Jets over Labrador and Quebec: noise effects on human health

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Objective: To determine whether the noise from low-level flights over Labrador and Quebec is harmful to human health.

Data source and selection: Search of MEDLINE for articles on the effect of noise, particularly impulse noise associated with low-level flights, and a search of the references from identified articles.

Data synthesis: The noise levels from low-level flights could affect hearing acuity. However, the more important consequences appear to be stress-mediated physiologic effects, especially cardiovascular ones, and psychologic distress, particularly in children. Subjective perception of control over the noise has been found to mitigate some physiologic effects.

Conclusion: There is sufficient evidence to show that the noise from low-level flights is harmful to human health.

Aircraft flying very low are invisible to radar. Low-level flights have been practised for military purposes for the past decade by the North Atlantic Treaty Organization (NATO) in Labrador and western Europe, particularly Germany. The proposed NATO Tactical Fighter Weapons Training Centre (TFWTC) in Goose Bay, Lab., would have increased the number of low-level flights to about 40 000 per year.¹ This proposal was withdrawn by NATO in May 1990, but not before it aroused the hostility of various groups concerned about the ecologic, sociologic, zoologic and legal ramifications and the health effects on the local people, particularly the Innu hunters. Among other things, concern focused on the effect of the noise on people and animals. Even though the plans for the TFWTC were cancelled, low-level flights at 30 m above the ground still occur out of Goose Bay. Under existing agreements with our NATO allies the number of flights may increase to 16 000 a year from the 6838 recorded in 1987.¹

This study was performed to determine whether the noise from low-level flights is harmful to people overflown in Labrador and Quebec.

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Because no research has been published on the effect of noise from low-level flights in Canada, recent medical literature was searched for related information on noise and health. Few appropriate papers were found through MEDLINE, but the citations in the Environmental Impact Study and the report of the Canadian Public Health Association (CPHA) Task Force on the Health Effects of Increased Flying Activity in the Labrador Area revealed many other references. Papers were selected that dealt with auditory and nonauditory effects of noise on humans, particularly noise associated with low-level flights.

**Effects on hearing**

Noise is measured in decibels, a logarithmic scale to encompass the vast spectrum of human hearing. An increase of 10 dB results in a tenfold increase in sound energy but only a twofold increase in perceived loudness.

To put noise levels in perspective, the threshold of hearing in youth is 0 dB. A whisper is about 30 dB, a jackhammer about 80 dB and a chain saw about 110 dB. A steady noise at 35 dB or a peak noise at 45 dB interferes with sleep. The threshold of discomfort in humans is approximately 120 dB, which is the noise level of a discotheque or an F4 fighter jet about 60 m away.

Exposure to loud noise can cause an auditory threshold shift; that is, the hearing threshold is increased so that a noise must be louder to be heard. A very loud noise can cause an immediate permanent threshold shift (PTS), and a less intense noise can cause a temporary threshold shift (TTS). Tinnitus and transient hearing loss after exposure to noise indicate TTS. A noise intensity loud enough to cause TTS may cause PTS after prolonged exposure, but the exact relation between the two is uncertain. For obvious ethical reasons TTS has generally been used as the endpoint in human experiments, although PTS has been used in animal studies.

Noise intensity that increases faster than 10 dB per second—impulse noise—is perceived to be louder than steady noise at the same intensity and can cause more hearing damage. Although the noise of a jet is steady a person overflown by one at a low level will experience impulse noise because the intensity peaks so rapidly. An ideal example of impulse noise is the sonic boom, an abrupt wave of noise caused by an aircraft breaking the sound barrier. Sonic booms are usually measured in pascals or pounds per square foot; these scales are not logarithmic.

In 1968 Rice and Coles, after exposing 12 young men to enormously loud, artificial boom-type noise up to 171 dB, found that TTS at levels up to 17 psf (814 Pa; about 152 dB) was "sufficiently small and transient" that noise from high-flying supersonic aircraft up to that level could be "disregarded as a potential auditory hazard." In another study 10 to 15 people were exposed to sonic booms whose peak positive pressure was 50 to 144 psf (2394 to 6895 Pa); this degree of pressure is equivalent to noise levels above 155 dB, which can cause immediate PTS. The subjects reported discomfort, fullness and ringing of the ears with the more intense booms but no distinct auditory pain. Hearing acuity was not measured, but the subjects did not report hearing loss.

These two studies have been used to demonstrate the innocuous effects of very loud noises on humans. However, they address neither the long-term auditory or physiologic effects of repeated loud noises nor the effects on the general population. They have been criticized by Reinis, Featherstone and Weiss, who showed the noxious effect of sonic booms on the microstructure of ears in different animal species; they were able to correlate this to hearing loss in rhesus monkeys. Hamernik and associates found that a combination of impulse and continuous noise was particularly destructive to hearing and sensory cells in the ears of chinchillas. Spreng investigated the physical damage to hair cells in animal ears and concluded that for safety the noise should not exceed 115 dB from a single daily overflight and 105 dB from multiple daily overflights.

It is, of course, dangerous to extrapolate animal data to humans, but this type of experiment cannot be done on humans. However, Laroche, Hétu and Poirier, in studying the effect of impulse noise on people, found that TTS occurred at peak levels as low as 102 to 104 dB. They also found that TTS was caused by impulse noise whose intensity was about 5 dB lower than that of steady noise. The effect of impulse noise on hearing is influenced by frequency (spectral content), duration, number of impulses, decay time and peak exposure level; individual susceptibility varies considerably.

The CPHA task force concluded that "occasionally low-level overflights produce noise levels that could be potentially damaging to hearing (139.02 [dB] perceived noise level), but generally they do not. Susceptible people exposed to such noise levels could be affected. However, the probability of this presently happening is very low because of the low frequency of the flights." One of the task force members has since pointed out that this might change if the frequency of flights increases.

**Other health effects**

Although hearing damage is probably the first
thing that comes to mind when discussing the effects of aircraft noise, it is not the effect that arouses the passions of those subjected to it. No one was standing on the Goose Bay runway at the cost of months of imprisonment to protest PTS!

What other health effects are there? Harris stated that "there is no unequivocal evidence that indicates that noise, of whatever kind, has an adverse effect on the health of man" and that "correlation . . . does not indicate a cause and effect relationship." Kryter, an acknowledged expert in the field of noise, stated that "there are no significant inherent adverse non-auditory physiological or psychological responses to sound or noise." He did not like "non-auditory" because all the effects of noise on humans are mediated through the auditory sense. They are caused not by sound waves directly affecting the autonomic nervous system but, rather, by physiologic stress induced by annoyance, interference with normal auditory functions and sleep behaviour, and fear. Nevertheless, Kryter accepted data showing that increased noise in residential areas was associated with (a) an increased number of people with physiologic and psychologic problems necessitating medical care and drug therapy, (b) an increased number of female infants who were preterm and of low birth weight, (c) an increased number of adults requiring admission to psychiatric hospitals and (d) decreased scholastic achievement by low-aptitude and middle-aptitude students in noisy schools. Kryter found the evidence of noise causing cardiovascular and blood pressure problems to be inconsistent.

Like Kryter, Westman and Walters also explored the use of "non-auditory," stating that "the auditory system and physiological responses to sound are inseparably connected. Therefore, all the effects of noise on the body mediated by the ears are 'auditory' effects." (Unfortunately no one seems to have come up with a better term for "noise effects excluding hearing damage.") Westman and Walters went on to say that "the evolutionary process has not allowed humans enough time to adapt hearing to sounds generated by loud modern noise sources. This means that the auditory apparatus is not prepared to cope with commonly encountered urban and industrial noise." They mentioned that over 40 studies showed "a consistent correlation between prolonged exposure to high intensity industrial noise and an increased prevalence of hypertension," the risk being greater with impulse than with steady noise. This correlation has been criticized because it could reflect other variables affecting workers in noisy industries. However, Westman and Walters quoted a study by Ising and Melchert showing "elevated diastolic and systolic blood pressures and urinary excretion of norepinephrine metabolites in brewery workers on days in which they deliberately did not wear hearing protective devices." Von Gierke and Harris found no correlation between hearing loss — presumably noise induced — and hypertension or cardiovascular disease in air force crew members. They took this as evidence against an association between prolonged noise exposure and chronic cardiovascular disease. However, it shows only that there was no correlation between hearing loss and cardiovascular disease. Only if audiologic vulnerability to noise were consistent in all humans, which we know it is not, would this lack of correlation have meaning.

In two studies investigators failed to find a higher incidence of self-reported psychiatric symptoms and drug use among adults in high-noise areas (near Heathrow Airport, London) than among those in low-noise areas. However, they did find that the incidence increased in relation to the level of annoyance the subjects reported, regardless of group. They postulated that there was a difference in degree of vulnerability to noise stress; those exhibiting a high degree of annoyance in the low-noise group were the most vulnerable, and those exhibiting a low degree in the high-noise group were "imperturbable." They calculated that some 16% of the population is sensitive to noise.

One of the most interesting and convincing studies, by Knipschild and Oudshoorn, did not involve blood pressure measurements, laboratory tests or public surveys. The authors simply looked at data on pharmacy purchases of certain drugs in two villages from 1967 to 1974. Both villages were quiet until 1969, when a new runway was built near one of them. The purchase of hypnotics and sedatives increased markedly in that village; in 1973 there was a decrease, but not to previous levels, when night flights were curtailed. Prescriptions for antacids (this was, of course, before cimetidine was available) and cardiovascular drugs, mainly antihypertensives, gradually doubled, with no subsequent reduction. There was no increase in drug purchases in the unaffected village.

All of these studies were of steady noise. Is impulse noise from low-level flights comparable? Probably not. Ising and Michalak, in a study involving elderly people, found that the increase in the systolic and diastolic blood pressures was much higher after exposure to noise with a fast rise time (as in low-level flights) than after exposure to noise with the same decibel peak but a slow rise time (as in jet take-off). The authors expressed concern about the risk of stroke among such people. This argument may be faulted because they extrapolated to the "worst-case" figures (out of necessity, given the ethics of human experimentation) and did not compare their results with blood pressure responses to
normal, everyday stimuli. Nevertheless, their study clearly shows that impulse noise from subsonic low-level flights has a much more noxious effect on blood pressure than does steady noise.

It is hard to escape the conclusion that there is a causal relation between exposure to noise and stress-related physiologic disease. The explanation by Kryter\(^26\) that these phenomena are due to “fear and annoyance” should not mean that they can be ignored or that they apply only to a neurotic sub-group. Kryter\(^27\) found that an 80-dB noise was more annoying if it was directly overhead than if it was off to one side. This is a reproducible phenomenon and does not reflect phobia or neurosis; it simply indicates that humans have reflexes and learned fear reactions to loud noises and rapidly approaching objects (physical intrusion), which cause annoyance. Annoyance may seem like a trivial word when higher decibels are involved, but it is the word commonly used in the literature for the subjective, unpleasant effect of noise.

**Annoyance**

Surveys of annoyance, on a scale of “Not annoyed” to “Highly annoyed,” may give quite accurate results. In fact, the correlation between noise levels from aircraft and reported annoyance is surprisingly good and is consistent in different nations. The proportion of people who are highly annoyed increases exponentially from under 10% at a day–night level (L\(_{dn}\)) of 55 (composite noise over 24 hours, with a 10-dB penalty for night-time noise) to over 60% at 75 to 80 L\(_{dn}\), at which point the curve approaches the perpendicular.\(^28\) Increases in the day–night level result in depreciation of high-priced housing and increases in physician contacts and fear of aircraft.

Although complaints increase with increased noise levels, there is an inherent weakness in using the frequency of complaints as a measure of annoyance. In Oklahoma City von Gierke and Nixon\(^29\) found that eight sonic booms a day at a median peak overpressure of 1.2 psf (57 Pa) elicited an initial onslaught of complaints, with “some degree of adaptation with time.” However, complaints reflect not only annoyance but also the expectation that they will have some effect. The decrease in complaints over time possibly reflected perceived futility as much as adaptation. At 1.6 psf (77 Pa) about one-fourth of the residents felt that they could not learn to live with eight sonic booms a day. Von Gierke and Nixon concluded from community surveys done in the United States that sonic booms of 1 psf (48 Pa) or more are unacceptable to a significant portion of the population. Similar results have been found in surveys done in several countries where the population has been exposed to sonic booms:\(^7,30\) 1 psf (48 Pa) is not bothersome, 1.5 psf (72 Pa) is annoying, and over 2 psf (96 Pa) is painful and elicits widespread public reaction.

Sonic booms and subsonic noise from low-level flights are impulse noises; however, sonic booms have additional annoying effects such as breaking windows. Much less research has been done on reactions to noise from low-level flights than on reactions to sonic booms.

**Perception of control**

Although Von Gierke and Harris\(^21\) found a lack of correlation between hearing loss and cardiovascular disease, they suggested that the positive attitude of the air force subjects toward the flying-related noise made them psychologically less vulnerable. The effect on noise-induced stress of the subject’s perceived control over the noise has in fact been studied. Hanson, Larson and Snowdon\(^31\) found that the plasma cortisol level increased in rhesus monkeys exposed to 100 dB. They then trained the monkeys to stop the noise by pressing a bar. In the experiment the monkeys were separated into four groups, each of which except the control group was exposed to 13-minute periods of noise. At the end of each period one group was able to press a bar to stop the noise, another had no bar to press and another could press a bar that had no effect. They noted a significant increase in the plasma cortisol level in the monkeys that had no bar to press or whose bar was ineffective; the level did not change in the other two groups.

Lundberg and Frankenhaeuser\(^32\) had similar findings in young male university students. They divided the subjects into matched pairs. One member of each pair was allowed to choose the maximum noise intensity (between 70 and 105 dB) that he was prepared to endure for the next 10 minutes; his partner had to endure the same noise level. They found that the catecholamine and cortisol excretion rates in urine, the heart rate, and the level of subjective effort and discomfort were lower among the subjects who chose the noise level than among the partners. Performance was not affected. The differences were consistent but except for the heart rate were not statistically significant. Singer, Acri and Schaeffer\(^33\) noted a delayed detrimental effect on performance and decision-making in humans who had no control over noise, as compared with those who had control; the latter could stop the noise by pressing a button but did not.

These data seem to indicate that the perception of control over noise, or the lack of it, is an important factor in noise-induced physiologic stress.

In Bargen’s report of effects of sonic booms on
rural Americans one of the most distressing effects that the subjects expressed was the sense of having the control over their lives taken away from them. They felt that having constitutional rights infringed upon by an agency, in this case the US Department of Defense, without public accountability "robs you of [your] peace of mind." 

Startle effect

Impulse noise with a rise time faster than 30 to 40 dB/s causes a startle reaction. A rapidly approaching jet produces impulse noise, and if it flies low and close to the observer it will elicit a startle reaction, as will a sonic boom.

The startle effect is not limited to aircraft noise and, in fact, is present from infancy. We test for it in newborns — clap your hands and the baby throws out its arms (Moro’s reflex). As adults we are all aware of the unpleasant effect of being startled by a sudden loud noise. Westman and Walters broke the startle effect down into three components: the orienting response, the startle reflex and the defensive response. They described and traced the neurologic pathway of each element and noted habituation or partial habituation of some components but not of others.

Does the startle effect extinguish with repetition? The answer depends on what you measure and how you measure it. For example, Pearson and Kryter found habituation to simulated sonic booms by measuring the heart rate; subjects were exposed to 10 sonic booms at random over 10 minutes in a laboratory setting. Von Gierke and Nixon quoted a study by Lukas and Kryter, who found partial adaptation to repeated simulated sonic booms by measuring electromyographic response. Spreng, however, using simulated noise from typical jet overflights (maximum 100 to 113 dB) in the laboratory, measured the heart rate but found no habituation with a pause of 3 to 9 minutes between exposures; each time the heart rate increased about 21 beats/min. With a pause of 25 to 60 seconds between exposures the increase in heart rate was only 11 to 15 beats/min; this was still well above the rate in response to noise from pile-driving or gunfire. Nixon and collaborators noted that the personnel operating the measuring equipment in their study all "expressed avoidance behavior consisting of involuntary ducking and flinching in response to the boom experience. . . . This behavior did not habituate during the three-day flight program. In fact, involuntary tensing or muscle set of the body in anticipation of booms appeared to be stronger for the later exposures than during the initial boom experience."

It appears that although habituation may occur in response to repetitive stimuli in the laboratory it does not occur if there is a significant time lapse between stimuli or if the noise is aperiodic. Where populations are subjected to sonic booms or low-level flights the noise is always aperiodic, and thus there is no habituation. Writing about his experience with sonic booms in Nevada Bargen stated that "when a sonic boom of 3 psf [144 Pa] or more hits my clinic, I invariably startle; this occurred once just seconds after I had finished using a spud to remove a metallic FB from a worker's eye — I shudder to think of what would have happened if the boom had been 15 seconds earlier. Now this thought or apprehension is always in my mind when doing a procedure of this nature" (personal communication, 1989).

Effect on children

The effect on children of noise from low-level flights, whether owing to the noise intensity or the startle effect or both, deserves special consideration. Both the lay and the medical press have given anecdotal accounts of the very distressing reactions of Innu children to noise from low overflights. Preuss and Bartels described acute terror and panic in children, screaming or freezing in infants and palpitations, shaking and dizziness in older children exposed to such noise in Germany. The reactions of the children from these two very different cultures — Innu and German — were remarkably similar. Preuss went on to describe behaviour problems in children in the heavily overflown district: increased sleep disturbance, bed-wetting, nail-biting, nervousness and slowed motor function; in addition, far from habituating, children and adults suffered worse reactions to noise from low-level flights if they had previously experienced it than if they had not. Curio and Ising found biochemical evidence of the physiologic distress of children in response to such noise by measuring the heart rate, the blood pressure and the urine cortisol level. The urine cortisol level in kindergarten children previously exposed to low-level flights was affected not only by a simulated overflight but also by the child's being told to expect a noise that did not in fact ensue.

Why should children be so severely affected by noise from low-level flights? Is it because their hearing is more acute, their nervous system is less mature or they are less experienced? Whatever the reason the effect on children is certainly a major factor in the demands of their parents regarding low-level flights. In Germany, where low-level flights are restricted to 75 m above the ground but are much more frequent than in Labrador, a major poll showed that 70% found the situation to be intolerable.
ble. One German child-care authority\textsuperscript{43} labelled low-level flights as "child abuse."

The Department of National Defence commissioned a $5.5 million environmental impact study of military flying activities in Goose Bay.\textsuperscript{1} Not surprisingly, it denigrated the effects of noise from low-level flights and even declared that there were no non-auditory health effects of noise below the level causing hearing damage. This assertion was based partly on the 1968 studies by Rice and Coles\textsuperscript{8} and Nixon and collaborators\textsuperscript{9} and partly on selective reports of experts such as Kryter,\textsuperscript{26} whose assertion that non-auditory health effects were due to "fear and annoyance"\textsuperscript{24} was used to imply that they were trivial. Among the deficiencies of the environmental impact study found by the Environmental Assessment Panel\textsuperscript{44} was its inadequate treatment of noise effects of military aircraft on humans.

Conclusions

Noise from low-level flights may have a mild deleterious effect on the hearing of people overflown, but this is overshadowed by other physiologic effects. Studies have shown that prolonged exposure to aircraft noise is associated not only with annoyance but also with stress-mediated physiologic changes such as hypertension. The degree of change may be mitigated by the subject’s sense of control over the noise.

People overflown by low-flying aircraft are exposed to loud impulse noise, which has particular consequences such as the startle effect. Some of the physical manifestations of the startle effect have been shown to diminish with repeated exposure in the laboratory setting but not with aperiodic exposure, as in the real world. Nevertheless, in a few studies people have been shown to survive extraordinarily loud sonic booms without apparent ill effects.

Studies in Germany, where low-level flights are much more frequent than in Canada, have shown that children are at particular risk of physiologic and psychologic damage from the noise produced.

It is difficult to identify what research should be done. As Balfie and Andersen\textsuperscript{45} pointed out, "assessment of impacts commenced long after low level flying began so appropriate baseline data may not exist." In West Germany research into the effects of low-level flights on humans ended in 1987, when the Research Council at Bonn University declared it to be unethical. Nevertheless, there seems to be enough evidence to conclude that noise from low-level flights in Quebec and Labrador is injurious to human health.

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References

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