

# Yrkeshygienikeren

Nr. 2, 2007



## Skadelig 17. mai-støy?

*Noise-induced auditory damage in children*

Side 3



# Noise-induced auditory damage in children

Gerald Fleischer  
Auditory Research; University of Giessen School of Medicine



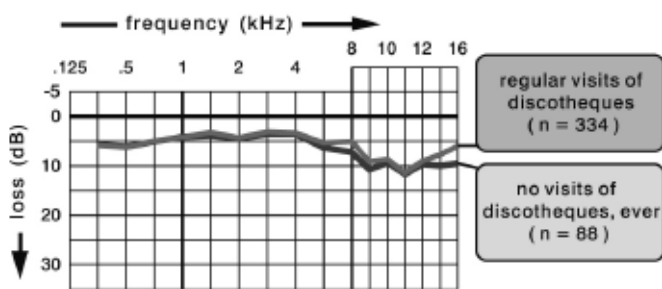
Our team is working on two major topics: One is the auditory **performance of entire groups** of persons, such as office personnel, construction workers, orchestra musicians, airline pilots, fire fighters, congenitally blind persons, nomads living without technical noise, and many other groups. Results on the auditory performance are compared and analysed using our newly developed method of auditory group curves [Fleischer and Müller (2005)], comparing individual hearing with normal aging of the ear. The other major topic is our **archive of acoustic impulses**. We systematically collect data on accidents, mishaps or attacks, that caused noise-induced damages. Victims and participants are questioned thoroughly as to the events(s) itself, and their auditory performance is measured, using primarily pure-tone audiometry up to 16 kHz. In nearly all cases powerful acoustic impulses have caused the damages. If it is possible the damaging events are re-enacted in the laboratory, using the same objects and arrangements, to determine the pressure-time history of the impulses. In this way it is possible to correlate the individual damage with the harmful impulse. We are determined to protect the ear, but in order to do so realistically and effectively, it is necessary to know what is harmful to ear and hearing. -

All told we now have roughly data on 10 thousand persons.

In Europe the average acoustic energy [  $Leq(8h)$  ] is being used at the workplace to avoid damage to the unprotected ear. It is based on ISO1999 and its concept that continuous noise is grinding the ear down. Results of an early study on the effects of **discotheques** (Fig. 1) revealed that young adults, not exposed to occupational noise, show no difference between fans and avoiders. Our data base on this aspect now contains information on about two thousand persons, but the results are the same.

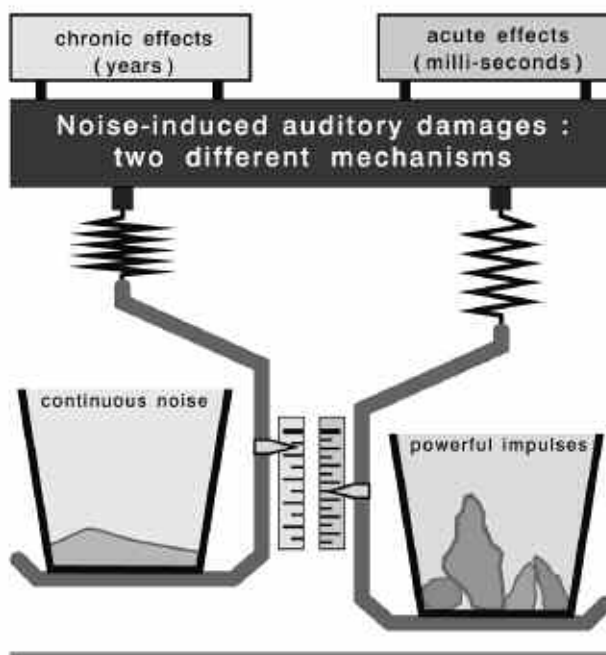
Looking through all our data we can say that powerful impulses close to the ear are responsible for most of the noise-induced auditory damages, (Fig. 2). Hence, it is important to fight impulses in order to protect the ear. The

Effects of discotheques on hearing



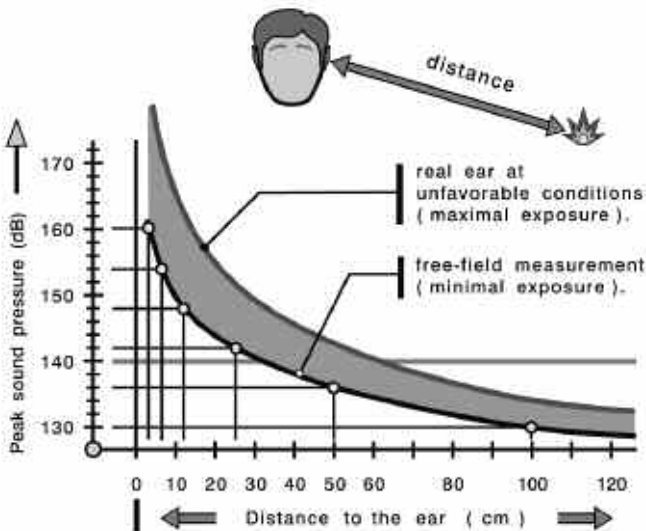
Men, aged 19 - 21 years, and not exposed to occupational noise.  
Data collected in Giessen, Germany, 1996/1997.

- Fig. 1 -



- Fig. 2 -

### Importance of the distance between ear and impulse



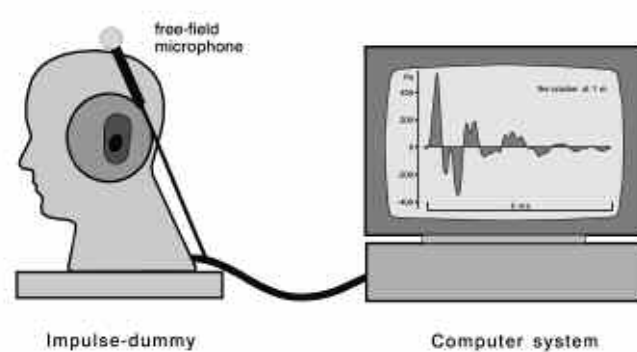
- Fig. 3 -

new regulations of the EU for noise at workplaces [EU-2003/10/EC] reduces the permitted level of continuous noise while still practically ignores the impulses. According to all our knowledge, this is a step in the wrong direction.

As far as hazardous impulses are concerned the important factor is the **distance between the impulse and the ear(s)**. Reducing the distance to the ear increases the peak level, because of simple physics, (Fig. 3). At free-field measurements there is only a little microphone close to the source of the impulse, so this condition is determining only the minimal exposure. However, if a person is present, its head is a barrier for the incoming pressure waves, increasing the sound pressure on the side of the impulse, and reducing it at the other side. Details depend upon the frequencies involved. Furthermore, the inner part of the outer ear, the outer acoustic meatus and the middle ear contribute because of resonances. As a result, the ear is exposed to much higher acoustic values than indicated by the free-field measurements. For an impulse, especially within the reach of the hands, its distance and location relative to the ear(s) is of utmost importance. Close to the ear even normally harmful devices can be very dangerous. Shots and impulses within a distance of 1 m to the ear should be measured with an impulse-dummy.

To get a hold on this problem, **impulse-dummies** have been designed that simulate these conditions. However, at the workplace and elsewhere, only free-field measurements are being used. They are easier to handle, but they ignore an often unwanted reality. For remeasuring hazardous impulses we use an impulse-dummy (Fig. 4), specially designed for powerful impulses. It can handle impulses of peak values up to 188 dB, and it is connected to a computer system that permits storage and a multitude of analyzing tasks. Since free-field measurements are officially demanded, we simultaneously take such measurements with a free-field microphone attached to the dummy. Such a system allows to re-enact the details between ears of the victim and the damaging impulse. While it is certainly an extremely valuable system it is nevertheless heavy and cumbersome. It would be a great step forward to have a measuring system so

### Impulse-dummy system for realistic measurements

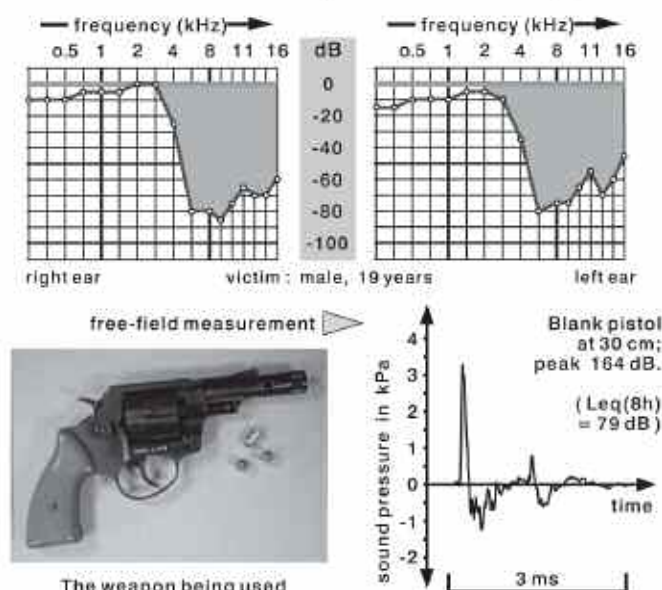


- Fig. 4 -

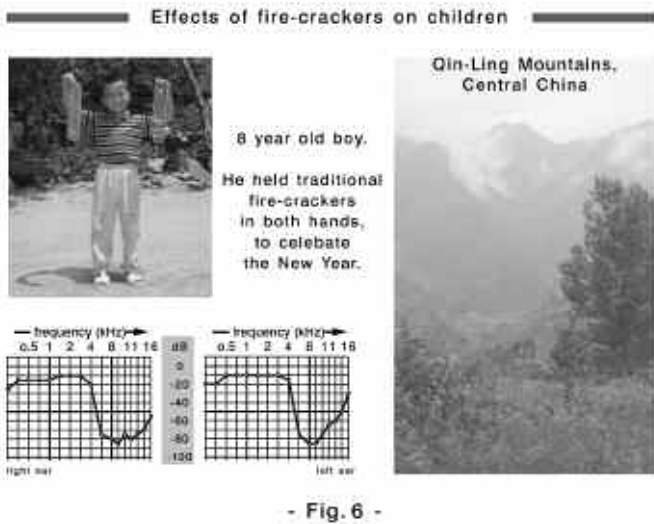
small that it can be used at the workplace for extended periods of time, under normal working conditions. We are working on it, but there is still systematic resistance by institutions and agencies in charge of occupational noise.

A typical example of a harmful impulse is the shot with a pistol or revolver (Fig. 5). The damaging event lasts roughly one thousandths of a second, creating an  $Leq(8h)$  of 79 dB, but causing massive damage to the ear. Hearing loss in the audiogram is characterized by a steep slope, starting at 3 kHz, and this is a typical indication of one or a number of very massive impulses. Such a damage-pattern in the audiogram is not caused by a high  $Leq$  over some time, but a clear sign for a strong acoustic impulse close to the ear. In this case, the distance to the ear was only about 30cm. In a study of damages caused by New Year celebrations in Germany, including the festivities for the new Millennium [Fleischer et al. (2003)], many such cases of hearing loss due to the use of blank pistols were found. Such dangerous weapons are freely available and the public is not aware of the danger to the ear. In most cases young men damaged their sense of hearing simply by using their own pistols to shoot into the air. Audiometry reveals whether they are right-handed or left-handed, since the ear on the side of the leading hand is closer to the weapon and thus usually shows more severe injuries.

### Attack with a blank pistol at close range

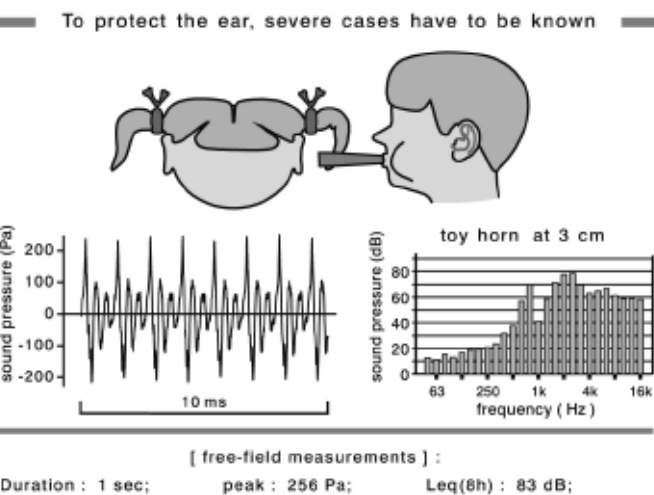


- Fig. 5 -



Such patterns are independent from a loud environment. In a survey of auditory performance in **remote parts of China** [Fleischer (2002)], in areas without any industrial or technical noise, we found lots of auditory damage caused by fire-crackers (Fig. 6) during celebrations of the new year. The boy shows how he used these traditional fire-crackers, and they are obviously close to the ear. Under these conditions, the peaks of the many short impulses at the ear are between 165 to 170 dB(lin), free-field measurement. - The auditory threshold in Fig. 6 below 3 kHz is not that good, but we know that this is not caused by the series of impulses, but by the ear that is not yet fully developed. - Studying nomadic people at the Tibet plateau shows the same results: many persons with damages caused by strong impulses close to the ear. In both these remote areas damages can be much more severe if home-made exploding devices are used to attract good luck.

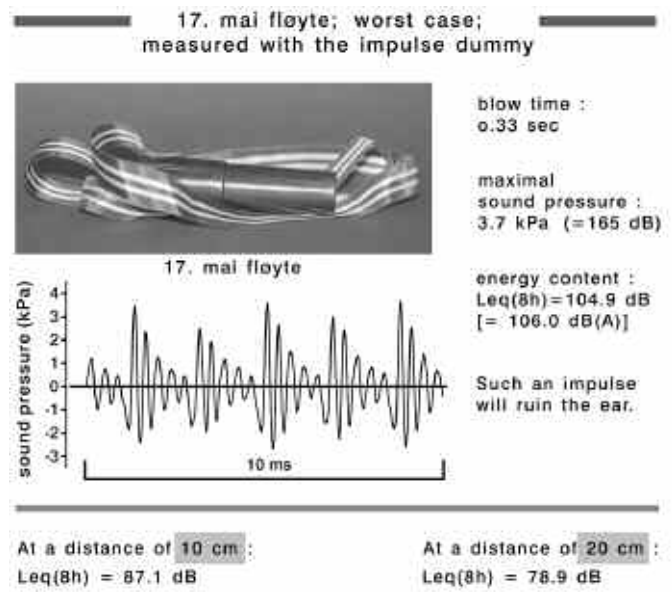
In Europe, **toy horns** of various types are being used by young children. Manufacturing of these plastic devices, made by injection moulding, may cost only a cent, and some are originally attached to a coiled paper snake. Usually no manufacturer is indicated so that eventual legal action is difficult. While some are tuned to lower frequencies and are less loud, others are not only extremely loud, but also tuned to higher frequencies, making them particularly dangerous. Used close to the ear (Fig. 7) the resulting impulses are harmful, causing

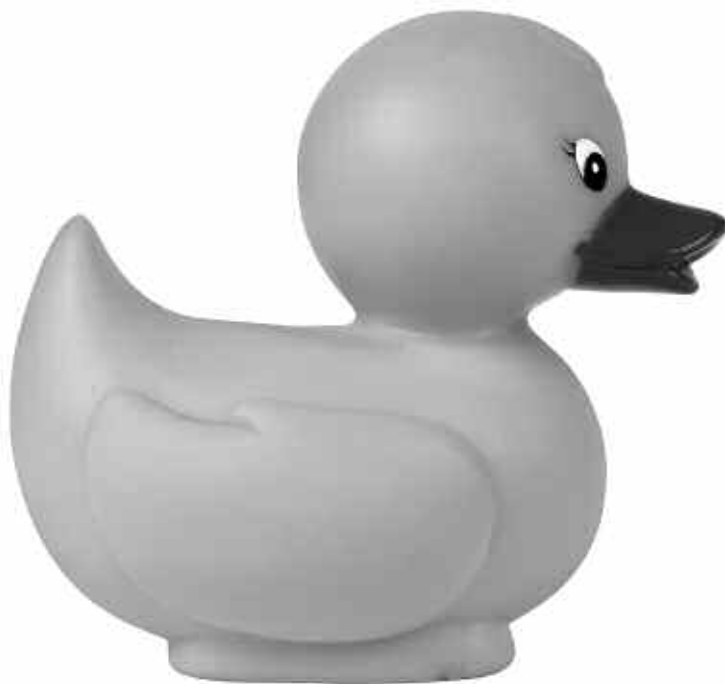


damaged hearing as well as tinnitus. One toy horn was extremely loud and dangerous, as shown by blowing directly into the ear of the impulse-dummy. It is possible to force the same amount of acoustic energy into the ear - in one second - that the ear of a person working at 85 dB(A) is receiving, accumulated over two years. In other words, using such a little piece of plastic makes it possible to force two years worth of occupational noise into an ear, in one blow. This particularly injurious little device was collected at a child's birthday party, and nobody knew how it got there. We used it for demonstration purposes, but earlier this year the vibrating tongue broke, making it functionally useless, but, of course, its signal has been recorded. - As seen in Fig. 7 the third-octave spectrum reveals that - in this case - most of the energy of the acoustic signal is at a few kHz, i.e. in a frequency range where the ear is most vulnerable to damage.

Fortunately most of these toy horns are not so excessively dangerous, but we cannot depend on it. One reason is that EU regulations for toys (EN-71) explicitly do not cover such mouth-activated devices. Manufacturers are free to sell anything to the unsuspecting public, no matter how dangerous it may be. But in order to protect the ear, it is necessary to know the details of harmful devices, and to face reality.

**A special topic is related to the 17. mai fløyte.** There are several different types of whistles or horns, and it is certainly the worst case, if someone is blowing right into the ear of a child, (Fig. 8). The impulse-dummy is designed to handle such an onslaught. One blow of the whistle shown can force about 100 days worth of occupational noise into the ear of a child, leading to massive damage. Of course, such devices should not be outlawed, but the general public - including children - should be made aware of the danger. It is about like razor blades. They are known to be dangerous, and they are handled carefully. - As a rule of thumb it can be said that the smaller these toys the more dangerous they can be, since they created high-pitched signals.





Similar toys are the cute (mostly yellow) **squeaking ducklets**. Nobody assumes that these can be injurious. Used directly at the ear of the impulse-dummy reveals that they are tuned to high frequencies and that the energy content of such an impulse is very harmful. Using such a squeaking ducklet at the ear of a baby can ruin the ear. One squeak results in an  $Leq(8h) = 92$  dB, but if a little brother or a grandmother wants to enjoy the baby with this toy it is likely that they use more than just one squeak. Furthermore, most of these squeaking toys have their energy concentrated around 3 to 4 kHz, making them maximally harmful. To cut it short, with a loud squeaking ducklet, used directly at the ear of a baby, that ear can suffer severe injury. Of course, the baby is crying, but nobody expects permanent damage to the ear. - It is not that rare that ENT specialists find - usually in teenagers - that one ear is hearing badly, but they have no idea what is responsible. At least part of these injuries will be caused by dangerous impulses of toys at or near the ear.

Whistles are also producing signals that are loud and high-pitched, and they should not be used close to the ear.

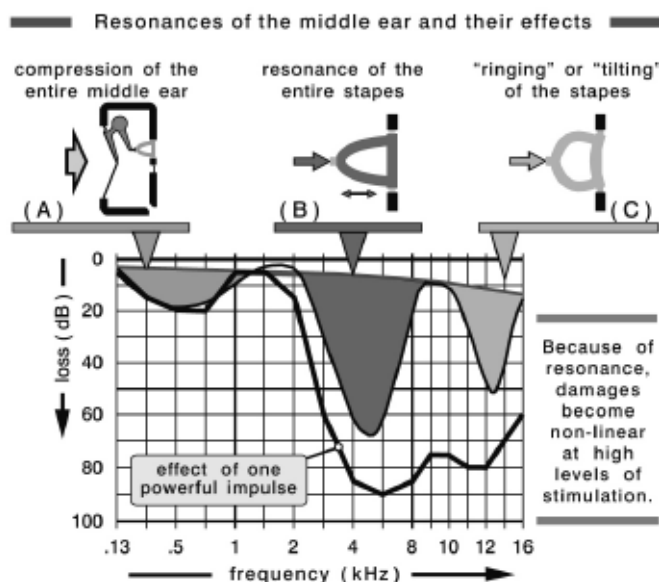
Another type of dangerous toys are **toy pistols**. Their impulses are very short, usually lasting only a millisecond. This is a strong disadvantage, because the auditory system needs about a tenth of a second to determine how loud a signal is. Such extremely short impulses do not appear as loud as they are. Our ear is underrating the danger corresponding to very short signals. Shots of toy pistols can cause permanent damage to the sense of hearing [Fleischer et al. (1999)] if used close to the ear. During the last decade the EU was forced to reduce the peak levels for these toys, but they are still not harmless. But there is another problem: globalization. Most of these devices come from East-Asia and manufacturers are not known to apply EU-regulations. At the port of entrance customs officials cannot check whether these toys comply to EU-regulations, because the relevant procedures are not only lousy, but they are complicated, awkward and cumbersome. If later damages

occur, and expensive measurements show that these devices do not conform to EU-regulations, everything has been sold. These regulations are not effective.

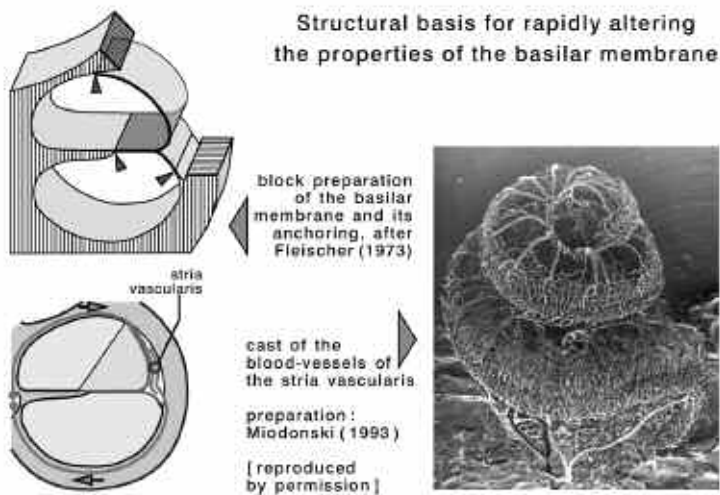
To improve this messy situation we are trying to find allies for the development and application of a device to be used by customs officials, at ports and airports. It shall have the size of a mobile phone, easy to use, and based on **measuring the worst case**, for whistle-like impulses as well as for the very short impulses of shots. If customs officials determine - within a minute - that the objects to be imported are too loud these products can be impounded until authorities decide what to do with them.

Going back to the ear, we want to look at the relation between impulses and the damage they cause, (Fig. 9). Comparing pressure-time history of harmful impulses to the corresponding hearing loss, as documented in the audiogram, **three types of resonances** are apparent. The most important is (B), the famous notch at about 4 kHz, which is caused by resonance of the entire stapes. At about 12 kHz to 14 kHz there is another vibrating mode of the stapes (C): it is ringing or tilting, if stimulated by such high frequencies. In all these cases the source of the impulse is within about a meter from the ear. Because attenuation of such high frequencies is so rapid that they cannot cover much longer distances. A third mode (A) is caused by a massive impulse with most of the energy concentrated at low frequencies. A shot of a battle-tank near by is an example, or a collision of two big objects at a construction site, such as an excavator accidentally hitting part of a truck. Such accidents are not common, and they are not related to toys or other small objects. The illustration shall give an overview on the mechanisms that are responsible for the various types of injury to ear and hearing.

There is another aspect that deserves some attention. Looking over the auditory threshold in persons who have been exposed to extremely high levels of occupational noise - without any auditory protection, for many years, or even decades - it is amazing to recognize that they are by no means deaf. It is apparent that there must be something we call „**survival mode**“ of the ear. Apparently



- Fig. 9 -



- Fig. 10 -

the ear is able to reduce its sensitivity if the environment is too loud. TTS (temporal threshold shift) is just one part of it. Anatomical details (Fig. 10) point to a mechanism that can be activated rapidly and long-lasting. Anchoring of the basilar membrane and vascular details of the stria vascularis point to a helpful cooperation. Increasing the blood-flow in specific parts of the stria vascularis - or throughout the cochlea - may reduce the sensitivity of the ear. Middle-ear muscles cannot protect the ear : for impulses they come too late, for continuous noise they fatigue way too early, and they have not effect at frequencies above about 1 kHz . Details in [Rabinowitz (1977)].

Data on documented impulses also show an interesting relation. At the same acoustic energy, the **very short impulses are much more harmful than longer ones**. Referee whistles are of interest from this aspect, because they are very loud and contain a lot of energy. Yet referees are hearing well, but persons exposed to such signals unexpectedly can suffer injury. It appears that the ear of the referee knows when the whistle will be blown, so that it can shift to the „survival mode“ in time. Anyhow, the auditory system is highly intelligent, with strategies for success and survival. It does not function like a grindstone, as implied by the simple Leq-mode of thinking.

**To summarize** it can be stated that the most important factor for noise-induced auditory damage in children is a small distance between impulse and ear. Toys, or other noise emitting objects that are normally not particularly dangerous can be very harmful if used directly at the ear, or very close to it. Especially dangerous are impulses that are extremely short or contain most of their energy at frequencies between about 2 kHz and 6 kHz. Most impulses can be anticipated, and hence preventive action is possible, if the persons involved are informed and motivated to avoid injury to ear and hearing.

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Contact: Auditory Research  
Justus-Liebig-University School of Medicine  
Aulweg 123; D-35392 Giessen; Germany  
phone : +49 641-99 47180 Fax : +49 641-99 47189  
e-mail : audio@med.uni-giessen.de