inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 63.1

QUALITY OF IMPULSIVE SOUNDS

R Bisping

Sound Analysis and Synthesis Systems, Ahornstr. 19, D-45134 Essen, Germany

Abstract

Two series of impulsive sounds were generated by either weighting tones of different frequencies and duration by a gaussian or by a double sided exponential window. Scaling of loudness and impulsiveness was done with the method of categorical partitioning (CP). The results showed that the duration of the impulses exerts a strong influence on both qualities. This effect is still maintained even with impulse duration in the range from 100 - 1000 ms. Furthermore the two types of windows significantly differ in their perceptual effects. An explanation for this result is suggested by time-frequency spectrum analysis revealing that the gaussian tone burst displays a double impulse pattern whereas the double exponential window is characterised by just one single impulse. As a consequence it is recommended to use double exponential impulses instead of the gaussian tone bursts for standardisation purposes of impulsive loudness.

1. Introduction

One of the findings of the »Fourth CEC Programme on Human Response to Impulsive Noise« was that the annoyance of impulsive sounds apparently is independent of its perceived impulsiveness, i.e. a sound may very well be impulsive but quiet or may be steady but loud and annoying etc. [1]. Despite this statistical independence which seems to be true for environmental noises, psychophysical data reliably show that below a time limit of 200 ms duration of the sound pressure level envelope (which can be defined as a physical measure of impulsiveness) a systematic dependence of loudness on impulsiveness can be observed. The impulse characteristics of standardised sound measuring systems account for this fact by weighting the measured level of a tone according to its duration [2]. For the standardisation of time-varying loudness it is equally important to weight the measured loudness of a sound relative to its time behaviour. Usually tone bursts weighted with an appropriate window to avoid unwanted click effects are used in calibration studies. Recently the German NALS-A1 committee on »Psychoacoustical measurement« decided to use tone bursts ranging from 10 - 1000 ms using a gaussian window for smoothing the edges defined by an amplitude increase from 10 - 90 % of full height within 2 ms. This procedure has the advantage of being compatible with a broad set of studies as many data within the area of impulsive loudness are based on similar stimuli [3]. As an alternative other types of windows, i.e. double sided exponential functions of the type »exp(-|t|/τ), t = time, τ = time constant« having exactly the same energy as a rectangular window of duration 2τ may be suitable. Figure 1 compares both types of windows.

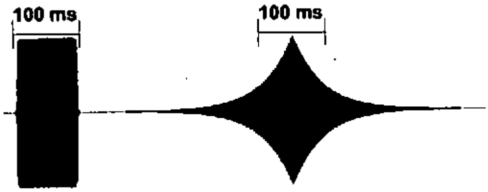

Figure 1: Gaussian weighted 100 ms tone burst versus double sided exponential tone with 2τ = 100 ms.

The difference in shape between the two windows is due to the fact that (having both a peak level of unity) the double exponential window is sufficiently defined by its time constant τ whereas the gaussian window needs the gaussian parameters <u>and</u> the duration of the tone for definition. Thus, for standardisation purposes double exponential windows might be preferable as their mathematical description in the time and frequency domain is very simple. Furthermore many natural acoustical phenomena such as booming, resonance etc. can be properly described by assuming sums of double sided exponential functions. Their perceptual quality, however, might be quite different than that of the gaussian window. In order to analyse the effects of both types of impulses an experiment was set up to scale their loudness and impulsiveness over a representative range of frequencies and time duration.

2. Method

Three different frequencies - 250, 1000, 4000 Hz - and 7 duration - 10, 20, 50, 100, 200, 500 1000 ms - were chosen as experimental conditions (gaussion signals were made available by HEAD acoustics, Aachen). The peak level of 80 dB was constant for both series. Stimuli within each series were presented with earphones that had been calibrated with a dummy head (HEAD acoustics, HMS I). Each condition was announced verbally and presented in random order. Each individual impulse was presented 4 times with a 3 seconds time-off between each tone. N = 13 subjects (9 male, 4 females, mean age: 25.4 years) scaled both qualities using the Categorical Partitioning method (CP) [4]. Figure 2 shows the loudness-scale. With impulsiveness the following attributes were chosen: steady, a little bit impulsive, somewhat impulsive, impulsive, very impulsive, highly impulsive, banging. Before scaling started subjects were trained using three sounds judged as very quiet, loud and very loud, and three other sounds scaled as steady, impulsive and highly impulsive in prior experiments.

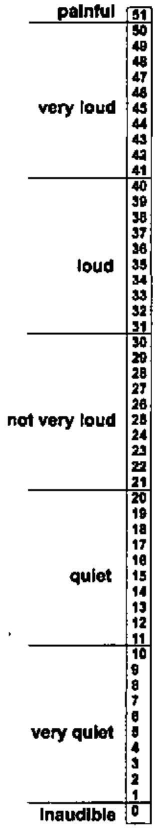

Figure 2: CP - loudness

3. Results

Figures 3 a and b shows the results. For loudness the analysis of variance reveals a significant effect of the frequency ($F(2, 24) = 43.5$, $P < 0.001$), i.e. loudness generally is increasing with increasing frequency, and a significant effect of the duration ($F(6, 72) = 41.5$, $P < 0.001$), i.e. loudness generally is increasing with increasing duration (note the substantial increase of loudness between 100 and 1000 ms for both windows). A significant interaction window x duration ($F(6, 72) = 5{,}61$, $P < 0.001$) and window x frequency ($F(2, 24) = 4.8$, $p < 0.02$) mainly is due to the fact that the gauss window generally has a steeper increase and higher level in loudness at 250 Hz than the double exponential window. With all three frequency conditions the impulsiveness decreases significantly dependent upon the duration ($F(6, 72) = 68$, $p < 0.001$; note the strong decrease in impulsiveness between 100 and 1000 ms). The difference between the two window types generally is significant ($F(1, 12) = 5.5$, $p < 0.05$), i.e. the double exponential window is rated as less impulsive than the gauss window.

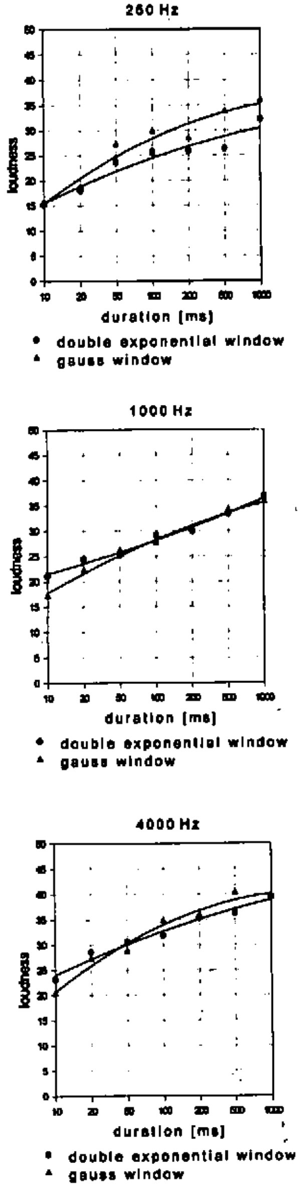

Figure 3 a: CP - loudness of the experimental conditions.

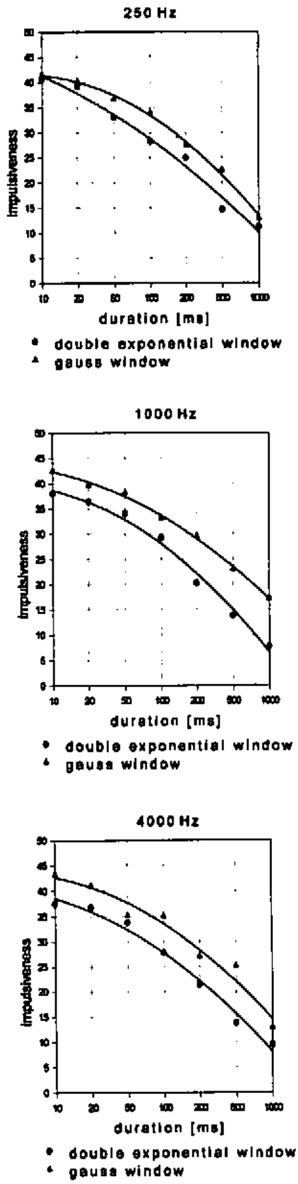

Figure 3 b: CP - impulsiveness of the experimental conditions.

4. Conclusion

The data show that the impulse duration has a strong impact on both perceptual qualities, i.e. loudness is strongly increasing and impulsiveness is decreasing while duration increases. This effect corresponds very well with the known data base [2, 3]. Surprisingly, however, for both impulse types a remarkable increase in loudness and strong decrease in impulsiveness is still maintained above a 100 ms impulse duration. In terms of the verbal categories used by the subjects this effect is related to the transition from »not very loud« to »loud« and »very impulsive« to »somewhat impulsive«, respectively. Thus, for the standardisation of impulsive loudness meters an appropriate weighting of loudness in the time range between 100 - 1000 ms is recommended. Figure 4 compares the spectrograms of both impulses.

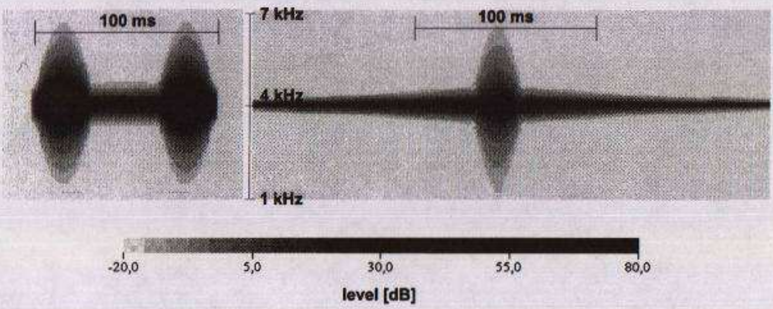

Figure 4: Spectrograms of the gaussian (left) and the double exponential window (right) imposed on a 4 kHz tone.

The spectra reveal that the gaussian window displays two impulses at both ends whereas the double exponential window shows just one. Thus, the perceptual effects observed (increased loudness at 250 Hz, generally increased impulsiveness) of the gaussian window can be assumed to be due to this remarkable difference in the physical behaviour of the two types of stimuli. As a consequence it is recommended to use double exponential impulses instead of gaussian tone bursts for standardisation of impulsive loudness meters.

References:

[1] C. G. Rice (1989). Human Response to Impulse Noise. Proceedings of the 13th International Congress on Acoustics, 3, 135 - 138.
[2] IEC 651 (1979). Sound Level Meters.
[3] E. Zwicker, & H. Fastl (1990). Psychoacoustics. Berlin etc.: Springer
[4] O. Heller (1985). Hörfeldaudiometrie mit dem Verfahren der Kategorieunterteilung (KU). Psychologische Beiträge, 27, 478 - 493.

References