Sozial- und Präventivmedizin Médecine sociale et préventive 19, 217–220 (1974)

The Sonic Boom – Effects on Humans

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Supersonic aircraft produce a boom which might startle the exposed population. It is important to analyze the long term consequences of the sonic boom.

1. Introduction

The appearance of civilian supersonic aircraft projects a number of years ago caused an increasing interest in the effects of sonic booms generated by such planes. Even if the development of supersonic aircraft has been slower than predicted, due to technical and economical difficulties, their importance will probably gradually increase within the next two or three decades. In addition, military aircraft have been flying supersonically over several years.

As the sonic boom thus constitutes a part of the general noise pollution, a knowledge of its effects on humans is required in order to provide a basis for control activities. These can include actions such as total ban on supersonic overflights over land, such as is the case e. g. in Switzerland or the establishment of special supersonic corridors, mainly over sparsely populated areas.

In the following a short review will be given of the various exposure effects that are encountered when humans are exposed to sonic booms. A general review of the problems involved has been presented at a recent symposium [3].

2. Technical characteristics

A sonic boom will be created when an aircraft moves at speed exceeding that of sound (> Mach 1.05). At this speed the pressure fluctuations due to the movement of the aircraft, which radiate in all directions during subsonic flight, come together in the form of shock waves. One such shock wave is created by the front part of the aircraft and is characterized by an increased pressure. Other shock waves are created along the irregularities of the body, but are usually of lesser magnitude. A final shock wave with negative pressure is created at the end of the aircraft. The pressure fluctuation of a typical sonic boom is illustrated in figure 1.

The shock waves appear like bow-waves from a boat proceeding through water. They will thus hit the ground after the passage of the aircraft. They will also be formed continuously as long as the plane proceeds in supersonic speed and are not confined to the moment when the plane penetrates through the "sound barrier".

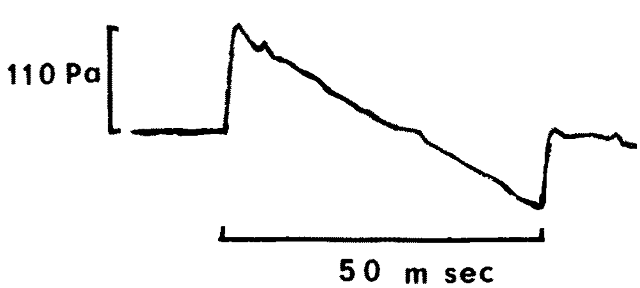

Figure 1
Pressure fluctuation of a typical sonic boom (N – wave). Time from Pa to P max. 1 m. sec.

The strength of the boom depends on the size of the aircraft and its altitude. The speed of the aircraft is of less importance. The strength (i. e. the overpressure of the shock wave) is expressed in Pascal. The width of the sonic boom carpet is determined by the altitude and the meteorological conditions. Due to the refraction of the shock wave in the atmosphere a distinct boarder line is present, outside of which no sonic boom phenomenon can be heard.

The human will perceive a sonic boom like a sharp, dry crack, a noise likened to distant thunder or a low rumble, all depending upon the intensity of the boom. Booms at about 20 Pa are perceived like thunder in distance. Levels of 20–60 Pa will cause an increasing noise which is sharper and at 80–200 Pa it is equivalent to a detonation of artillery fire or thunder very close by. Military fighters in the Mirage category at about 10,000 m altitude, will cause booms of about 60 Pa. The Concorde at cruising altitude will create booms ranging from 60 to 120 Pa.

3. Effects

Like other sounds with a sharp wave front, the sonic boom will cause certain specific effects in addition to the traditional noise exposure effects. The effects after sonic boom exposure have been studied both in laboratory and field experiments, using real sonic booms as well as booms produced by different simulators.

Experience has demonstrated that the main exposure effects in humans are the appearance of the startle response, disturbance of ongoing activities and disturbance of rest and sleep [3]. The presence of these primary reactions might secondarily lead to the development of annoyance reactions in the exposed population.

The energy contained in the boom is not sufficiently high to cause a temporary or permanent hearing loss, nor will it induce any direct traumatic effects on the body.

3.1. Startle responses

Exposure to sonic booms might initiate a startle response in the exposed subject. This response is characterized by a startle reflex with contraction of the muscles around the eyes, in the limbs and the eyelids [7]. This is followed by temporary acceleration of the heart beat and temporary increase of the blood pressure. These changes in the circulation system are very small and are only detectable a few tenths of a second after the exposure [6]. The startle reflex in itself is difficult to supress and the degree if habituation is relatively low. This reflex might be accompanied by an orientating response, where the subject inadvertedly turns the head and his attention towards the location of the noise.

The appearance of startle responses in persons exposed to sonic booms has recently been studied in a field experiment. Test persons were observed during overflights with military aircraft at different altitudes, and the extent of startle reactions was determined in relation to the intensity of the boom [6].

It was found that the extent of the reaction in a single test subject was not related to boom intensity, in that certain subjects showed the same reaction to booms of both high and low levels, whereas others did not react even to extremely high boom levels. However the number of the persons in a group that reacted was found to be related to the level. The degree of reaction within a group can thus be used as an exposure criterion when dose-response relationships are to be established.

It was found that boom levels of around 50 Pa caused very little reaction. When the level reached 100 Pa the extent of reactions increased and at levels of around 300 Pa practically all the subjects reacted to the boom. A summary of the results is given in figure 2. These experiments also demonstrated a tendency of habituation after exposure to more than 10 sonic booms.

Essentially the same findings have been reported from experiments where subjects were exposed to boom from a sonic boom simulator with a very realistic boom.

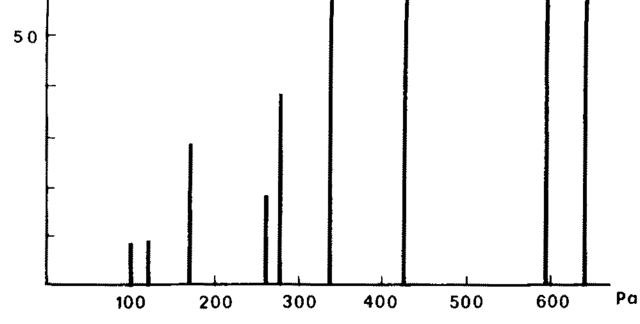

Figure 2
Startle reaction in groups of subjects exposed to sonic booms of varying intensity. Response is percent respondants in each group.

It has been postulated that the presence of a startle reaction also implies that ongoing activities were impaired and that the involuntary muscle contractions would lead to deleterious effects on certain critical ongoing activities. Only a few experiments have been performed to study this problem, where the effects of boom exposure on persons performing a complicated tracking task have been evaluated. These studies generally show that the effects are small and that they only deteriorate the performance of very complicated precision tasks. The results do thus not indicate that relatively gross muscular movements such as driving a car would be affected by the boom exposure [5, 8].

The startle response will also cause the attention to be derived from an ongoing task. It has been shown in experiments with test persons that performance of a complicated visual test might be affected so that the subjects interrupt the ongoing test momentarily. The length of this interruption has been shown to correlate to the boom level. Effects have been demonstrated already at boom levels of around 60 Pa [8].

3.2 Sleep disturbance

Due to its sudden nature and relatively high intensity in comparison with other night sounds, the sonic boom has a great potentiality for awakening effects. This was demonstrated already in the study performed in Oklahoma City in 1964, when military aircraft overflew the city at regular intervals through a 6 months period, creating sonic booms of up to 70 Pa. 20 % of the population in the study reported interference with their sleep although no night exposures were performed [1].

The major part of sleep effects studies has been performed in laboratory conditions. The drawbacks from such studies are that a relatively small number of subjects can be studied and that the conditions are different from those normally present in the subject's regular environment. Also, in several of these studies sonic boom simulators with poor technical characteristics have been used.

Results from these studies generally indicate that boom levels of 60–70 Pa have effects of sleep. Differences have been demonstrated between reactions among males and females, as well as between different age groups [2].

Only one limited field experiment has been performed. In this, military aircraft flew over a soldier population and a rural community at 4 a. m. on irregular intervals through a 3 months period. The booms created were of an intensity of around 60 Pa. In the military population around 10 % of the exposed persons were awakened, whereas in the civilian population where the reactions were evaluated with the aid of a social survey, between 50 and 60 % reported sleep disturbance [4]. The above studies of sonic booms effects on sleep have been performed under conditions where the environmental noise of other sources has been low. It has thus not been possible to determine, if masking effects are caused by other noises e. g. traffic noise.

3.3 Annoyance

Annoyance can be generally defined as a feeling of displeasure associated with any agent or condition realized or believed by an individual or a group to be adversely effecting them. The degree of the exposure itself as well as intervening psycho-social variables determine the occurrence of an annoyance response among exposed individuals.

Annoyance reactions in a population exposed to environmental agents are usually evaluated using social survey techniques. Provided these are performed according to established principles, the results are reproducible and represent useful criteria for public health purposes.

Only a limited number of social survey studies on annoyance after exposure to sonic booms have been reported. The largest annoyance study was performed in the Oklahoma City study, where during a 6 months' period, 1253 booms were generated over the city. The boom levels varied from 25 to 90 Pa. Almost all persons interviewed had perceived the sonic boom and could report their reactions to the exposure. 56 % of the respondents indicated serious annoyance and 38 % indicated that startle reactions were present [1].

Subsequently, more limited studies have been performed in France, Sweden and England. In an experimental 10 day exposure with 1–6 booms per day, with a level from 5 to 95 Pa, 5 % of the interviewed population reported that they were "very annoyed" by the booms [6].

4. Comments

When available information on sonic boom exposure effects is going to be evaluated for public health purposes, severe limitations become apparent. As a situation with regularly flying civilian supersonic aircraft does not exist today, the laboratory and field studies performed had to be designed to simulate the conditions of such an exposure situation. Even in an extensive study like in Oklahoma City, the experimental factor was always present and might in addition to the press coverage that was given the experiments have influenced the results. Field experiments of shorter duration also represent an exposure that is very different to one with regularly flying supersonic aircraft. It thus appears difficult at the moment to assess the usefulness of the annoyance data which have been produced, and it is probably of more interest to evaluate the effects on primary reactions such as startle and sleep.

Although experimental conditions vary, there seems to be a fairly good agreement that effects will start to occur at boom levels of around 50 Pa. The effects are initially rather limited within the exposed group, but as levels increase up to 100 Pa the extension of the effects will increase. At levels of around 300 Pa both sleep disturbance and startle reaction become apparent among the majority of the exposed subjects.

Of particular interest is possible habituation. In this respect data is very limited as well. Habituation has been demonstrated to occur in experiments where the startle reaction has been evaluated using a rather simple test and at exposure levels around 100 to 200 Pa. This would be in agreement with experience from other types of impulsive noises. At higher exposure levels, the habituation effect is less marked and the startle reflex will occur also after several years of exposure.

There is also some evidence that the habituation of the startle response is associated with the degree of difficulty of the test being used to evaluate the response [6]. It is furthermore probable that the degree of habituation might be different when individuals are exposed in the normal surrounding as compared to when they are tested under laboratory conditions.

For the evaluation of the sleep disturbance effect, the attenuation of normal buildings and the influence of background noise become of importance. These questions have not yet been studied in sufficient detail

In summary, experience from available studies makes it possible to define several important effects in humans due to sonic boom exposure. Although the information is incomplete, preliminary dose-response relationships can be established. Certain of the effects encountered are found also after exposure to other noises, such as ordinary traffic noise, noise within buildings, from construction sites and overflying aircraft. Other effects are specifically related to the physical characteristics of the boom.

Although additional research is needed and should be encouraged in view of the expected future increase of this exposure agent, available data can be used by public health authorities to establish exposure standards.

Summary

The effects of sonic booms on humans are reviewed. The most important effects are the development of startle responses, disturbance of ongoing activities, interference with sleep and annoyance. The information available on the occurrence of these effects is reviewed with special emphasis on dose-response relationships. The application and limitations of available information for public health purposes is discussed.

Zusammenfassung

Der Überschallknall

Die Wirkungen des Überschallknalls auf die Menschen werden beurteilt. Die wichtigsten Wirkungen sind Erschrecken, Arbeitsunterbrechungen, Schlafstörung und allgemeine Belästigung. Die verfügbaren Informationen über diese Wirkungen werden beurteilt. Spezielles Gewicht ist auf das Verhältnis zwischen der Dosis und der Reaktion gelegt. Die Anwendung und Begrenzung der vorhandenen Informationen für die Volksgesundheit werden diskutiert.

Résumé

Le bang sonique

Il s'agit d'une révision des effets de l'exposition au bang sonique chez l'homme. Les effets les plus importants sont la réaction de sursaut, l'interférence aux diverses activités, le dérangement du sommeil et le développement de la gêne. Les données à disposition relatives à ces effets, ont surtout été évaluées au niveau de la relation entre la dose et la réaction. L'utilité et la délimitation des informations disponibles pour les autorités de la santé publique ont été étudiées.

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