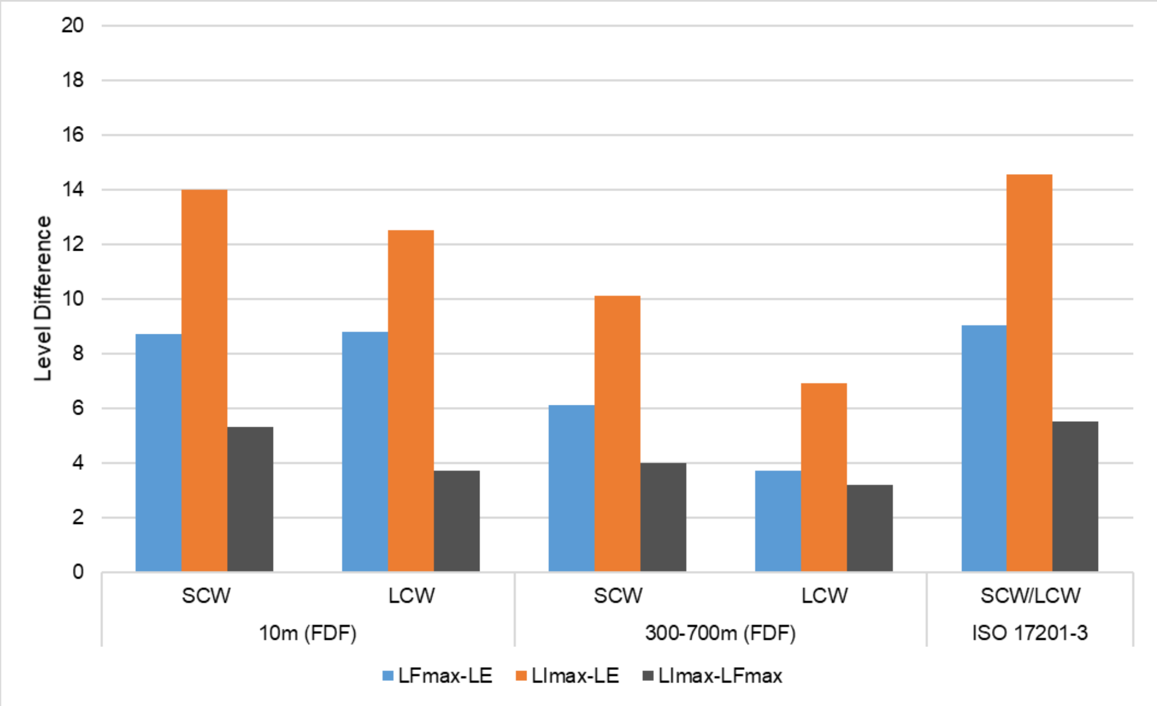
5 DESCRIPTORS USED FOR SHOOTING NOISE ASSESSMENT

Shooting noise or noise from weapons associated with military facilities was often studied for noise annoyance in the past. For small calibre weapons, the A-weighted noise exposure level, $L_{AE,}$ has often been found correlated with noise annoyance (Markula 2006). For assessment, noise annoyance associated with large calibre or high energy weapons, the C-weighted exposure level L_{CE} has been found relevant and has been used in ISO 1996-1. The annoyance rating of firearms from calibre 7.62 to 155 mm was studied by Vos (Vos, 2001a). The study found an outdoor L_{AE} of the impulsive sound correlated with noise annoyance in the laboratory study. Similar findings were noted by Meloni and Rosenheck (Meloni 1995) who found that if shooting noise is predominantly heard through open windows, the A-weighted sound exposure level is appropriate for predicting annoyance and no weapon specific level correction (penalty) for small, medium or large weapons is needed (Mark Brink 2009). Some other researchers have found L_{Aeq}, L_{AImax} or L_{AFmax} noise metrics of the weapon noise correlated with annoyance. The use of these noise metrics for evaluation of weapon noise annoyance varies between countries and there is no general agreement on the best descriptor for evaluating noise annoyance. A summary of the noise metrics used by different countries for evaluating noise annoyance associated with small calibre weapons and heavy weapons are listed in Table 1 below.

Table 1 Descriptors used in different countries for weapon noise evaluation (Source: (Markula 2006))

Weapon Type	Descriptor	Countries Used
Small Calibre Weapon	L_{AImax}	Nordic Countries, Austria, Netherlands and Australia
	L_{AFmax}	Germany, Czech Republic
	L_{peak}	Australia, United States
	L_{AE}	United States
Large Calibre Weapon	L_{CE}	Sweden, Germany, Denmark and the United States
	L_{CDN}	Norway
	L_{peak}	Australia and Netherlands
	L_{AImax}	Netherlands
	L_{AFmax}	Germany, the United Kingdom and Switzerland
	L_{AE}	Czech Republic

For the assessment of weapon noise in relation to impulsiveness, noise annoyance, audibility and comparison with existing environmental noise, it is often necessary to convert between the different noise metrics. The level difference between these metrics for small and large calibre weapon varies due to their impulsive character. Figure 3 below present the differences between some of these quantities for small calibre and large weapons measured in shooting ranges in Finnish Defence Forces (FDD) and compare them with recommended guideline values in ISO/CD 17201-3:2003 (ISO 2003). In general, the level difference decreases with increased distance.



Source: (Markula 2006):
Figure 3 Level difference of small and large calibre weapon at close and at long distance in two shooting ranges (and in two different weather conditions) in Finnish Defence Forces

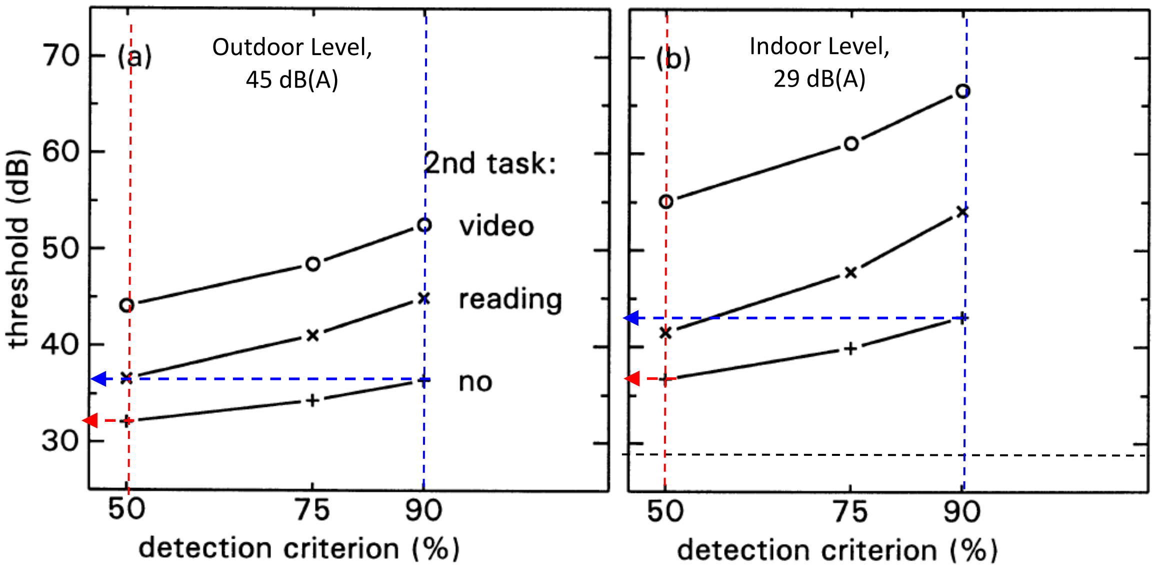
6 INDISCERNIBILITY AND PERCEPTION OF SHOOTING NOISE

A subject sound is considered indiscernible if it cannot be heard in the presence of background noise. This essentially means that the subject sound is masked by the soundscape. This is a signal-to-noise phenomenon and can be defined in terms of sound detectability (Thorne 2011). Detection of a sound is referred to as determination of the presence of an acoustic signal (Kim F Fluitt 2015). The presence of background noise affects the auditory detection of sound. Research on auditory signal detection suggest that a sound may have limited value to a listener if the sound has been just “detected” but not “recognised”. “Recognition” of a sound is referred to as determination of the source of the acoustic signal or the narrow class of sound it belongs to (Kim F Fluitt 2015). A sound that is “detected” in the presence of a background noise environment may not result in any response by the listener if the person is unable to “recognise” whether the sound belongs to the environment or was due to an extraneous source. Such sounds may be a friendly signal, a threat or may have neutral character (Kim F Fluitt 2015).

Although auditory signal detection has been extensively studied, detection of low amplitude impulsive noise associated with weapons in the presence of background noise has been rarely investigated. The following are references of some research literature where impulsive noise from weapons were evaluated in the presence of different background noise levels and a criteria for threshold of auditability was established.

Several research papers have shown that in the case of a narrowband signal and wideband background noise, detection of sound signal may occur at much lower levels such as signal to noise ratio of -5 to -10 dB (Miller GA 1951) (JB 1971). Research undertaken by Abouchacra showed that detection of a magazine insertion sound into a M-16 rifle in a jungle environment (70 dB(A)), white noise (30 dB(A)) and pink noise (70 dB(A)) was 75% detected at a threshold level of -7, -9 and -4 dB signal to noise ratio (Abouchacra K 2007). Threshold of detection for a M16 bolt click sound in pink noise and jungle ambient background noise averaged a signal to noise ratio of –8 dB (pink noise) and –10 dB (jungle noise) (Letowski T 2004).

Vos (Vos, 2001a) performed laboratory experiments, where noise from various weapons (7.62 mm to 155 mm calibre) were evaluated by 24 subjects, to establish a threshold of discernibility in the presence of different background noise levels (windows open or closed) and tasks involved (listening to the bangs only or, as a secondary task, reading short stories or watching movies (with sound) on TV). A filtered pink noise level of 29 dB(A) was used to simulate an indoor environment and 45 dB(A) was used to simulate outdoor noise environment. As shown in Figure 4 below, it was found that for a 50% probability of detection of an impulsive noise from a weapon, an A-weighted exposure level of L_{AE} 32 dB(A) was required to detect the weapon noise in the presence of a background noise level of 45 dB(A). Based on the data provided by (Markula 2006) for the conversion of noise metrics for impulsive weapon noise, presented in Figure 3, this exposure level (L_{AE} 32 dB(A)) would be equivalent to a maximum noise level of L_{AImax} 39 dB(A) approximately. As a result, it can be determined that the weapon noise level is likely to be discernible at 50% probability (when the listener is involved with no other tasks) when the L_{AImax} level is 6 dB(A) below the background noise level. Below this level, noise is likely to be indiscernible. Of course, the probability of detection would increase with the increased level of weapon noise exposure level above background. For example, when detection criterion is 90%, the criteria is 2 dB below the background noise level. The above results are presented for an outdoor setting condition (with windows open). In an indoor setting, the weapon outdoor noise level should be 14 dB and 21 dB above the indoor background noise level for a 50% and 90% detection criterion respectively.



Source: (Vos, 2001a)
Figure 4 Thresholds (L_{AE}) at which weapon noise levels (outdoor) were discernible during different task levels. Figure(a) was background indoor noise level with windows open and Figure (b) windows closed condition.

Further research performed by US Army Human Engineering Laboratory (Georges R. Garinther 1985) developed a theoretical set of criteria for military noise (MIL-STD-1979) that should be met at a specified measurement distance, to be undetectable at a listener's location. These criteria are based on assessing the weapon noise based on two different background noise conditions by a young adult listener with normal hearing sensitivity. The criteria is used for designing materiel having noise levels that minimise aural detection by an enemy. This limit assumes that the listener is (1) in a quiet rural area and that the closest highway and community noise sources are further than 4 km away (Level 1: ambient noise level 33 dB(A)) and (2) in the quietest background noise levels which are likely to be encountered in practice, and that the closest highway and community noise sources are further than 10 km away (Level 2: ambient noise level 23 dB(A)).

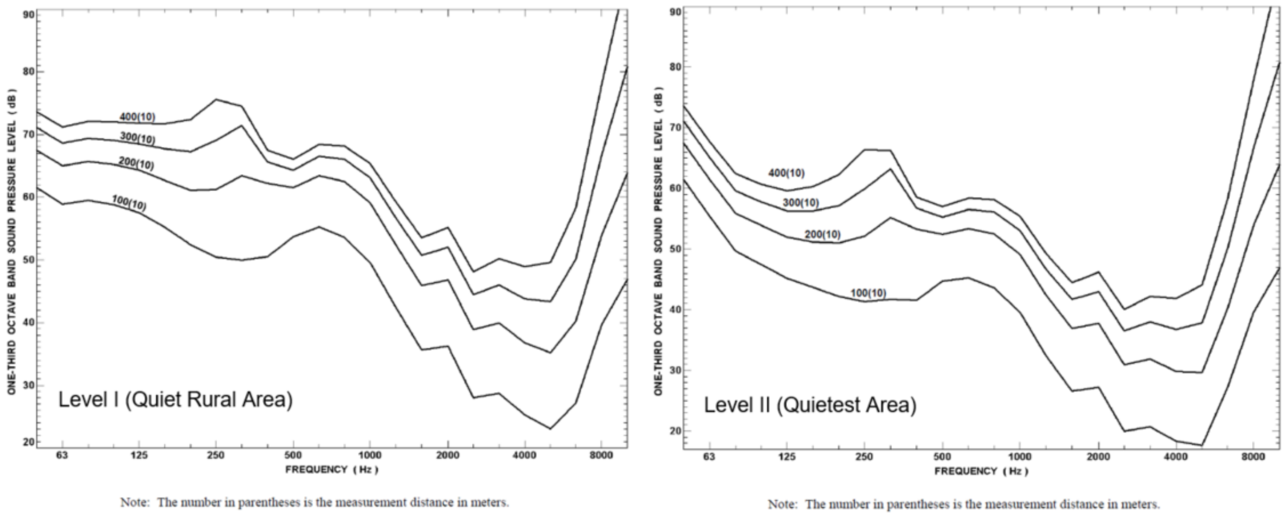
Criteria levels were determined by assuming that non-detectability is provided by setting the signal level of the weapon noise just equal to the background noise level (0 dB S/N ratio) for each 1/3-octave band. To account for low frequency masking, this spectrum was then converted to an auditory filter band spectrum using the procedure of Fidell and Horonjeff (Fidell 1982). The auditory filter spectrum was then modified by signal detection theory to produce 50 percent detection with a 1 percent false alarm rate. The non-detectable SPL at receiver location was defined as shown in Equation 1. This not-to-be-exceeded level was then transferred back to the measurement location by considering geometric spreading, atmospheric absorption, and the ground effect (including turbulence). The level not to be exceeded at the measurement location for various non-detectability distances was calculated for each 1/3-octave band from Equation 2. A graphical presentation of the noise limit for Level 1 and Level II background noise conditions is shown in Figure 5 below.

$$L_2 = L_A + 10Log_{10}\left(\frac{d'}{nw^{0.5}}\right) \quad (1)$$

Where,
$L_2 = Nondetectable\ SPL\ at\ receiver\ location\ (threshold\ of\ hearing)$
$L_A = Auditory\ filter\ band\ level, dB$
$d' = 2.32$
$n = Listener\ efficiency\ (assumed\ 0.4)$
$w = Effective\ auditory\ filter\ bandwidth, Hz$

$$L_1 = L_2 + 20Log_{10}\left(\frac{r_2}{r_1}\right) + \alpha\left(\frac{r_2}{r_1}\right) + A_{ge}(r_2) - A_{ge}(r_1) \quad (2)$$

Where,
$L_1 = Sound\ pressure\ level\ at\ the\ measurement\ location, dB$
$L_2 = Sound\ pressure\ level\ at\ the\ listener\ location\ producing\ nondetectability\ for\ that\ band, in\ dB$
$r_1 = The\ distance\ from\ the\ noise\ source\ to\ the\ measurement\ location, m$
$r_2 = The\ distance\ from\ the\ noise\ source\ to\ the\ listener\ location, m$
$\alpha = Sound\ attenuation\ coefficient\ due\ to\ atmospheric\ absorption, dB/m$
$A_{ge}(r_2) = Excess\ attenuation\ due\ to\ ground\ effect\ between\ the\ source\ and\ listener\ locations, dB$
$A_{ge}(r_1) = Excess\ attenuation\ due\ to\ ground\ effect\ between\ the\ source\ and\ measurement\ locations, dB$



Source: (Defence 2015)

Figure 5 Level I and Level II aural non-detectability limits for 100 – 400 meters.

There is currently minimal research literature on the evaluation of weapon impulsive noise in the presence of ambient noise/background. However, there are a number of studies available that suggest an outdoor weapon noise level that would be acceptable or potentially minimise the noise annoyance and can be considered for land use planning. A socio-acoustic investigation was performed on 201 residents in the vicinity of a sub-urban rifle range which determined that 10% of the sample population would be seriously affected at a level of 85 dB (L_{Peak}) which is equivalent to an L_{AE} 55 dB. This level is recommended as a reasonable criteria for land use planning (Bullen 1982). In a later study at a more active military range, this criteria was confirmed, however with a caveat that the 85 dB (L_{Peak}) criteria is only valid for up to one million rounds per year. For new and expanded ranges, a more conservative criterion of 80 dB (L_{Peak}) was adopted.

Given the number of ammunition rounds heavily influences the value of average noise level metrics such as L_E and L_{eq}, but not single event metrics such as L_{Peak}, there is reasonable grounds for supplementing average metrics with single event metrics in noise impact assessments (Pater 2007).

One disadvantage of a fixed criterion is that it does not account for where the noise source is located. It might be expected that a firing range placed in rural surroundings will have a greater noise impact than one located close to a busy highway. A fixed criterion does not differentiate between these two surroundings (Swallow, Hemingway and Pearlie 1999).

7 CONCLUDING REMARKS

The potential impact of military shooting noise from Defence and law enforcement training facilities is far less understood than effects of steady or quasi-steady sources such as traffic or industrial noise. Military training areas often involve different combinations of small to large calibre weapons which creates a site-specific and quite complex myriad of sources. Controlling noise from these facilities might require meeting indiscernibility criteria for operational and environmental reason. A literature review has been conducted in this paper on the indiscernibility noise criteria of an impulsive noise source in the presence of background noise. Establishing the criteria for indiscernibility of impulsive weapons noise has proven to be quite a difficult and complex task.

The perception and indiscernibility of weapons noise from indoor or outdoor shooting ranges in the presence of background noise depends on many acoustic and non-acoustic factors. However, the background noise level at the listener's location is likely the single most important acoustic factor for determining aural non-detectability. The background noise level in any given environment is typically variable in nature. Therefore, any change in environmental conditions may alter the discernibility of the weapons noise event of interest, and it is not clear the extent to which a change in those conditions would influence sound-source audibility.

The intention of noise criteria is typically to strike a balance between the establishment and operation of noise generating activities and acoustic quality objectives, balancing the need to not discourage development with maintaining the amenity of the surrounding community, often driven by the desire of policymakers to minimise annoyance and thereby minimise complaints. However, the assessment and enforcement of criteria based on indiscernibility poses some challenges for both acousticians and policymakers.

One example of a specific challenge is the assessment of large arms weapons noise. Large amplitude impulsive sounds, such as those produced by artillery fire can excite noticeable vibration of buildings and rattling of lightweight objects. The perception of the sound is influenced by secondary mechanisms whereby the airborne noise may not be audible outside, yet receivers within a building perceive it via a different transmission path.

Further research would therefore be required to establish criteria based on weapon noise perception in presence of a background noise. A 10 dB below the background noise level would reduce the possibility of sound detection and recognition, however, the indiscernibility at the receiver location depends on the factors discussed in this paper. The non-detectability requirements suggested in MIL-STD-1474E is regarded as a good tool for indiscernibility design in relation to weapon noise.

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