EXPLORING THE IMPACTS OF CONSISTENCY IN SOUND MASKING

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1 Introduction

A sound masking system's effectiveness is directly related to its ability to closely match the specified spectrum. Though specifications currently dictate desired levels, they often allow a relatively wide range of spatial variation. To some extent, this leniency is a remnant of the capability of legacy technologies. However, many also assume that these variations do not affect performance to an unacceptable degree.

This paper outlines a series of masking tests and speech intelligibility calculations conducted in an office space. Its purpose is to determine the impacts of inconsistencies in the masking sound and whether general predictive rules can be found.

2 Method

Articulation Index values were calculated for field tests, per ASTM E1130-08[1]. Tests were done for 5 source and 16 listener locations representing varying conditions. Results were converted to comprehension levels, using a transfer function from AI to the percent comprehension of sentences upon first presentation (Figure 1)[2].

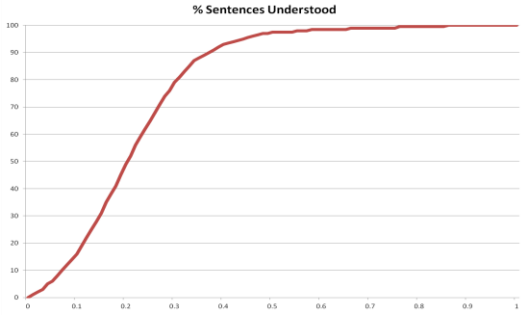

Figure 1: Translation of Articulation Index (horizontal axis) to percent comprehension of sentences on first presentation to listener (vertical axis).

The impact of varying masking levels was analyzed by calculating AI for masking ranging from 42 to 48dBA, in 1dBA increments. The masking spectrum was held constant at each overall level.

The AI calculation was subsequently investigated for general rules applicable to all site conditions.

3 Results

Two representative samples of the sixteen test sets are summarized below (Figures 2 and 3).

In Test A2, the source and listener were in workstations 4.9m (16 feet) apart. The unmasked background level was 41.9dBA and AI was 0.367. With masking at 48dBA, AI was 0.150. AI increased to 0.349 with masking at 42dBA. Translated to comprehension, a listener at A2 would understand 31% of the conversation with 48dBA of masking and 87% with 42dBA of masking. Comprehension increases rapidly as masking decreases. For each 1dBA decrease in masking, comprehension rose by 6 to 12%, with an average increase of 9.3%.

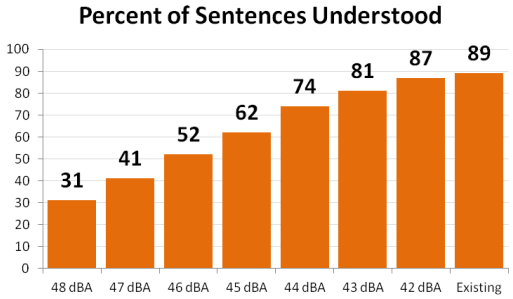

Figure 2: Percent comprehension at location A2 with varying sound masking levels.

In Test B2, the source and listener were in workstations 4.7m (15.5 feet) apart. The unmasked background level was 40.6 dBA and AI was 0.339. With masking at 48dBA AI was 0.099. AI increased to 0.296 with masking at 42dBA. A listener in location B2 would understand 14% of the conversation with 48dBA of masking and 76% with 42dBA of masking. For each 1dBA decrease in masking, comprehension rose by 8 to 14%, with an average increase of 10.2%.

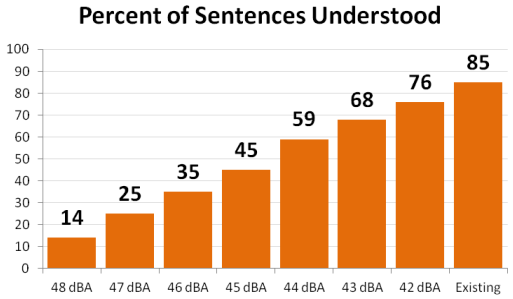

Figure 3: Percent comprehension at location B2 with varying sound masking levels.

4 Discussion

System specifications typically state that masking levels be met within set spatial tolerances. A variation of +/-2dBA is the most common, giving a 4dBA range. Analysis showed that this range is too broad, given its impact on speech comprehension.

In test A2, a system specified for 46dBA would conform if between 44 and 48dBA (Figure 4). However, comprehension over this range rises from 31% to 74% – an absolute shift of 43%. In relative terms, comprehension

where masking is lowest is 239% of where masking is highest.

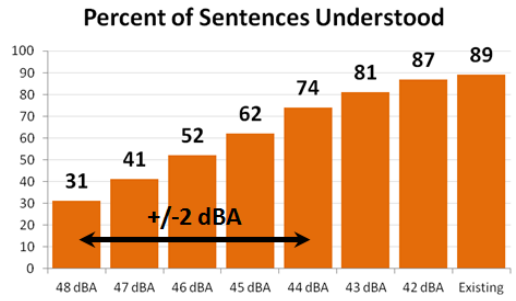

Figure 4: Range of comprehension at A2 with +/-2dBA masking.

In test B2, masking specified for 45dBA could vary over a range of 47 to 43dBA (Figure 5). Comprehension would range from 25 to 68% - an absolute change of 43%. Speech comprehension at worst is 272% of that in areas with the highest masking.

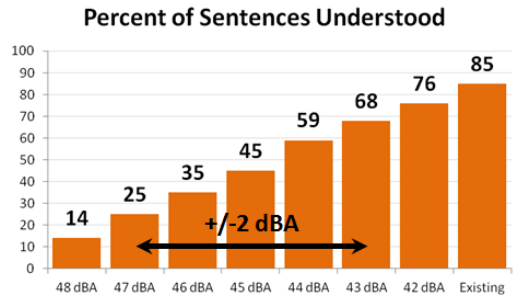

Figure 5: Range of comprehension at B2 with +/-2dBA masking.

Similar results were found at varying masking levels and in all of the test scenarios where the source and listener were distant enough for the masking to take effect.

Beyond these location specific results, this study also sought to establish a general rule for the relationship between comprehension and masking level. Analysis of the AI formula demonstrated that one can predict an increase of 0.0333 in AI for each 1dBA decrease in masking level. Each 1dBA drop in masking yields a 1dBA increase in the signal-to-noise ratio (SNR). When multiplied across the AI band weightings and summed, the result is 0.0333 (Table 1). This holds true so long as the conversation at the listener location is at least 1dB above the masking level in each third-octave band used in the AI calculation. If not, the change in AI decreases by the weighted value of any 0 SNR bands.

Thus, one can generally state the relative impact of inconsistency in masking levels without knowing the site conditions. For absolute AI or comprehension levels, site tests are needed; however, for relative comparisons, only tolerances or expected variations are necessary. For example, a system permitting a 4dBA range allows a 4 x 0.0333 = 0.1332 change in AI. A system permitting a 1dBA range results in a smaller 0.0333 change in AI.

The impact on listeners is better assessed through a conversion to speech comprehension. By analyzing the AI-comprehension transfer function in Figure 1, one finds that, for a given listener, the maximum impact on comprehension from a 0.0333 increase in AI is 12%. The maximum impact from a 0.1332 increase in AI is 43%. Comparatively, the more consistent system provides 88 to 100% masking effectiveness in all areas, while the less consistent system varies from 57 to 100%.

Results show that if a sound masking system were to vary spatially by more than the +/-2dBA considered above, the impact on speech comprehension would be even greater.

Frequency Band	AI Weighting
200	0.00040
250	0.00100
315	0.00100
400	0.00140
500	0.00140
630	0.00200
800	0.00200
1000	0.00240
1250	0.00300
1600	0.00370
2000	0.00380
2500	0.00340
3150	0.00340
4000	0.00240
5000	0.00200
TOTAL	**0.03330**

Table 1: Band weightings used in Articulation Index calculation.

There are several additional observations from this study that merit further attention in future papers.

5 Conclusion

The impact of varying masking levels on speech comprehension is significant and not commonly appreciated. This finding strongly argues for a tightening of traditionally-accepted tolerances for spatial uniformity.

The comparative performance of masking systems in terms of their effect on speech comprehension can be quantified without considering site conditions once the specified or expected variation in masking level is known.

References

[1] ASTM E1130-08 Standard Test Method for Objective Measurement of Speech Privacy in Open Plan Spaces Using Articulation Index.

[2] ANSI S3.5-1969(R1986) Methods for Calculation of the Articulation Index, Figure 15.