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SCALES FOR MEASURING HELICOPTER NOISE

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INTRODUCTION

For many years there has been concern that existing noise scales such as Effective Perceived Noise Level (EPNL) and A-weighted sound level (L_A) may not properly account for impulsiveness and other features which distinguish the sound of helicopters from that of fixed-wing aircraft. Helicopters which generate 'blade-slap' are perceived to be particularly annoying and the noise certification authorities have considered various proposals to incorporate 'impulse corrections' into the measurement scales (e.g. Ref.1). However, the need for such a correction has proved difficult to substantiate. Molino (Ref.2) recently reviewed 31 psychoacoustic experiments aimed at helicopter noise (excluding the present study) and while many of these supported the need for such a correction many others did not.

The objective of this study, which is described fully in Reference 3, was to gather together a large collection of helicopter noise recordings from which a test sample could be drawn to cover wide but realistic variations of the major variables of interest, i.e. duration, tonality and impulsiveness. Each sound would be rated with respect to its annoyance evoking qualities by a group of test subjects and measured on various common noise scales including L_A and EPNL. In addition to assessing the performance of these scales it might be possible to isolate directly the independent contributions of the three variables to judged annoyance.

THE EXPERIMENTS

The tests involved 119 recorded aircraft sounds; 89 helicopters and 30 CTOLs (Conventional take-off and landing aircraft). These represented 22 different helicopter types and 15 CTOL types. Most of the helicopter sounds were level flyovers although some approach descent recordings were used. The CTOLs, all turbine powered transport aircraft, were recorded at positions close to the nominal approach and flyover certification points.

The sounds were replayed to test subjects in random sequence, mixed with a standard reference sound (also an aircraft flyover) which was recorded at different levels over a 21dB range. Each subject was asked to rate the annoying qualities of each sound on a continuous numerical rating scale from 0 (not annoying at all) to 10 (extremely annoying). A mean subjective score SS was then computed for each sound and the response scale was calibrated against the sound levels of the reference sound. In fact the relationship for the reference sound was sufficiently linear to allow use of the linear regression line to transform each score value SS to an equivalent annoyance level NL (defined as the sound level of the equally annoying reference sound).

The main experiment required four 30 minute test sessions for each test subject. Between 36 and 40 subjects (undergraduate students in the age range 19-23 years) took part in each test. Sounds were presented via headphones and the recordings were analysed into $1/_3$-octave band spectral time histories taking account of the headphone frequency response. Much of the experiment was subsequently repeated using loudspeaker presentation in the acoustic test facilities at NASA Langley Research Center in the USA although these further tests are not described here.

RESULTS

Figure 1 is a typical 'scatter diagram' showing measured sound level L_A plotted against annoyance level NL where the latter is also defined in dB(A). (Both variables correspond to maximum levels recorded during the corresponding flyovers). Different plotting symbols are used to distinguish helicopters (subdivided into 'more' and 'less' impulsive sounds) and CTOLs (subdivided into approaches and take-offs). The performance of the scale L_A as a predictor of actual annoyance level NL may be assessed from Figure 1 in a variety of ways but clearly a logical index is the variance or standard deviation of the error ($NL-L_A$). Significance may also be attached to the relationships between the mean errors for the different sub-samples. These statistics were therefore computed for all noise measurement scales and all groups of sounds.

FINDINGS

1. The Perceived Noise Level Scale and the commonly used weighted sound level scales such as L_A and L_D are equivalent in terms of their general ability to predict annoyance levels for helicopters, for CTOLs or for all sounds combined.
2. Conventional duration corrections (+ 3dB per doubling of duration) improve the annoyance predicting performance of all basic scales to which they were applied; duration is a highly significant contributor to judged annoyance.

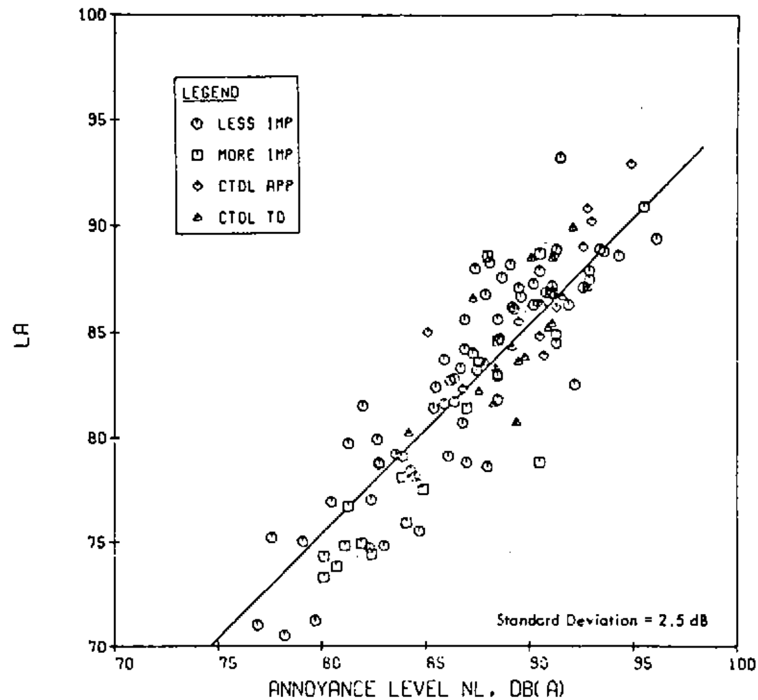

Figure 1. Measured Levels Versus Judged Annoyance Levels

3. On average, helicopter flyover sounds are judged equally annoying to CTOL sounds when their measured levels on the time-integrated scales (such as EPNL and L_{AX}) are approximately 2dB higher.
4. Multiple regression analysis indicated that provided the helicopter/CTOL difference of about 2dB is taken into account, the particular linear combination of level, duration, and tone corrections inherent in EPNL is close to optimum.
5. All scales of time-integrated sound level are very consistent predictors of CTOL noise annoyance levels; for these sounds, the variance of the prediction error is of the same magnitude as that of the estimated experimental error (around 1dB).
6. All scales of time-integrated level predict the annoyance levels of helicopter noise significantly less consistently than those of CTOL noise. This is probably due to the wide range of acoustic

characteristics exhibited by helicopters of different types.

7. Impulse corrections did not improve EPNL as a predictor of helicopter noise annoyance. Nor did the impulse correction emerge as a significant predictor variable in multiple regression analysis.
8. The reason that impulse corrections are not effective/not required is probably that impulsiveness (a) increases the spectral level of helicopter noise in the frequency range 125-500HZ and (b) causes a significant increase in signal duration; which together adequately amplify the sound level as measured on the conventional scales.

CONCLUSIONS

The results suggest that some previous studies of impulsiveness corrections for helicopter noise may have been confounded by interactions between frequency distribution, duration and impulsiveness. Although this kind of multi-colinearity could not be avoided here, the risky consequences of a limited selection of test signals have been minimized. It is concluded that for the general prediction of the annoyance evoking potential of helicopter noise which is not very different in character from that to which we are accustomed, the standard EPNL procedure is as good as other current noise measurement scales and does not require special provision to penalise impulsiveness.

REFERENCES

1. ISO Draft Addendum ISO 3891/DADI, "Measurement of Noise from Helicopters for Certification Purposes", 1979.
2. Molino, J.A., "Should helicopter noise be measured differently from other aircraft noise? - A review of the psychoacoustic literature", NASA CR 3609, November 1982.
3. Ollerhead, J.B., "Laboratory Studies of Scales for Measuring Helicopter Noise", NASA CR 3610, November 1982.