Edinburgh, Scotland
EURONOISE 2009
October 26-28

Aspects of startling noises

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ABSTRACT

In a pilot study, aspects of startling noises were investigated. For a typical synthetic broadband sound, i.e. uniform exciting noise, the influence of the following stimulus parameters on startling reactions were studied: (1) Magnitude of a level increase (5...40 dB, 10ms rise time) above a pedestal of 45 dB (2) Level increase of 30 dB for pedestals between 40 and 55 dB as well as 20 dB for pedestals between 50 an 65 dB (10ms rise time). (3) Rise times between 1 and 300 ms for a level increase of 35 dB above a 50 dB pedestal.

For the parameters considered in the pilot study, the magnitude of the level increase of a rising edge was found to be crucial for the startling reaction. Rise times between 1 and 10 ms lead to similar startling reactions, which were approximately halved for 200 ms rise time.

In a first approach to modeling startling reactions to synthetic noises, the increase in percentile loudness N_5 proves promising. Additionally, to predict startling of technical sounds, the onset rate of the loudness-time function seems to be of importance.

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1. INTRODUCTION

The evaluation of noise immissions can be assessed using the percentile loudness N_5 (e.g. Fastl 2000, Fastl et al. 2003, Stemplinger 1999). When applying this physically measured magnitude even effects like railway bonus or aircraft malus can be described in line with subjective evaluations (Fastl 2000). However, it is well known that sounds with quick increases in level can be particularly annoying (e.g. Spreng 1985, Fastl et al. 2007, Marshall and Davies 2007). Therefore, in a pilot study, aspects of startling noises were studied in particular for synthetic sounds as well as some technical sounds.

In this paper, results for the startling effects produced by synthetic sounds are given and described by means of the increase in percentile loudness. Moreover, for the description of startling effects elicited by technical sounds an assessment is proposed which uses in addition to the increase in percentile loudness N_5 also the rise time of the loudness-time function.

2. EXPERIMENTS

Experiments were performed by 14 subjects with normal hearing ability aged between 20 and 32 years (median 25.5 years). Sounds were presented diotically in a sound proof booth using electrodynamic headphones (Beyer DT 48) with free field equalizer according to Fastl and Zwicker (2007, p.7). Uniform exciting noise (Fastl and Zwicker 2007, p. 171) served as the basis for the synthetic sounds. Technical sounds were recorded in mono with a DAT recorder.

For the evaluation of startling effects the scale displayed in figure 1 was used. Each subject judged each sound four times in different sequences; from the resulting respective 56 data points medians and interquartiles were calculated. Before each experiment the subjects were presented some typical sounds for training.

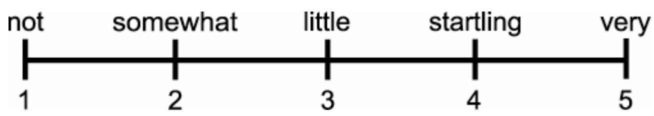

Figure 1: Verbal and numeric 5-step-scale used to rate the startling of sounds.

3. RESULTS AND DISCUSSION

A. Variation of the increase in level

In a first set of experiments, the magnitude of the increase in level above a pedestal of 45 dB was varied in 5 dB steps between 5 and 40 dB. The rise time was kept constant at 10 ms. Table 1 gives an overview of the stimuli used.

Table 1: *Stimuli used in experiment 1. Increase in level ΔL and percentile loudness ΔN_5 of the stimuli over a pedestal of 45 dB (4.6 sone). Rise time was fixed at 10 ms.*

Sound No.	L_{ped} [dB]	ΔL [dB]	N_{5ped} [sone]	ΔN_5 [sone]
1	45	5	4.6	2.4
2	45	10	4.6	4.6
3	45	15	4.6	8.1
4	45	20	4.6	12.8
5	45	25	4.6	19.6
6	45	30	4.6	28.2
7	45	35	4.6	40.3
8	45	40	4.6	54.5

In Table 1, in addition to the pedestal level L_{ped} and the level increase ΔL in dB the corresponding magnitudes in percentile loudness N_{5ped} and ΔN_5 are given in sone.

Figure 2 shows the startling effect as a function of the increase in level ΔL in dB (left panel) and as a function of the increase in percentile loudness ΔN_5 in sone (right panel).

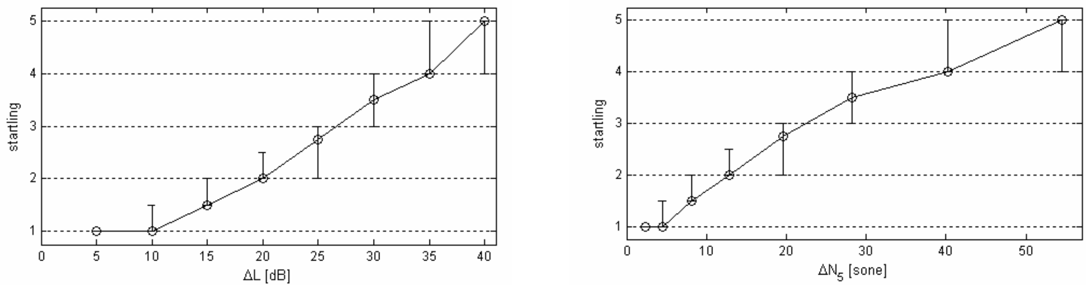

Figure 2: Startling effect of uniform exciting noise as a function of the increase in level (left) or the increase in percentile loudness N_5 (right). Pedestal L_{ped} = 45 dB or N_{5ped} = 4.6 sone. Rise time t_R = 10 ms.

The data displayed in figure 2 reveal that for an increase in level by 5 or 10 dB no startling effect (1) is observed. The corresponding increase in percentile level, N_5, amounts to 2.4 or 4.6 sone, respectively. This means that even an increase to about double the value of the pedestal loudness does not elicit a startling effect.

With larger magnitudes of the increase in level or percentile loudness, the startling effect increases almost linearly. Interestingly, an increase in level by 20 dB over a pedestal of 45 dB, which plays an important role in Germany for the assessment of industrial noise immissions (TA Lärm), elicits only little startling (2). With respect to percentile loudness the increase from 4.6 sone by ΔN_5 = 12.8 sone to 17.4 sone corresponds almost to a quadrupling of loudness.

B. Variation of the pedestal level

In this experiment an increase in level of 20 dB for pedestal levels between 50 and 65 dB as well as an increase by 30 dB for pedestals between 40 and 55 dB was realized. The rise time again was kept constant at 10 ms. Table 2 gives an overview of the stimuli used.

Table 2: *Stimuli used in experiment 2.*

Sound No.	L_{ped} [dB]	ΔL [dB]	N_{5ped} [sone]	ΔN_5 [sone]
1	40	30	3.0	21.1
2	45	30	4.6	28.2
3	50	30	6.8	37.7
4	55	30	9.7	50.3
5	50	20	6.8	17.4
6	55	20	9.7	23.3
7	60	20	13.6	31.4
8	65	20	18.9	41.5

The data displayed in figure 3 show the startling effect as a function of the maximally achieved level (left) as well as the increase in percentile loudness ΔN_5 (right).

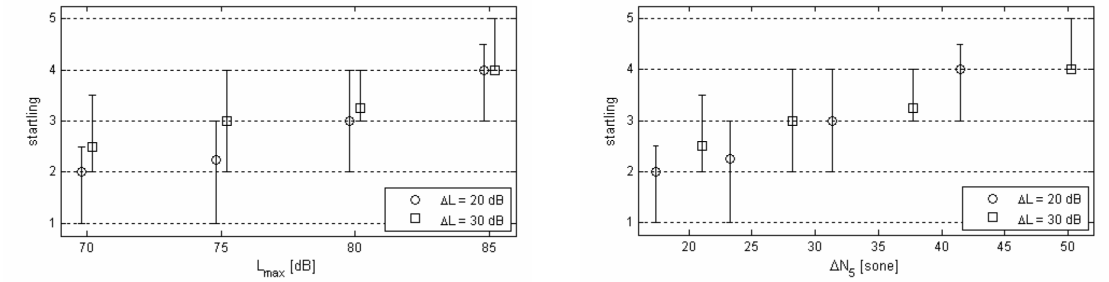

Figure 3: Startling effect of uniform exciting noise as a function of the maximally achieved level (left) or the increase in percentile loudness ΔN_5 (right). Level increase 20 dB (circles) or 30 dB (squares) as well as corresponding increase in percentile loudness. Rise time t_R = 10 ms.

In line with the data displayed in figure 2, data plotted in figure 3 show that a level increase by 20 dB from 50 to 70 dB elicits only little startling (2), whereas a level increase by 30 dB from 45 to 75 dB elicits a somewhat startling effect (3). The same increase in level of 30 dB from 55 to 85 dB is already startling (4). Interestingly, the same evaluation “startling” (4) is also obtained for an increase in level by 20 dB from 65 to 85 dB. Obviously, at high levels, the maximally achieved level seems to be more important than the magnitude of the increase in level.

Data displayed in the right panel of figure 3 indicate that an increase in percentile loudness N_5 from 9.7 sone by ΔN_5 = 23.3 sone to a total of 33 sone, i.e. by more than a factor of three, elicits only little startling (2). However, an increase by more than a factor of six from 9.7 sone by ΔN_5 = 50.3 sone to 60 sone leads to startling effects (4). As shown in figure 2, an increase of percentile loudness N_5 from 4.6 sone by ΔN_5 = 54.5 sone to 59.1 sone, i.e. by more than a factor of 12, leads to very startling reactions (5).

C. Variation of the rise time

In this experiment, the rise time was varied between 1 ms and 300 ms for an increase by 35 dB over a pedestal with a level of 50 dB. Table 3 enables an overview of the stimuli used.

Table 3: *Stimuli used in experiment 3.*

Sound No.	t_R [ms]	ΔL [dB]	N_{5ped} [dB]	ΔN_5 [dB]
1	1	35	6.8	52.8
2	5	35	6.8	52.8
3	10	35	6.8	52.8
4	20	35	6.8	52.8
5	50	35	6.8	53.0
6	100	35	6.8	53.7
7	300	35	6.8	53.9

According to the data shown in Table 3, the percentile loudness of the pedestal N_{5ped} is constant at 6.8 sone. Despite the fact that the increase in level was fixed at 35 dB, the increase in percentile loudness ΔN_5 gets somewhat larger for rise times above 50 ms: because of the slower rise times, within the time window for loudness analysis, marginally higher values of percentile loudness N_5 are obtained.

The data displayed in figure 4 show the dependence of the startling effect on the rise time t_R as well as the increase ΔN_5 of the percentile loudness N_5.

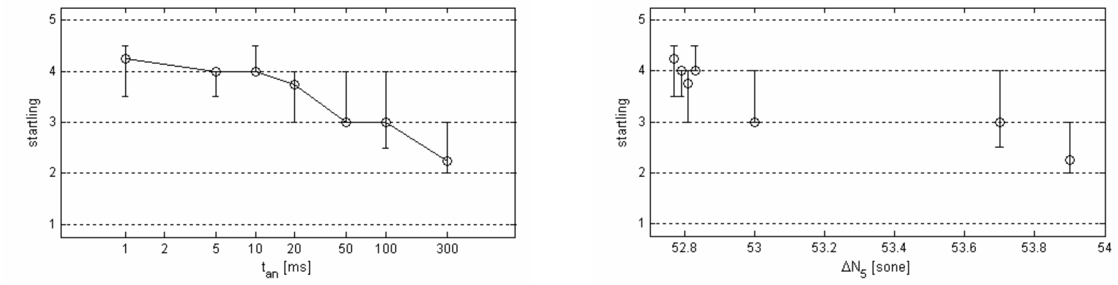

Figure 4: Startling effect of uniform exciting noise as a function of the rise time t_R (left) or the increase in percentile loudness ΔN_5 (right). Level of pedestal is 50 dB, increase in level is 35 dB.

Even for the shortest rise time of 1 ms, the startling effect reaches only “startling” (4), and not its maximum “very startling” (5). This result is in line with data shown in figure 3 for an increase in level from 55 to 85 dB although the data displayed in figure 4 refer to an increase in level from 50 to 85 dB. The left panel of figure 4 shows that for rise times between 1 ms and 20 ms, the startling effect is almost independent of rise time. However, for 50 ms, 100 ms, and in particular for 300ms rise time, the startling effect is considerably reduced.

The data displayed in the right panel of figure 4 indicate that for short rise times up to 20 ms the startling effect is almost the same for same increase in percentile loudness ΔN_5. However, for longer rise times, a marginal increase in ΔN_5 goes with a significant reduction in the startling effect. This result suggests that for sounds with short rise times, their startling effect can be described by the increase in percentile loudness N_5. However, for sounds with longer rise times (i.e. 50 ms and more), in addition to ΔN_5 presumably also the rise time has to be considered to describe their startling effect.

D. Outlook

The findings obtained for the startling effects of synthetic sounds were applied in a short pilot study concerning the startling effects of technical sounds. Table 4 gives an overview of the sounds used together with their pedestal percentile loudness N_{5ped} their increase in percentile loudness ΔN_5 as well as their rise time t_R.

Table 4: *Features of the technical sounds used in the pilot study.*

Sound No.	Description	N_{5ped} [sone]	ΔN_5 [sone]	t_R [ms]
1	Bicycle - bell I	3.4	16.9	45
2	Bicycle - bell II	4.0	19.6	45
3	Train passby	13.9	23.3	1000
4	Siren	33.2	24.1	30
5	Car horn	7.6	29.8	20
6	Motor-bike kick-start	8.9	37.9	265
7	Motor-bike passby	35.4	40.6	160
8	Grenade	6.9	64.1	1

In the first stage the startling reactions were determined experimentally for the sounds listed. The results were then compared with calculated estimates for the startling reactions. Estimates were based on the data from the earlier experiments with synthetic sounds.

A major determining factor for the startling reaction is the increase in percentile loudness ΔN_5. Figure 2 reveals that the startling reaction increases almost linearly with ΔN_5. Fitting a linear function to the data in Figure 2 leads to the linear approximation S_{lin} for startling reactions based solely on ΔN_5:

S_{lin} = 0.0662·ΔN_5+0.9035 for ΔN_5 < 61.9 sone
S_{lin} = 5 for ΔN_5 >= 61.9 sone

Additionally, the results in Figure 4 show that startling is – although to a lesser extent – affected by the rise time t_R of the stimuli in question. Sounds with a slower transition from minimum to maximum loudness elicit less startling than those with a faster transition. To account for that effect an additional weighting factor for sounds with rise times slower than 50 ms is introduced. It can be estimated from the data in Figure 4 and postulated as follows: Up to 50 ms, startling is independent of the rise time. For higher values of t_R the startling reaction decreases by approximately 10 % for every doubling of the rise time. This leads to the approximation S for startling reactions as indicated below:

S = S_{lin} ·(1.3912-0.1·ln(t_R/[ms]) for t_R > 50 ms
S = S_{lin} Otherwise

Applying both approximations to the technical sounds of the pilot study, and comparing the calculations with the experimental data, leads to the results displayed in Figure 5.

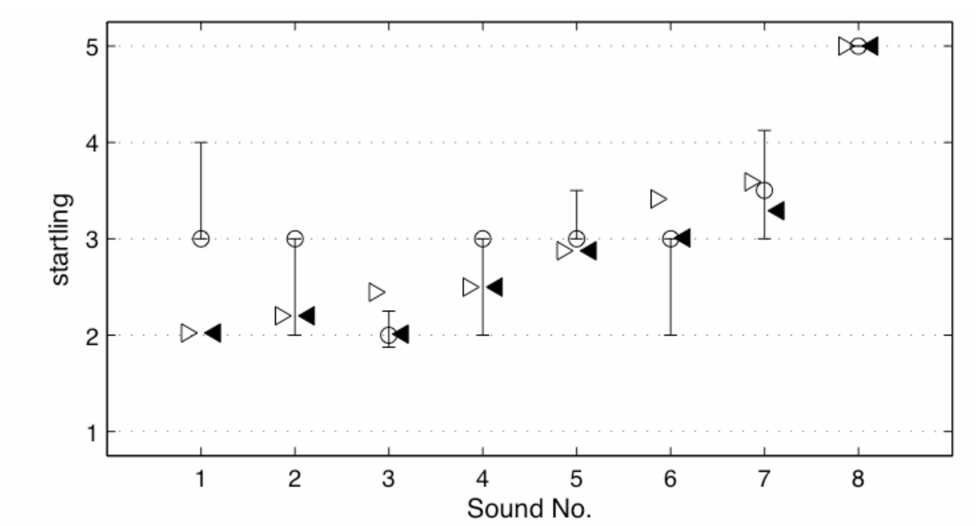

Figure 5: Startling effects of the technical sounds listed in Table 4. Circles and errorbars show medians and inter-quartile ranges for the experimental data. Unfilled triangles give estimates for startling based on increase in percentile loudness ΔN_5 only, filled triangles additionally consider the rise time of the sounds in the calculation.

The data displayed in figure 5 indicate that when only the increase in percentile loudness ΔN_5 is considered (unfilled triangles), the startling effects of four out of eight technical sounds can be described within the inter-quartiles. However, when in addition to the increase in percentile loudness ΔN_5 the rise time t_R is taken into account (filled triangles), the startling of six out of eight technical sounds can be described. For sound #1, even this combined description fails, whereas for sound #5, the description is very close to the median of the subjective evaluations.

4. CONCLUSIONS

In this pilot study it was shown that startling of noises from synthetic sounds can be described on the basis of the increase in percentile loudness N_5. For the description of the startling effects elicited by technical sounds, in addition to the increase in percentile loudness N_5, the rise time has to be taken into account. It is expected that with this approach, startling effects of many technical sounds will be able to be assessed in line with subjective evaluations. However, it was also found that for the sound of a bicycle-bell the predictions may be off by one category out of five.

ACKNOWLEDGMENTS

The authors would like to thank Ms. Jessica Monaghan for proof-reading this manuscript.

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