NOISE EFFECTS 98 – A SUMMARY

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On my first visit to Sydney, not only did I have the pleasure of participating in the 7th International Congress on Noise as a Public Health Problem, but I picked up some unexpected information. First, I learned that boomerangs are coming back. I learned that half-way around the world is actually further away than all the way around. And I learned from a taxi driver from Kenya that the best way to eat an elephant standing in your path is to cut it up in little pieces. The challenge of writing a short narrative that highlights the findings of well over 200 papers is enormous. My job is to eat an elephant.

We are learning to build mathematical models of the auditory system that are good enough to predict impulse-noise hazards. We are discovering that community exposures to potentially harmful noise can be successfully decreased. However, developing universally accepted noise-control and noise-exposure policies is almost always more political than mathematical. Decision makers have so many non-scientific forces to contend with, that policies need to be compromises. Research workers – and it doesn't matter whether they study auditory effects or non-auditory effects of noise – need to remember that maintaining public health requires strong political support. It's never enough to write a perfect proposal. It's never enough to get all the money you need. It's never enough to find a better measurement technique or to write the best predictive equation that's ever been seen. And it's never enough to define the exact maximum safe noise level for every foreseeable condition. First the researcher has to understand the political basis that will eventually determine whether a standard will be set and, if it is, what it will be.

Researchers and politicians have a basic obligation to keep each other educated about the factors each has to work with. The World Health Organization is pointing the way by looking at abatement, at forecasting and assessment of source controls, at setting standards, and at testing compliance with current standards.

Political decision-makers recognize that we need to be able to compare annoyance measurements made in one country with annoyance measurements made in another. But how can we do that job when our questionnaires are in so many different languages? Luckily, statistical scaling techniques are making it possible to find both equidistant values and comparable anchor points. The object is to create a universal annoyance scale, and it's nice to recognize that so far, the biggest problems are mathematical rather than political.

Obviously, variations derive from language differences – even the word *annoyance* in my native language and my native country conveys a meaning that the word may not carry when directly translated into another language. In fact, it may not convey quite the same meaning in another country whose native language is English or even in a different part of my own country. If we want French anchor points and scales to match Japanese anchor points and scales, for instance, we will probably have to expand the vocabularies we use to gauge people's reactions to noise. We will likely have to deal with *nuisance* and *disturbance* as well as *annoyance*. And we will have to ask subjects to scale their responses to noise rather than simply give us a dichotomous judgment. As ancient research shows, it's still unlikely that using more than five or six scale points will increase our accuracy or improve our knowledge.

Now to data. We know that the reaction to a noise from one source seems to be unaffected by noises from other sources. The reason may be as simple as the fact that adding additional equally-intense or less-intense sounds to an annoying signal increases the loudness only slightly. The reason may be far more complex than that. We've learned that low-frequency noise indoors is more annoying than other noises at the same loudness levels. Outdoors, near wind turbines, mid-frequency sounds, amplitude modulated at about 20 Hz, were the most acceptable. This modulation frequency is more in the *roughness* category than the *beating* category. Also, turbine spectra with enough high-frequency components to make a swishing or whistling sound were quite annoying. An intuitively satisfying study shows that home owners who bought houses in noisy neighborhoods are less disturbed by increases in the noise level than home owners who bought houses in quiet neighborhoods. Attitude clearly affects reactions to noise.

We are beginning to see more countries concerned about the monetary costs of noise and especially of transportation noise. Researchers and government officials have an opportunity to join together in figuring out optimum ways to measure those costs. Costs also influence how we do laboratory experiments. In that context, there's an intriguing finding from an Australian study – the ratings for 10-second signals are as reliable and accurate as the ratings for 2-hour signals.

One thing that fascinates me as we move in five-year increments from Congress to Congress is how measurement techniques change. For example, EEG is still used as a primary physiological measure of sleep quality, but more and more studies are using global measurements of activity. We've learned from interviews with a wide range of noise-exposed people that significant sleep effects occur only for adults in the age range between 21 and 40. Older people must be less sensitive to noise during sleep. Objective increases in sleep problems, though, were smaller than subjective ratings suggested they would be. Age, gender, and personal and work habits seem to matter more than the ratings.

The acoustics in 28% of American schools are bad enough to interfere with students learning and teachers teaching. A majority of schools in the UK have the same problem. Noise dose measurements in Danish kindergartens come out as high as 85 dB(A), and teachers complain of tinnitus. Noise and acoustic problems are the second most common school-environment difficulty in Sweden. Other countries are equally concerned about classroom noise. The biggest noise problems seem to be those that the students create themselves. They talk, they move around, they shift their chairs and tables. The noise levels seem worst in the backs of the classrooms. So my old teachers may have had the right idea when they moved the slower and more distractable students to the front of the room. But interestingly enough, despite the fact that they recognize that the greatest noise comes from people, teachers and students both say that they'd prefer going to school in a quieter part of the city.

In preschool, the quieter the classroom is, the better the reading readiness and language competence scores are. In the early school grades, chronic exposure to aircraft noise leads to reading deficits and long-term annoyance. Maybe it also reduces language mastery, cognitive processing, and memory, although one study shows that chronic noise may not affect long-term memory or motivation at all. On the other hand, children performed a vigilance task and a highly frustrating task – that's not a puzzle, but a completable task – did better when it was noisy than when it was quiet. But children who live in quiet areas (and whose sleep is therefore not disturbed by noise) make fewer errors in discriminating details and they complete more test items. One interesting confirmation of the noisiness of little children is that people who work in day-care centers often seek medical help for voice disorders, apparently because they have to speak loudly over long periods of time.

To move on to adult environments, we've learned that noise-created distraction is unrelated to the level of the sound and that it probably doesn't matter whether the distractor is speech or non-speech. Unpredictability and variability seem to be the distracting elements. So all the past reports that people adapt to railway noise much more easily than to highway noise make good sense. Train noise is more predictable.

If you're faced with the task of having to classify a sound emanating from something or someone, you will be handicapped if you can only use one sense. But that's exactly what happens with many visual-display systems. Relatively recently developed 3-D-audio displays used in conjunction with visual displays ought to help air-traffic controllers, pilots, trained observers, and others who are involved in search tasks, maybe even in noisy environments where they have to wear hearing protectors.

People who have to use hearing protectors in noisy environments do continue to complain that they can't hear what their coworkers are saying. Two approaches are being studied more closely than they have been. One is the attempt to select protectors that optimize speech understanding rather than noise attenuation. The other is to use active-noise-reduction headsets. When the noise level is extremely high, active-noise-reduction is probably the only reasonable choice. When the noise level is comparatively low, tuning hearing-protector response is likely going to help. But when we're dealing with the usual work-environment, decreasing attenuation may not be a very safe idea. An old solution may work better. Remember that we each select a level for our speech that depends on feedback to our own ears. Wearing hearing protection decreases the apparent noise level, so most of us tend to talk more quietly. Call it an inverse Lombard effect. We need to remember to say to workers, "When you put on hearing protectors, people can't hear *you*." They should all just raise their voices.

Now to a few practical points about noise and communication. The first one is that in a military tank where the noise contains high-level low-frequency components, the tank drivers select communication sound-pressure levels close to 110 dB. That's considerably more than the upward-spread-of-masking standards predict. You have to use Zwicker's masking curves in order to predict accurately the speech-to-noise ratios needed for good understandability. Next, in relatively quiet environments, speech probably conveys the best emergency information. But in noisy situations where complex signals might be misheard, simple shifts in pitch and in the rate of change of the signal lead intuitively to correct interpretations of what a helicopter pilot, for example, needs to do. Faster change means faster. Rising pitch means go up. And so on. Also, if you customize a standard active-noise-reduction headset to meet the signal requirements of someone with even a profound hearing loss, the user will hear less noise and better speech. That means that for comparatively little money, we may be able to help people who are currently unable to work effectively in noise.

We have every reason to believe that noise creates physiological changes outside the auditory system. And yet one interesting new finding is that if you think noise won't affect your health, it probably won't. Still, subjects who fill out questionnaires report increased physical and mental problems as a function of increases in high-level noise.

Let's get to actual physiological measurements. One study showed that office noise probably doesn't affect the quality of work, but it does raise catecholamine levels and may decrease motivation to complete challenging tasks. Another study, on sleep effects, showed that although noise creates changes in stress hormones, the changes adapt out. Most people present only small effects. High levels of traffic noise don't seem to change hypertension much at all. But moderately high levels may slightly increase the risk of ischemic heart disease. It may be that people who are particularly annoyed by the noise are at a higher risk. But today, there's no clear evidence. We've learned that workplace noise levels above 95 dB(A) are related to menstrual abnormalities. We don't know yet what the effects of hearing protection might be, but it should provide a valuable topic to study. Also, there's an interesting finding that noise sensitivity-not noise, but sensitivity to noise-is related to mental disturbance.

We need to see a lot more studies of the auditory and non-auditory effects of noise when other stressors are present. It would be particularly interesting to learn more about how commonly used drugs interact with noise, how heat and light and vibration interact with noise, how work interruption and complex mental tasks and fatigue interact with noise, how air and water pollutants interact with noise, and so on and so on and so on. An especially well done piece of work from China tells us that carbon monoxide may magnify the effect of noise on hypertension. But being old and male is still more likely to be related to hypertension than noise exposure is. Russian researchers have a fairly long history of studying physiological effects of noise and of interactions. A new Russian study hints at visual and autonomic changes when people are subjected to combined noise and heat. But the data suggest that we really have to see more multi-stressor studies with good controls.

Studies of noise-induced hearing loss are producing some fascinating information. For instance, we know that one effect of noise exposure is a kind of poisoning of the inner ear. It looks as if cell-killing proteins and other such chemical factors can be counteracted so we can treat or even prevent noise-induced hearing loss. Some of the suggested antitoxins may be difficult to get into living human cochleas, although some may be dropped onto the round window through the tympanic membrane. Probably infrequently. But injections or even oral doses of magnesium can increase levels in the perilymph. And that seems to reduce permanent threshold shift significantly. That's very exciting. We are blessed with some large-sample longitudinal studies that are already providing useful information and should continue to give us stable data for years to come.

We are also blessed with a new set of tools to measure and predict hearing damage: the several varieties of otoacoustic emissions. Emissions that are evoked by transient signals seem to be good and sensitive measures of outer-hair-cell deterioration. I am a little concerned about the predictive value of otoacoustic emissions because they are generally calibrated against temporary-threshold-shift data. Now TTS has proven to be a valuable tool. But we still don't have a clear, longitudinal demonstration that TTS predicts permanent threshold shift. With that in mind, the consensus is that if you measure otoacoustic emissions, particularly those that are evoked by transient signals, you can detect considerably smaller threshold shifts than you can with Békésy audiometry, you can do it a lot faster, and you don't need to be quite so fastidious about the acoustic environment in which you do your testing. One limitation to otoacoustic-emission testing is that current equipment is limited to just a couple of kinds of emission-evoking signals. We ought to try to learn more about the effects of differently shaped waveforms and envelopes before we decide that the kinds of signals we use today are adequate for the predictions we ultimately want to make.

Now let me talk a moment about theory and then about practicality. First, the equal-energy hypothesis is still with us as it should be. It works well. If it worked perfectly, then, for example, 20 short pulses of a sound at a given amplitude ought to produce the same threshold shift as 10 similar pulses but with the pulse duration doubled. But that doesn't happen. Maybe the reason is that the ear adds the energy of its own resonances to click-like signals. Maybe not. But the data show that if you make your impulses shorter or if you increase the number of short pulses, you'll get more temporary threshold shift than the equal-energy hypothesis suggests.

Now for the practical. Apparently a first-rate education program can save a large number of young ears. In Norway, extensive public information about the hazards of loud music has been circulated via television, radio, newspapers, teen magazines, and warnings on headsets. Pre-military high-frequency hearing loss among 18-year-old men increased from 15% in 1981 to 35% in 1987. Then, with the advent of the education program, it began to fall – to 31% in 1990, 25% in 1992, and so on down to 11% in 1996. In Sweden, comparable measurements have shown a fairly consistent 14% of young men with high-frequency losses. In 1993 in Britain, though, 45% of 20-year-old men had hearing losses. I don't know the Australian figures, but we've learned that Australian rock concerts are very loud. And the tested young people who work in them, either as musicians or as sound engineers, all had hearing losses except for one student who always used earplugs. On the other hand, age-corrected audiograms for symphony musicians look normal. That finding is a little troublesome to me. First, it's still likely that a significant proportion of the age correction actually reflects effects of noise exposure. If symphony musicians show the same age effects as people whose work and recreation put them in noisy places, they may indeed have some noise-induced hearing loss. Second, there's a long history of violinists who play several hours a day having progressive losses in their left ears. Because I've tested several of them myself, I worry that the current research didn't discover some.

The people who keep trying to force us sedentary types to exercise have a little more data to support their ideas. We've learned that although strenuous large-muscle activity during or immediately following noise exposure doesn't affect the amount of temporary threshold shift, it cuts recovery time by a significant fraction.

Not too many years ago, the only things that roared were waterfalls and windstorms and thunder. Then came engines and sirens and electronic amplifiers. It's an easy intuitive leap to suppose that the masking and the startle effects produced by cars zooming by or by jets passing overhead should interfere significantly with wildlife. Apparently that intuition is nearly worthless. For example, past researchers have pointed out the presence of thriving colonies of game birds beside major highways and contented cows grazing between the runways at major airports. Aircraft noise, even with sudden level changes, has no noticeable effects on osprey mating behavior. Large, flightless birds may run around together saying to each other, "What was *that*?" If there are effects on most bird populations, they are subtle, so we need samples that are much larger than anyone has put together so far. Wind-created background levels of low-frequency noise in the quiet ocean seem to be as high as the noise levels in major shipping lanes. So marine animals have probably always been subjected to as much communication interference as they are during this mechanical age. Sudden changes in noise created by ocean-surface activity may have a behavioral effect on whales, but some of the observed behaviors occurred without any rapid noise-level changes.

A couple of unrelated findings may be pointing the way toward some clinically useful information. First, some rats have cardiovascular systems that react to noise. Those rats show significantly greater threshold shifts than rats whose cardiovascular systems don't react to noise. Also, noise appears to encourage the growth of extra supporting cells and ganglion cells in newborn chicks. It's not clear whether those new cells provide protection against further noise damage, and it's not clear whether the newly grown cells ultimately might provide working hair cells that could create an auditory sensation. But the rat studies and the newborn-chick studies look as if we ought to find out more about the underlying processes.

My general reaction to the Congress papers and workshops is glowing. But while I have the opportunity to make them, I do have a few extra comments. First, we still face a problem that dates back before the earliest of these Congresses: much community-response research, some sleep research, and some physiological research continue to measure noise levels at varying distances outside test rooms rather than inside. As a result, we don't know what noise subjects received. We can't make successful comparisons of data from one study with data from any other study. We can't even compare the noise exposure of a subject in one study with that of another subject in the same study. Even if you correct for the distance between your sound-level meter and your listener, buildings have walls that are different from each other. And they don't just attenuate. They also filter. A wall in Fiji is likely to transmit sound differently from a wall in Sydney or a wall in Helsinki. We don't need to know how much sound the automobile or airplane makes. We need to know the sound that the subject hears. The common explanation for continuing to use doubtful signal measurements is the trouble and expense of valid metering or recording. But the fact is that the money spent on collecting 40 years of equivocal data could have bought lots of clean data based on actual noise exposures.

Second, as happens at many meetings, a few papers at this Congress discussed results as "borderline significant" or "nearly significant" or "marginally significant." One of my least-liked but most respected statistics professors used to remind us regularly that confidence levels are not data; they are criteria. He told us repeatedly that you choose a confidence level *before* you start work and then measure your results against it. If you do that, you'll never be tempted to use "borderline" or "nearly" or "marginally" significant. You'll just write "insignificant" instead.

Third, we haven't scratched the surface yet of the potential noise problems created by digital recordings. For example, a session at last year's Cannes Film Festival was called "Are Movies Too Loud?" They are. It's true that with digital recording, the noise floor can be dropped pretty much as far as you'd like. But a side effect is that theater operators can turn up the gain enough to get Godzilla to scream at sound pressure levels of 110 or 115 dB for five minutes or more.

I'm happy to see our consensus that we must work more closely with developing countries. ICBEN can offer those countries considerable help, and they can offer us new kinds of problems to solve and new groups of people to test.

Finally, an original and unique purpose of these Congresses has been to bring together three groups of interdependent people who seldom get to explain their needs to each other: representatives from the research community, from the industrial community, and from the governmental / political community. As in most years, a majority of the papers I've summarised were from researchers. And although I would always like to see even more industrial and governmental participants, both on the platform and in the audience, the opportunity to interact with Congress delegates from all three groups improves everyone's understanding of the problems we are all trying to solve. Congratulations to everybody and especially to the program committee. It's a real pleasure to find so much good work from so many parts of the world. And we have papers from countries that never participated before. That's very gratifying.

Many of the reports offered at this Congress are important, and several are exciting. New methods and novel approaches are providing us with a better grasp of noise effects and, sometimes unexpectedly, non-effects. I can hardly wait to hear what we'll know at the next Congress in 2003. It's an honor to thank everyone who made this serious work so much fun. Dix Ward, to whom this Congress is dedicated and who is, in a sense, the father of us all, would have been pleased. I am too.