TRAINING FOR HEALTH CARE PROVIDERS

[Date ...Place ...Event...Sponsor...Organizer]

CHILDREN AND NOISE

Children's Health and the Environment

WHO Training Package for the Health Sector

World Health Organization

www.who.int/ceh

1

<<NOTE TO USER: Please add details of the date, time, place and sponsorship of the meeting for which you are using this presentation in the space indicated.>>

This presentation on Children and Noise is part of a comprehensive set of training materials for health care providers on children, the environment and health.

<<NOTE TO USER: This is a large set of slides from which the presenter should select the most relevant ones to use in a specific presentation. These slides cover many facets of the problem. Present only those slides that apply most directly to the local situation in the region. It is also very useful if you present regional/local examples of noise prevention programs, if available, and choose local relevant pictures.>>

CONTENTS

Children and noise

LEARNING OBJECTIVES

To **understand, recognize** and **know**

1. Definition and characteristics of sound and noise
2. Sources and settings of noise exposure
3. Adverse effects of noise exposure
   - On physical health
   - On psychological health
   - On cognition
4. **Weight of the evidence of the harm to children**
   - **Special vulnerability of children**
   - **Various noise exposure scenarios in settings where children develop**
5. Interventions and preventive strategies

These are the learning objectives for this module. After the presentation, the audience should understand, recognize and know

<<READ SLIDE>>

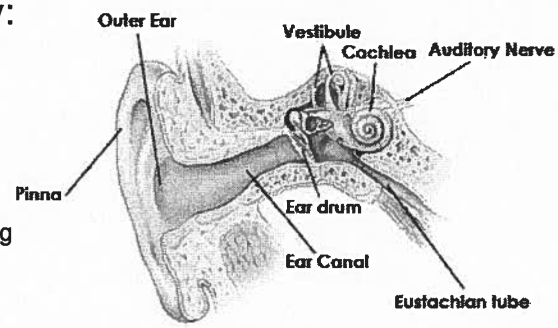
CONTENTS

Children and noise

DEFINITION: SOUND AND NOISE

Sound is characterized by:

- ❖ Vibration
  - Frequency (**Hz**)
  - Intensity (Pa or **dB**)
    - Decibel scale logarithmic
    - Begins at threshold of hearing
- ❖ Periodicity
- ❖ Duration



NASA

"Noise is an unwanted or objectionable sound"

5

What is sound? Sound is a mechanic vibration propagated by elastic media (as air and water) which alters the pressure displacing the particles, and can be recognized by a person or an instrument.

Vibration and noise can never be separated but vibration can exist without audible noise.

Sound is characterized by its intrinsic characteristics:

•**Vibration:** Sound is a mechanic vibration, expressed as a combination of pressure (Pascals, Pa) and frequency (Hertz, Hz)

•**Frequency** or pitch is the number of cycles per second (Hertz, Hz or kilo Hertz, KHz).

•**Intensity** or loudness is the "level of sonorous pressure" and is measured in Pascals (Pa) or decibels (dB). The audible spectrum of the human ear is between 0.00002 Pa (corresponds to 0 dB) and 20 Pa (corresponds to 120 dB). The intensity of human speech is approximately 50 dB. Decibels are used for convenience to express sound on a compressed, logarithmic scale in the human audible spectrum.

•**Periodicity:** describes the pattern of repetition of a sound within a period of time: short sounds that are repeated.

•**Duration**: is the acoustic sense developed by the continuity of a sound in a period of time, for example music, voice or machinery.

What is noise? Noise is an unwanted or objectionable sound. Generally, the acoustic signals that produce a pleasant sense (music, bells) are recognized as "sound" and the unpleasant sounds as "noise" (for example: produced by a machine or airplane). It can be a pollutant and environmental stressor, and the meaning of sound is important in determining reaction of different individuals to the same sound. One person's music is another's noise.

The human ear is an instrument that detects vibration within a set range of frequencies. Air, liquid or solid propagates vibration; without them, sound does not exist. Sound does not exist in the vacuum. The higher the level of pressure of the sonorous wave, the shorter the period of time needed to be perceived by the ear.

Why are not all vibrations audible?

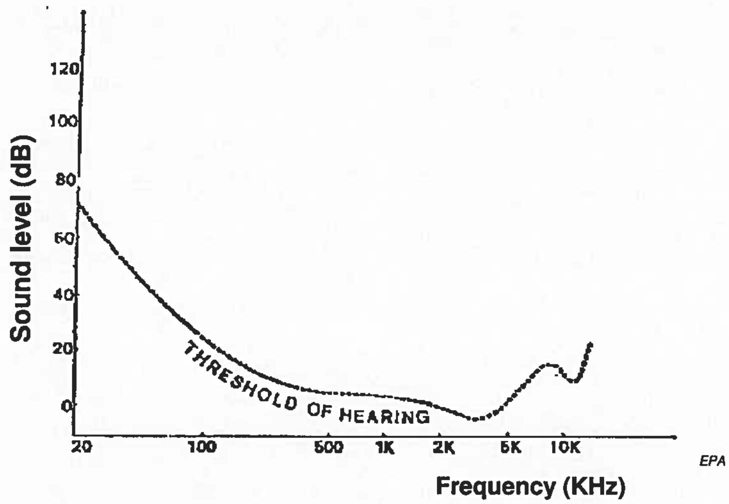
The ear is a frequency analyzer. The eardrum separates tone and conduction in two different ways: by the nervous system and by the bones. The nervous system connects the cochlea to the temporal region of both hemispheres of the brain. The cochlea perceives vibration transmitted directly from the bones of the head.

Picture:

•NASA

Children and noise

THRESHOLDS OF HUMAN HEARING



6

Why is noise sometimes inaudible?

Threshold of hearing is defined as the minimum efficient sonorous pressure (Pa or dB) that can be heard without background noise of a pure tone at a specific frequency (Hz or KHz, cycles per second).

The human audible frequency range is from 20 to 20.000 Hertz (Hz). Frequencies out of this range are not detected by the human ear. The ear is not equally sensitive to all the frequencies.* The most audible frequencies are between 2000 and 3000 Hz (range within which the least pressure is needed to provoke the conscious recognition of a sound). This range can be easily identified where the curve is at its minimum and corresponds to human speaking frequencies.

For this reason, sound meters are usually fitted with a filter whose response to frequency is a bit like that of the human ear. The most widely used sound level filter is the A scale, which roughly corresponds to the inverse of the 40 dB (at 1 kHz) equal-loudness curve. Using this filter, the sound level meter is thus less sensitive to very high and very low frequencies. Measurements made on this scale are expressed as **dBA**.

The "normal threshold" of hearing is defined in "young people with a healthy auditory system".

The **"pain threshold"** is the high level (high dB) audible sound where the level of pressure of the sound produces discomfort or pain. The pressures of the sounds are over the curve: "ultrasounds". Very powerful levels of sound can be perceived by the human ear but cause discomfort and pain.

*Pressures below the audible level are called "infra-sounds": the pressure is detected but our hearing mechanism is not adapted to making the sound evident to the human ear (under the curve in the graphic). These frequencies (less than 20 Hz, not audible for the human ear) can be produced by machines or "ultrasonic" motors of planes. Out of the limits of the human threshold of hearing exists sound that can be perceived by special equipment or animals such as dolphins and bats that are equipped to perceive sound that humans can not perceive. The human being hears a very short portion of the existing sounds, the very weak and the ones above and below of the thresholds are not perceived or they are accompanied by pain, ***and can produce damage to a system that is not prepared to perceive them as the person may not be able to protect her/himself from this deleterious exposure***. There is individual variation within these general parameters.

Reference:

•Noise effects handbook, National Association of Noise Control Officials. *Office of the Scientific Assistant, Office of Noise Abatement and Control, U.S. Environmental Protection Agency*, 1979, revised 1981 (www.nonoise.org/library/handbook/handbook.htm).

Picture:

•EPA (U.S. Environmental Protection Agency)

Children and noise

MAGNITUDE AND EFFECTS OF SOUND

COMMON EXAMPLE	dBA	EFFECT
Breathing	0-10	Hearing threshold
Conversation at home	50	Quiet
Freeway traffic (15 m), vacuum cleaner, noisy party	70	**Annoying**, intrusive, interferes with phone use
Average factory, train (at 15 m)	80	**Possible** hearing damage
Jet take-off (at 305 m), motorcycle	100	**Damage** if over 1 minute
Thunderclap, textile loom, chain saw, siren, rock concert	120	Human **pain** threshold
Toy cap pistol, Jet takeoff (at 25 m), firecracker	150	**Eardrum rupture**

This abbreviated table correlates common sounds with effects on hearing.

Additional examples for discussion are listed below:

-Quiet suburb or quiet conversation	50 dB A	No significant effect
-Conversation in a busy place, background music or traffic	60 dB A	Intrusive
-Freeway traffic at 15 metres	70 dB A	Annoying
-Average factory, train at 15 metres	80 dB A	Possible hearing damage
-Busy urban street, diesel truck	90 dB A	Chronic hearing damage if exposure over 8 hours
-Subway noise	90 dB A	Chronic hearing damage, speech interfering
-Jet take-off 300 metres	100 dB A	More severe than above
-Stereo held close ear	110 dB A	More severe than above
-Live rock music, jet take off 160 mts	120 dB A	As above, human pain threshold
-Earphones at loud level	130 dB A	More severe than above
-Toy cap pistol, firecracker close ear	150 dB A	Acute damage (eardrum rupture)

dBA weighting curve: response of a filter that is applied to sound level meters to mimic (roughly) the response of human hearing. So a typical human equal loudness curve is somewhat similar to the dBA curve, but inverted.

Reference:

•Children's health and the environment: A review of evidence. Tamburlini G et al., eds. *EEA-WHO*, 2002 (www.eea.europa.eu/publications/environmental_issue_report_2002_29)

Children and noise

SOURCES OF NOISE

Outdoor sources

- ❖ Transport
  - Aircraft
  - Road
  - Rail
- ❖ Occupational
  - Machinery
- ❖ Neighbours
  - Machinery
  - Loud music

Indoor sources

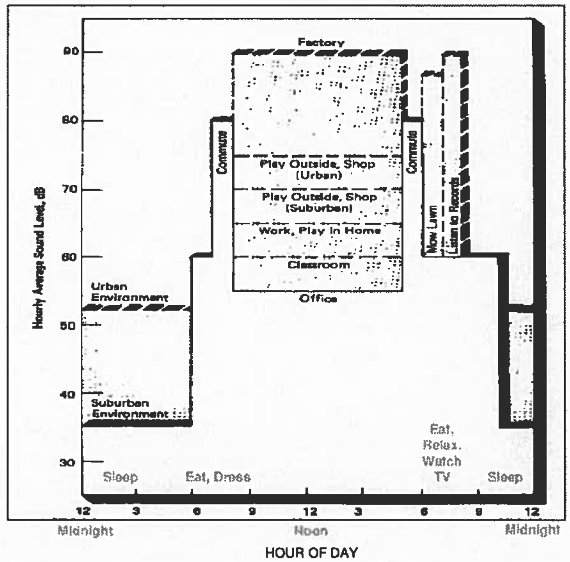
- ❖ Ambient noise outside
- ❖ Building design and location
- ❖ Room acoustics
- ❖ Activities of occupants
  - Children

Common sources of outdoor noise arise from transportation (aircraft, car and truck traffic, and trains), occupations (construction machinery, assembly lines), and even from neighbours (yard equipment, loud music). Indoor noise is affected by outdoor noise, and indoor sources such as TV, radio, music and children at play. The level is modified by building design and location as well as room acoustics.

Children and noise

SETTINGS OF NOISE EXPOSURE: "NOISE-SCAPE"

Hypothesized lifestyle noise exposure patterns



EPA

The concept of a "noise-scape" can be useful in thinking about noise exposures. That is, obvious loud noises are imposed upon a background of noises that will vary according to general location (urban vs. rural), time of day (day vs. night) and activity (school vs. play). This image is a schematic representation which illustrates these different aspects of the "noise-scape".

Reference:

•Noise effects handbook, National Association of Noise Control Officials. *Office of the Scientific Assistant, Office of Noise Abatement and Control, U.S. Environmental Protection Agency*, 1979, revised 1981 (www.nonoise.org/library/handbook/handbook.htm).

Picture:

•*EPA (U.S. Environmental Protection Agency)*

NOISE EXPOSURE IN EU

- 40% of population exposed to Leq > 55 dBA during the day
- 20% of population exposed to Leq > 65 dBA during the day
- 30% of population exposed to Lmax > 55 dBA during the night
- Hazard is increasing

Leq: average sound level over the period of the measurement, usually measured A-weighted

Lmax: maximum A-weighted noise level

dBA weighting curve: response of a filter that is applied to sound level meters to mimic (roughly) the response of human hearing. So a typical human equal loudness curve is somewhat similar to the dBA curve, but inverted.

Reference:

•Berglund B et al., eds. Guidelines for Community Noise. Geneva, *WHO*, 1999.

Children and noise

NOISE CONTAMINATION

- Noise exceeding safety threshold is widespread:
  - In neighbourhoods
  - Schools, hospitals and care centres
  - Urban and suburban areas
  - Activities inside the buildings (elevators, water tubs, music in discotheque)
  - From children themselves (toys, equipment, children playing or practicing sports in a close yard)
  - Traffic: heavy road, railways, highways, subways, airports
  - Industrial activities
  - Building and road construction, renovation
- Increased environmental noise levels - more noise sources
- Also linked to population growth

Noise contamination or noise pollution is a concept which implies harmful levels of excess noise. Noise intense enough to cause harm is widely spread.

<<READ SLIDE>>

Children and noise

VULNERABLE GROUPS OF CHILDREN

- ❖ The fetus and babies
- ❖ Preterm, low birth weight and small for gestational age babies
- ❖ Children with dyslexia and hyperactivity
- ❖ Children on ototoxic medication

It is logical to consider certain subgroups of children (since conception) to be particularly at risk for harm from excess noise exposure. These include the fetus, babies and very young infants born preterm, with low birth weight or small for gestational age. Also, children who have learning disabilities or attention difficulties may be more likely to develop early problems with mild hearing loss compared to children without these challenges, and children on ototoxic medications may have higher likelihood of developing problems from exposure to excess noise.

Reference:

•Carvalho WB, et al. Noise level in a pediatric intensive care unit. *J Pediatr*, 2005, 81:495-8.

OBJECTIVES: The purpose of this study was to verify the noise level at a PICU. METHODS: This prospective observational study was performed in a 10 bed PICU at a teaching hospital located in a densely populated district within the city of São Paulo, Brazil. Sound pressure levels (dBA) were measured 24 hours during a 6-day period. Noise recording equipment was placed in the PICU access corridor, nursing station, two open wards with three and five beds, and in isolation rooms. The resulting curves were analyzed. RESULTS: A basal noise level variation between 60 and 70 dBA was identified, with a maximum level of 120 dBA. The most significant noise levels were recorded during the day and were produced by the staff. CONCLUSION: The basal noise level identified exceeds International Noise Council recommendations. Education regarding the effects of noise on human hearing and its relation to stress is the essential basis for the development of a noise reduction program.

Children and noise

VULNERABILITY OF CHILDREN

- ❖ Different perception of dangers of noise
  - Can not recognize the dangerous exposures
- ❖ Lack of ability to control the environment
  - Are not able to identify and avoid the source of noxious noise
  - Exposure *intra utero*
- ❖ Noise can interfere with communication of danger
- ❖ May be more exposed due to their behaviour
  - Exploratory or risk behaviour (in children and teenagers)

14

Special vulnerability of children to noise. The known increased risk is due to
<<READ SLIDE>>

Noise effects in children

"Children may be more prone to the adverse effects of noise because they may be more frequently exposed….and they are more susceptible to the impact of noise". (Tamburlini, 2002)

Reference:

•Children's health and the environment: A review of evidence. Tamburlini G et al., eds. *EEA-WHO*, 2002 (www.eea.europa.eu/publications/environmental_issue_report_2002_29)

Children and noise

VULNERABILITY OF CHILDREN

Why might children be more susceptible to noise effects?

- Possible increased risk due to immaturity
  Increased cochlear susceptibility?
  - *In utero*
  - Animal data studies
- Critical periods in relation to learning
- Lack of developed coping repertoires
- Vulnerable tasks \ Vulnerable settings (schools, home, streets)

What might be the implications of noise effects?

- Lifelong impairment of learning and education
- Short-term deficit followed by adaptation
- Non intentional lesions

15

<<READ SLIDE>>

Exposure to excessive noise and vibration during pregnancy may result in high frequency hearing loss in the newborn, may be associated with prematurity and growth retardation, although the scientific evidence remains inconclusive.

The role of the amniotic fluid is not yet defined, nor when and which noises or vibrations can damage the fetal development of the auditory system (e.g. cochlea). Concern about synergism between exposure to noise and ototoxic drugs remains incompletely defined. There are studies on fetal audition dating from 1932 that explore the reaction of the fetus to external noises but even today this remains incompletely characterized.

References:

•Children's health and the environment: A review of evidence, Ed. Tamburlini G. et al, *EEA-WHO, 2002* (www.eea.europa.eu/publications/environmental_issue_report_2002_29).

•National Institute of Public Health Denmark. Health Effects of Noise on Children and Perception of the Risk of Noise. Bistrup ML, ed. *Copenhagen, Denmark: National Institute of Public Health Denmark,* 2001, 29.

Di jmesf o!boe!opjt f!

BEWFSTF!FGGFDUT!
GSPN!FYDFTT!OPJTF!FYQPTVSF

- Ejsf duf bsdebn bhf
  - ó Opjt f !joevdf e!i f bsjoh!mpt t
  - ó Opjt f !joevdf e!ui sf t i pme!t i jgu
- Jbejsf dubewf st f !f ggf dut
  - ó Qi zt jpmphjdbmf ggf dut
  - ó Qt zdi pmphjdbmf ggf dut
- Jn qbjsf e!dphojujpo

Di bsbduf sjt ujdt !pgui f !t pvoe!dbo!n pejgz!f ggf du

28

Adverse effects can be divided into direct damage, indirect adverse effects and impaired cognition. Many effects of noise exposure are more thoroughly studied in adults than in children.

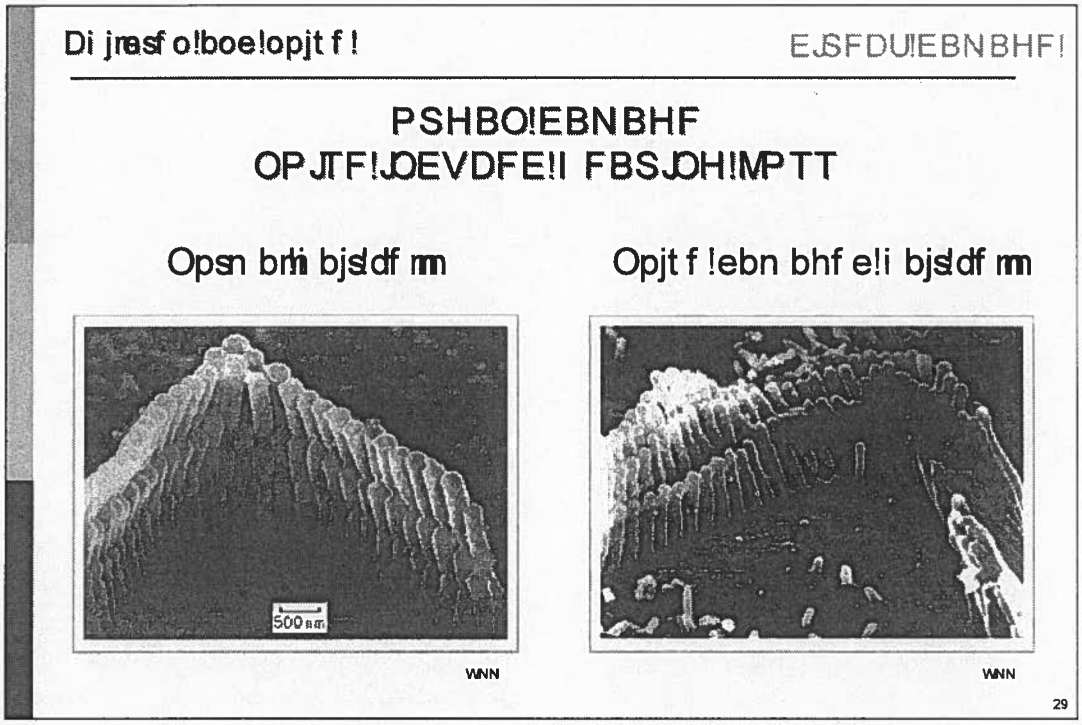
The degree of adverse effect is modified by the sound characteristics.

•**Vibration:** can be acute or chronic, audible or inaudible. Vibration can be transmitted to all the body directly through the skin or bones.

•**Frequencies:** lower and higher (ultra and infra sounds) can also damage the human hearing system, despite being imperceptible, and have important consequences for life (loss of hearing). These consequences can also be present after chronic exposure to low frequency non audible sounds (chronic back noise exposure). Incubators are an example of this exposure.

•**Intensity:** Direct blows to the ears, very loud noise (pneumatic hammer or drill, fire arms, rocket), and sudden but intense sounds can destroy the eardrum and damage the hair cells of the cochlea by bypassing the protective reflexes. Acute trauma can cause a lifelong lesion.

•**Periodicity and Duration**: Impulse noise is more harmful than continuous because it bypass the natural protective reaction, the damping-out of the ossicles mediated by the facial nerve. Loud noise may result in temporary decrease in the sensitivity of hearing and tinnitus, but repeated exposure may cause these temporary conditions to become permanent.



Normal healthy "hair cells" transform vibration into nerve impulses sending messages to the brain. Trauma to the hair cells of the cochlea results in hearing loss. Prolonged exposure to sounds louder than 85 dBA is potentially injurious (85 dBA is tolerable for an occupational exposure). Continuous exposure to hazardous levels of noise tend to affect high frequencies regions of the cochlea first. Noise induces hearing loss gradually, imperceptibly, and often painlessly. Often, the problem is not recognized early enough to provide protection. Further, it may not be recognized as a problem, but merely considered a normal consequence of ordinary exposure, and part of the environment and daily life.

References:

•Moeller, Environmental health, *Harvard University Press*, 1992

•VIMM (Veterinarian Institute of Molecular Medicine, Italy): www.vimm.it/cochlea/cochleapages/theory/hcells/hcells.htm

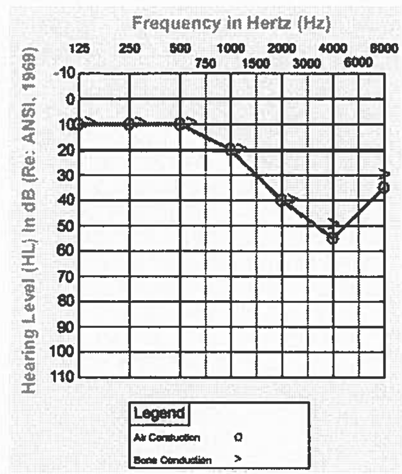
Pictures:

• *VIMM (Veterinarian Institute of Molecular Medicine, Italy): www.vimm.it/cochlea/cochleapages/theory/hcells/hcells.htm - used with copyright permission.*

Di jmsf o!boe!opjt f ! EJSFDU!EBN BHF!

BVEJPHSBN

Opjt f .joevdf e!
i f bsjoh!mpt t



PTI B

2

<< NOTE TO USER: If possible place an audiogram of a child living in your local environment here to illustrate either normal hearing, or hearing damaged by environmental noise. >>

Noise-induced hearing loss is insidious, but increases with time, usually beginning in adolescent years. As shown here, it affects the high frequencies first. The speech window is between 500 and 4000 Hz, so it is not surprising that high frequency loss of large magnitude could go undetected for long periods of time without formal testing.

Picture:

• *OSHA (U.S. Department of Labor Occupational Safety & Health Administration) www.osha.gov/dts/osta/otm/noise/images/sensorineural_loss_audiogram.gif*

Di jmesf o!boe!opjt f ! EJSFDU!EBNBHF!

DI JMESFO!BOE!OPJTF;!TFUUJOHT

Opjt f !buli pn f	61!. 91!!eC!B
I pn f !bqqmjbodf t	89!. 213!!eC!B
Opjt f !jo!jodvcbupst !!	71!. 86!eC!B-! qf bl !t pvoet !231!!eC!B
Opjt f !jo!i pt qjubm!	?!81!!eC!B
Ebz.dbsf !jot ujuvujpot !!	86!ò 92!eC!B
Opjt f !gspn !upzt !qf bl !t pvoet	8: !. 251!!eC!B
Cbdl hspvoe!opjt f !jo!t di pppm	57/6!ò 88/4!eC!B

31

These ranges represent excessive everyday exposures of children to sound.

References:

•Committee on Environmental Health. Noise: A Hazard for the Fetus and Newborn. *Pediatrics*, 1997, 100:724-27.

•Etzel RA, ed. Pediatric Environmental Health. 2nd ed. American Academy of Pediatrics Committee on Environmental Health.; *Elk Grove Village, IL: American Academy of Pediatrics*, 2003.

OPJTF!JOEVDFE!UISFTIPME!TIJGU!)OJUT*

- Jojujbmmz!. b!ufnqpsbsz!dpoejujpo
  - ó Efdsfbtf!jo!tfotjujwjuz!up!opjtf
  - ó Ujoojuvt
- Dbvtfe!cz!fyqptvsf!up!mpve!opjtft
- Nbz!cf!sfwfstjcmf!ps!jssfwfstjcmf
  - ó Tfwfsjuz!boe!evsbujpo!pg!fyqptvsf
  - ó Dpoujovpvt!boe!sfdvssfou!fyqptvsf

Exposure to loud noise may result in a temporary decrease in the sensitivity of hearing and tinnitus. This condition, called temporary noise-induced threshold shift (NITS), lasts for several hours depending on the degree of exposure, and may become permanent depending on the severity and duration of noise exposure. Noise induced threshold shifts may be reversible; however, continued excessive noise exposure could lead to progression of NITS to include other frequencies and lead to increase severity and permanent hearing loss. The consequences of these measured NITS may be enormous if they progress to a persistent minimal sensorineural hearing loss. In school-aged children, minimal sensorineural hearing loss has been associated with poor school performance and social and emotional dysfunction.

Di jmesf o!boe!opjt f ! EJSFDU!EBNBHF!

QSFWBMFODF!OPJTF!JOEVDFE!UI SFTI PME!TI JGUT

Obujpobmmz vswf z!VT!di jmesf o!)o>635: *

Di bsbdufsjt ujdt	&	): 6& !DJ*
Bhf ; 7.22!zf bst !pme	9/6	)7/: .21/1*
23.2: !zf bst !pme	26/6	)24/4.28/7*
Tf y; Nbmf	25/9	)23/4.28/4*
Gf n bmf	21/2	)9/4.22/9*
Vscbo!t ubuvt ;		
Nf uspqpmjubo	22/:	): /9.25/1*
Opo.n f uspqpmjubo	24/1	)22/4.25/7*

Ojt I bsBT-!Qf ejbusjdt -!3112-!219)2*;51.4

33

This is evidence that children are experiencing changes in hearing which are consistent with excess noise exposure. These data show the prevalence of Noise Induced Threshold Shift (NITS) in children which increases with age. The prevalence of NITS in one or both ears among children 6-19 year of age in the USA was recently found to be 12.5% (or 5.2 million) children affected. Most children with NITS have an early phase of NITS in only one ear and involving only a single frequency, however among children with NITS, 4.9% had moderate to profound NITS. This table demonstrates several points. First, older children have a higher prevalence of NITS compared to younger children suggesting that ongoing exposure to excess noise in the environment may be causing cumulative hearing damage. Boys in this survey were more likely to have evidence of excess noise exposure measured as NITS compared to girls, but there was little difference between urban and non-urban status.

Reference:

•Niskar AS. Estimated prevalence of noise-induced hearing threshold shifts among children 6 to 19 years of age: the Third National Health and Nutrition Examination Survey, 1988-1994, United States. *Pediatrics,* 2001, 108(1):40-3

This analysis estimates the first nationally representative prevalence of noise-induced hearing threshold shifts (NITS) among US children. Historically, NITS has not been considered a common cause of childhood hearing problems. Among children, NITS can be a progressive problem with continued exposure to excessive noise, which can lead to high-frequency sound discrimination difficulties (eg, speech consonants and whistles). The Third National Health and Nutrition Examination Survey (NHANES III) was conducted from 1988 to 1994. NHANES III is a national population-based cross-sectional survey with a household interview, audiometric testing at 0.5 to 8 kHz, and compliance testing. A total of 5249 children aged 6 to 19 years completed audiometry and compliance testing for both ears in NHANES III. The criteria used to assess NITS included audiometry indicating a noise notch in at least 1 ear. RESULTS: Of US children 6 to 19 years old, 12.5% (approximately 5.2 million) are estimated to have NITS in 1 or both ears. In the majority of the children meeting NITS criteria, only 1 ear and only 1 frequency are affected. In this analysis, all children identified with NITS passed compliance testing, which essentially rules out middle ear disorders such as conductive hearing loss. The prevalence estimate of NITS differed by sociodemographics, including age and sex. CONCLUSIONS: These findings suggest that children are being exposed to excessive amounts of hazardous levels of noise, and children's hearing is vulnerable to these exposures. These data support the need for research on appropriate hearing conservation methods and for NITS screening programs among school-aged children. Public health interventions such as education, training, audiometric testing, exposure assessment, hearing protection, and noise control when feasible are all components of occupational hearing conservation that could be adapted to children's needs with children-specific research.

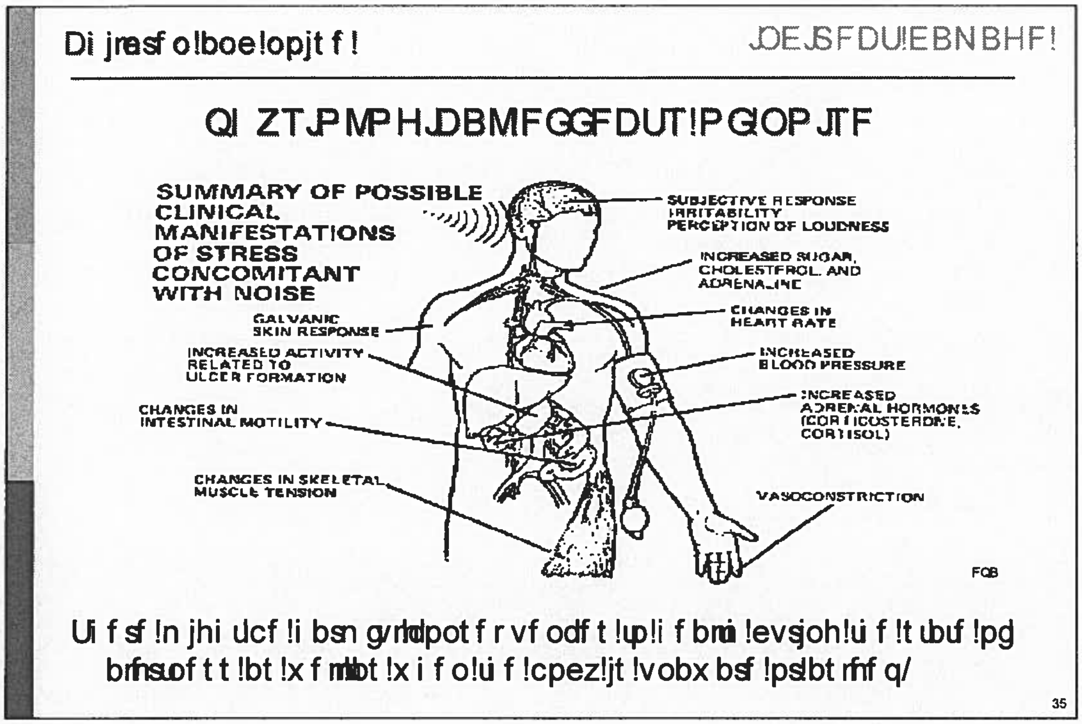
JOEJSFDU!BEWFSTF!FGGFDUT

❖ Tusf t t .sf mbuf e!t pn bujd!f ggf dut
- ó Tusf t t !i psn pof
- ó Cmppe!qsf t t vsf !
- ó Nvt dmf!t qbt n

❖ Qt zdi pmphjdbm!f ggf dut
- ó Boopzbodf !0Jut pmbujpo
- ó Tmf f q!ejt uvscbodf !
- ó Nf oubm!i f bmui

❖ Dphojujwf !f ggf dut !
- ó Sf bejoh-!dpodf oubujpo-!n f n psz-!buuf oujpo

The next section will review the indirect adverse effects of noise listed here.



There are a variety of physiological effects that have been documented or postulated as a result of excess noise exposure.

<<READ SLIDE>>

References:

Stress response:

•Frankenhaeuser M. Immediate and delayed effects of noise on performance and arousal. *Biol Psychol,* 1974, 2:127-33

Increased excretion of adrenaline and noradrenaline demonstrated in humans exposed to noise at 90 dBA for 30 minutes.

•Henkin RI. Effect of sound on the hypothalamic-pituitary-adrenal axis. *Am J. Physiol,* 1963, 204:710-14

Hypothalamic- pituitary- adrenal axis is sensitive to noise as low as 65 dBA (53% increase in plasma 17 HO corticosteroid levels).

•Rosenberg J. Jets over Labrador and Quebec: noise effects on human health. *Can. Med. Assoc. J.,* 1991, 144(7):869-75.

Biochemical evidence of the stress response was found in elevated urinary cortisol and hypertension accompanied a 30 minute exposure to 100dBA in 60 children aged 11 to 16 years.

Sleep derivation:

Noise levels at 40-50 dBA result in 10-20% increase in awakening or EEG changes

•Falk SA. Hospital noise levels and potential health hazards. *Engl. J Med.,* 1973, 289(15):774-81

•Hilton BA. Quantity and quality of patient's sleep and sleep-disturbing factors in respiratory intensive care unit, *J Adv Nurs,* 1976, 1(6):453-68

•Thiessen GJ. Disturbance of sleep by noise. *J. Acoustic Soc. Am.,* 1978, 64(1):216-22

Cardiovascular effects:

•Etzel RA, ed. *Pediatric Environmental Health.* 2nd ed. American Academy of Pediatrics Committee on Environmental Health. Elk Grove Village, IL: American Academy of Pediatrics; 2003.

Exposure to noise levels greater than 70 dBA causes increases in vasoconstriction, heart rate and blood pressure

Picture:

•EPA (U.S. Environmental Protection Agency)

Di jmesf o!boe!opjt f! JOE JSFDU!EBN BHF!

TUSFTT!I PSNPOFT!. DI JMESFO

Opjt f! uzqf !)rhr *	Opjt f! fyqpt vsf	O≤	Besf obrjof	Opsbesf obrjof	Dpsujt pm	Bvu ps
Bjsdsbgu	64-!73	328	,	,	,	Fwbot -!2: : 9!
Bjsdsbgu	67-!81	51	1	1	1	Jt joh-!2: : : !
Spbe-!Sbjm	=61-!?71	226	1	1	,	Fwbot -!3112!
Spbe	41.65-!66.89	67			,	Jt joh-!3112!
Bjsdsbgu	=68-!?77	349			1	Tubot gf me-!3112!
Bjsdsbgu	64-!73	315	1	1	1	I bjof t -!3112!

, !jodsf bt f !x ju !opjt f -!!!!. ef dsf bt f !x ju !opjt f -!!!!!1!op!f gf du

Bebqf elgpn !Cbcjt di X-!Opjt f!I fbm -3114-6)29*;2.22

36

In experimental studies with humans carried out in the laboratory, unequivocal findings of noise exposure on the endocrine system have been sometimes observed. However, exposure conditions vary considerably between experiments. Furthermore, secretory patterns of hormone excretion vary between individuals. It is not clear as to what extent findings from experimental studies on endocrine responses of noise reflect a potential health hazard. To more completely characterize these indirect adverse effects of excess noise, there is a need to 1) develop a consensus on measurement techniques, 2) replicate results of adult studies in children, and 3) link hormone levels to health impairment. When it is done, stress hormone responses may identify risk groups.

Leq: average sound level over the period of the measurement, usually measured A-weighted

N°: number of subjects

Reference:

•Babisch W. Stress hormones in the research on cardiovascular effects of noise. *Noise Health*, 2003, 5(18):1-11

In recent years, the measurement of stress hormones including adrenaline, noradrenaline and cortisol has been widely used to study the possible increase in cardiovascular risk of noise exposed subjects. Since endocrine changes manifesting in physiological disorders come first in the chain of cause-effect for perceived noise stress, noise effects in stress hormones may therefore be detected in populations after relatively short periods of noise exposure. This makes stress hormones a useful stress indicator, but regarding a risk assessment, the interpretation of endocrine noise effects is often a qualitative one rather than a quantitative one. Stress hormones can be used in noise studies to study mechanisms of physiological reactions to noise and to identify vulnerable groups. A review is given about findings in stress hormones from laboratory, occupational and environmental studies.

Di jmsf o!boe!opjt f!

JOEJSFDU!EBNBHF!

CMPPE!QSFTTVSF . BJSDSBGU!OPJTF

Tuvez	Qt zt !)n n I h*	Qejb!)n n I h*	Tpvoe!mfwf m)Mf r *
Lbsbhpejob-!2: 7:	bcopsn brjjf t	bcopsn brjjf t	ejt ubodf !gspn !bjsqpsu
Dpi f o-!2: 91	4.8	4.5	=81!eCB!)joeppst *
Dpi f o-!2: 92	op!f gg du	op!f gg du	81!eCB!)joeppst *
Fwbot -!2: : 6	3	1	79!eCB!)pvueppst *
Fwbot -!2: : 9	4	4	75!eCB!)pvueppst *
Npssf mm2: : 9	of hbujwf !	of hbujwf	BOF!J56!)pvueppst *
Npssf mm3111	op!f gg du	of hbujwf	BOF!J56!)pvueppst *

- Jbdpot jt uf oulqjduvsf ;!4!qpt jujwf -!5!of hbujwf !t uvejf t
- Qspt qf dujwf !t uvejf t ;!2!qpt jujwf -!2!of hbujwf !t uvez
- N bhojuvef !pgf gg dugpvoe!jo!qpt jujwf !t uvejf t !n bz!cf !sf mfwbou

37

Studies on elevated blood pressure and noise exposure (from aircraft) are also inconsistent. Only the cross-sectional study of Cohen shows that aircraft noise exposure (specifically at school) is statistically significantly associated with increases in systolic and diastolic blood pressure.

Leq: average sound level over the period of the measurement, usually measured A-weighted

Psys: systolic pressure

Pdia: diastolic pressure

dBA weighting curve: response of a filter that is applied to sound level meters to mimic (roughly) the response of human hearing.

So a typical human equal loudness curve is somewhat similar to the dBA curve, but inverted.

ANEI: Australian Noise Exposure Index.

References:

Aircraft Noise:

•Cohen S. Physiological, motivational and cognitive effects of aircraft noise on children: moving from the laboratory to the field. *Am Psychol.*, 1980, 35:231-43.

•Cohen S. Aircraft noise and children: longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. *J. Pers Soc Psychol.*, 1981, 40:331-45

•Evans G. Chronic noise and psychological stress. *Psychological Science,* 1995, 6:333-38

•Evans G. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. *Psychological Science*, 1998, 9:75-77

•Karagodina IL. Effect of aircraft noise on the population near airports. *Hygiene and Sanitation*, 1969, 34:182-187

•Morrell S. Cross-sectional relationship between blood pressure of school children and aircraft noise. In N.L. Carter, & R.F.S Job (Eds.), Noise Effects. *Proceedings of the 7th International on Noise as a Public Health Problem. Sydney, Australia: Noise Effects Inc*, 1998, 275-79.

•Morrell S. Cross sectional and longitudinal results of a follow up examination of child blood pressure and aircraft noise. *The Inner Sydney Child Blood Pressure Study. Proceedings Internoise, SFA, Nice, France*, 2000, 4:2071.

•van Kempen E. et al. Noise exposure and children's blood pressure and heart rate: the RANCH project. *Occup Environ Med.,* 2006, 63:632-39

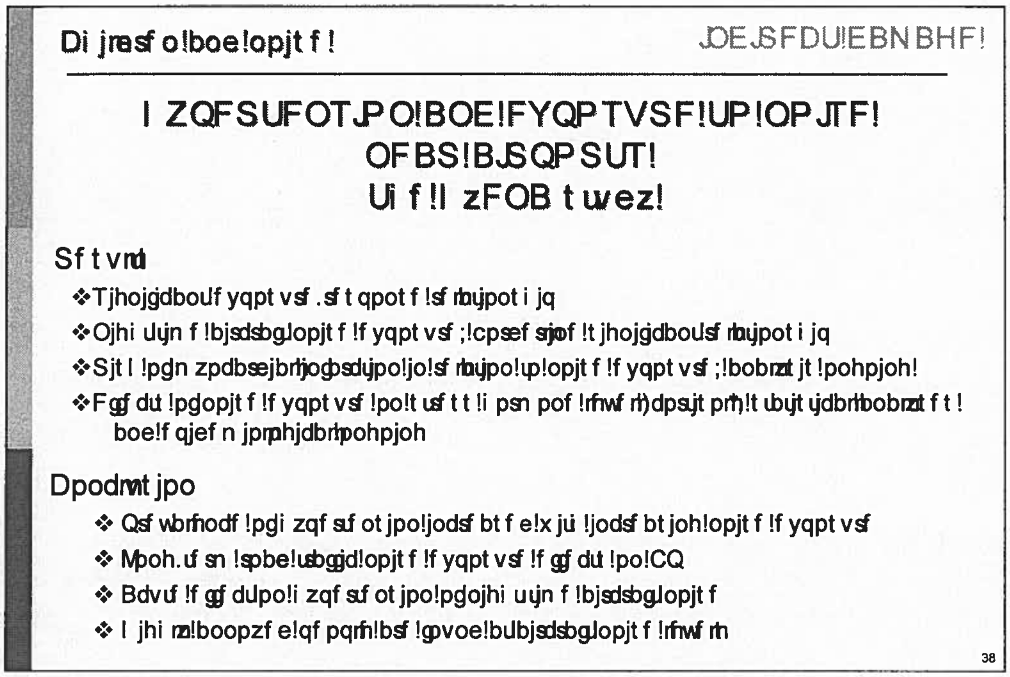
BACKGROUND: Conclusions that can be drawn from earlier studies on noise and children's blood pressure are limited due to inconsistent results, methodological problems, and the focus on school noise exposure. OBJECTIVES: To investigate the effects of aircraft and road traffic noise exposure on children's blood pressure and heart rate. METHODS: Participants were 1283 children (age 9-11 years) attending 62 primary schools around two European airports. Data were pooled and analysed using multilevel modelling. Adjustments were made for a range of socioeconomic and lifestyle factors. RESULTS: After pooling the data, aircraft noise exposure at school was related to a statistically non-significant increase in blood pressure and heart rate. Aircraft noise exposure at home was related to a statistically significant increase in blood pressure. Aircraft noise exposure during the night at home was positively and significantly associated with blood pressure. The findings differed between the Dutch and British samples. Negative associations were found between road traffic noise exposure and blood pressure, which cannot be explained. CONCLUSION: On the basis of this study and previous scientific literature, no unequivocal conclusions can be drawn about the relationship between community noise and children's blood pressure.

Traffic Noise:

•Babisch W. Blood pressure of 8-14 year old children in relation to traffic noise at home--results of the German Environmental Survey for Children (GerES IV). *The Science of the total environment*, 2009, 407(22):5839-43.

•Babisch W, Kamp I. Exposure-response relationship of the association between aircraft noise and the risk of hypertension. *Noise Health.* 2009 Jul-Sep, 11(44):161-8.

•Belojevic G et al. Urban road-traffic noise and blood pressure and heart rate in preschool children. *Environ Int.* 2008, 34(2):226-31. Epub 2007 Sep 14.



An increasing number of people live near airports with considerable noise and air pollution. The Hypertension and Exposure to Noise near Airports (HYENA) project aims to assess the impact of airport-related noise exposure on blood pressure (BP) and cardiovascular disease using a cross-sectional study design.

Although the study has been made in adults (men and women between 45-70 years old), it might be a good cardiovascular disease predictor in children.

Reference:

•Jarup L. Hypertension and Exposure to Noise near Airports (HYENA): Study Design and Noise Exposure Assessment. *Environ Health Perspect.*, 2005, 113(11):1473–1478.

Di jmesf o!boe!opjt f ! JOEJSFDU!EBNBHF

QTZDI PMPHJDBMEBNBHF

❖ Fyqpt vsf !up!n pef sbuf !mfwf mt!pg!opjt f dbo!dbvt f !
- 6Qt zdi pmphjdbmt usf t t
- 6Boopzbodf -!jouf sgf sf odf !x jui !bdujwjuz-!jt pmbujpo
- 6I f bebdi f -!ujsf eof t t !boe!jssjubcjmjuz<!n bz!jn qbjs!jouf mmfduvbm!gvodujpo!boe!qf sgpsn bodf !pg dpn qmfy!ubt l t

❖ Fyqpt vsf !up!jouf ot f !mfwf mt!pg!opjt f dbo
- 6Dbvt f !qf st pobmjuz!di bohf t !boe!bhhsf t t jwf 0wjpmfouf bdujpot
- 6Sf evdf !bcjmjuz!up!dpqf
- 6Bmuf s!x psl !qf sgpsn bodf !boe!jouf mmfduvbm!gvodujpo
- 6Nbz!dbvt f !n vt dmf !t qbt n !boe!bmtp!csf bl !b!cpof !)x i f o!dpn cjof e!x jui t uspoh!wjcsbujpo*
- 6Tmff q!ejt uvscbodf
- 6Di bohf t !jo!n f oubm!i f bmui /

❖ Fyqpt vsf !up!t veef o-!vof yqf duf e!opjt f dbo!dbvt f
- 6Tubsumf !sf bdujpo!x jui !t usf t t !sf t qpot f t
- 6Dbvt f !opo!jouf oujpobm!jokvsjf t

39

Psychological effects correlate with intensity (or loudness) of the noise.

Exposure to **moderate levels of noise** can cause psychological stress.

Other effects can be:

• Annoyance (fear, anger, feeling bothered, feelings of being involuntarily and unavoidably harmed, and feelings of having privacy invaded), interference with activity.

•Headache, tiredness and irritability are also common reactions to noise.

•Possible impairment of intellectual function and performance of complex tasks. Depends on the nature of sound and individual tolerance.

Exposure to **Intense level of noise** can:
- Cause personality changes and provoke aggressive and violent reactions.
- Reduce ability to cope.
- Alter work performance and intellectual function.
- Cause muscle spasm and also break a bone (when combined with strong vibration).
- Cause sleep disturbance.
- Provoke changes in mental health.

Exposure to **sudden, unexpected noise** can cause:
- Startle reaction with stress responses.
- Cause non intentional injuries.

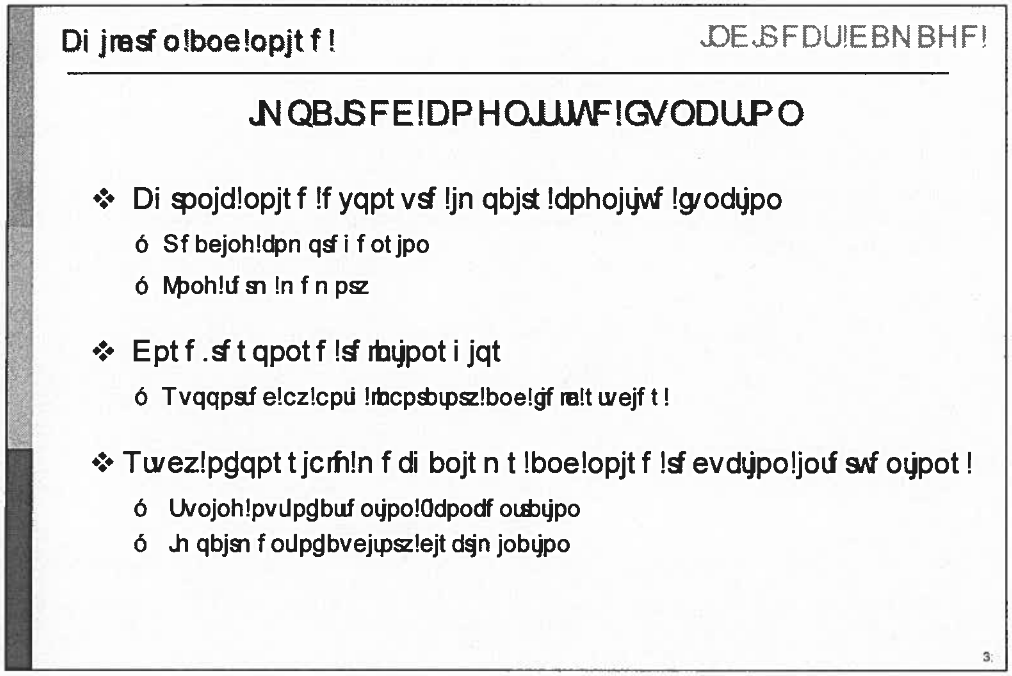
Stress response consisting in acute terror and panic was described in children upon exposure to sonic booms.

References:

•Kam PC. Noise pollution in the anaesthetic and intensive care environment. *Anaesthesia*, 1994, 49(11):982-6

•Kujala T, Brattico E. Detrimental noise effects on brain's speech functions. *Biol Psychol.* 2009, 81(3):135-43. Epub 2009 Apr 8.

•Rosenberg J. Jets over Labrador and Quebec: noise effects on human health. *Can. Med. Assoc. J.*, 1991, 144(7):869-75



The most robust area of study on noise and effects in children comes from studies which evaluate the effect of noise on learning and cognitive function; there are possible mechanisms, including noise-related changes in attention or distraction and impaired auditory discrimination.

<<READ SLIDE>>

Di jmesf o!boe!opjt f! JNQBDSFE!DPHOJUJPO

FOWJSPONFOUBM!OPJTF!BOE!DPHOJUJWF! EFWFMPQNFOU!JO!QSFTDI PPM!DI JMESFO

- Di jmesf o!7!n pou t !. 6!zf bst
- Jowf st f !bt t pdjbujpot !cf ux f f o!opjt f !mfwf mt!bui pn f !boe!dphojujwf ! ef wf mpqn f ou

X bdi t UE/!Fbsmz!Fyqf sjf odf !boe!I vn bo!Ef wf mpqn f ou!Ofx !Zpsl !Qmfovn -!2: 93!
Fwbot !HX /!Di jmesf o(t !Fowjspon f ot -2: : 4-21)2*;42.62

41

Effects of noise on cognitive development have been documented in preschool ages as well. Higher levels of noise at home are associated with decrements in cognitive development for age.

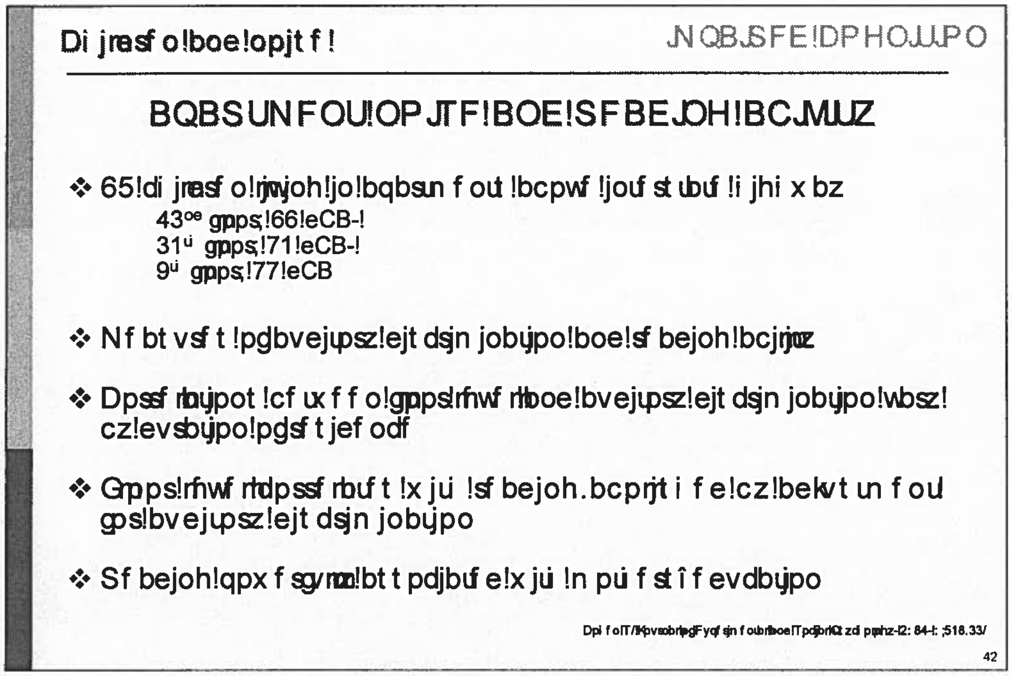
References:

•Evans GW. Non-auditory effects of noise on children: A critical review. *Children's Environments,* 1993,10(1):31-51.

•Maxwell LE et al. The effects of noise on pre-school children's pre-reading skills. *Journal of Environmental Psychology*, 2000, 20(1):91-97.

•Wachs TD. Early Experience and Human Development. *New York Plenum,* 1982.

•Yang W, Bradley JS. Effects of room acoustics on the intelligibility of speech in classrooms for young children. *J Acoust Soc Am.* 2009, 125(2):922-33.



This study shows that street traffic noise measured on different floors of a multilevel apartment correlates inversely with auditory discrimination and reading ability. The higher floors were quieter and children scored better on reading ability and auditory discrimination. Correlations varied with duration of residence, and when reading level scores were adjusted for auditory discrimination measures, the floor level effect disappeared. Reading is also powerfully associated with mother's education.

Reference:

•Cohen S. Apartment noise, auditory discrimination, and reading ability in children. *Journal of Experimental and Social Psychology*, 1973, 9:407-22.

Di jmesf o!boe!opjt f! JNQBJSFE!DPHOJUJPO

SBJMX BZ!OPJTF!BOE!SFBEJOH!TDPSFT

- Sf bejoh!t dpsf t !dpn qbsf e!cf ux f f o!dmbt t f t !jo!t bn f !t di ppm
- Fyqpt f e0opuf yqpt f e!up!sbjmx bz!opjt f
- Op!t f mfdujpo!pgdi jmesf o!jo!up!dmbt t f t
- Qppsf s!qf sgpsn bodf !po!bdi jf wf n f oUuf t upo!opjt z!t jef
- Nf bt vsjoh!sf bejoh!bhf !4.5!n pou t !cf i joe!po!opjt z!t jef

Cspo{bgu!BM!Fowjspon f oubo!Cf i bwjps!2; 86-!8;!528.39

43

This study compared reading scores between classrooms in the same school that were exposed and not exposed to railway noise. Poorer performance was noted on the noisy side with a 3-4 month delay compared to the quieter side. There was no selection of the children in each class. This is supportive evidence that noise impaired reading leaming.

Reference:

•Bronzaft AL. The effect of elevated train noise on reading ability. *Environment and Behavior.* 1975, 7:517-28.

Di jmesf o!boe!opjt f! JNQBJSFE!DPHOJUJPO

JNQBJSFE!DPHOJUJWF!GVODUJPO

- Mpt !Bohf mft !bjsqpsu!t uvez!
  Dpl f oIT/!Bn !Qt zdi pmi!2: 91-!46;342.54/!
- Of x !Zpsl !bjsqpsu!t udjuz!
  Fwbot !H/!Fowjspon f oUboe!Cf ! bwjps!2: : 8-!3:)6*;749.767/
- Nvojdi !bjsqpsu!t uvez
  Fwbot !H/!Qt zdi pmphjdbm!Tdjf odf -!2: : 9-!: ;86.88-!Qt zdi pmphjdbm!Tdjf odf -!2: : 6-7;444.49
- I f bui spx !t uvejf t
  ! bjof t !NN/!Qt zdi pmphjdbm!Nf ejdjof -!3112b-c-d-!Kl!Fqjef n jpm!Dpn n vojuz!! f bmi -!3113-!67)3*;24:

Pwf s!31!t uvejf t !i bwf !sf qpsuf e!ui bu
opjt f !bewf st f mz!bggf dut di jmesf oït !bdbef n jd!qf sgpsn bodf

44

Many studies have reported that noise can adversely affect children's academic performance. Transport noise is well-studied. Some of the most important studies are the Los Angeles airport study, the New York airport study, the Munich and Heathrow studies.

References:

•Cohen S. Physiological, motivational and cognitive effects of aircraft noise on children: moving from the laboratory to the field. *Am Psychol.*, 1980, 35:231-43.

•Cohen S. Aircraft noise and children: longitudinal and cross-sectional evidence on adaptation to noise and the effectiveness of noise abatement. *J. Pers Soc Psychol.*, 1981, 40:331-45

•Evans G. Chronic noise and psychological stress. *Psychological Science*, 1995, 6:333-38

•Evans G. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. *Psychological Science,* 1998, 9:75-77

•Evans G. Chronic noise exposure and reading deficits: The mediating effects of language acquisition. *Environment and Behavior*, 1997, 29(5):638-656.

•Haines MM. Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine*, 2001a, 31:265-77.

•Haines MM. The West London Schools Study: the effects of chronic aircraft noise exposure on child health. *Psychological Medicine*, 2001b, 31:1385-96.

•Haines MM. A follow-up study of effects of chronic noise exposure on child stress responses and cognition. *International Journal of Epidemiology*, 2001c, 30:839-45.

•Haines MM. Multilevel modelling of aircraft noise on performance tests in schools around Heathrow Airport London. *J Epidemiol Community Health*, 2002, 56(2):139-44

•Ristovska G. et al. Psychosocial effects of community noise: cross sectional study of school children in urban center of Skopje, Macedonia. *Croat Med J.* 2004, 45(4):473-6.

AIM: To assess noise exposure in school children in urban center in different residential areas and to examine psychosocial effects of chronic noise exposure in school children, taking into account their socioeconomic status. METHODS: We measured community noise on specific measurement points in residential-administrative-market area and suburban residential area. We determined the average energy-equivalent sound level for 8 hours (LAeq, 8 h) or 16 hours (LAeq, 16 h) and compared measured noise levels with World Health Organization (WHO) guidelines. Psychological effects were examined in two groups of children: children exposed to noise level LAeq, 8 h >55 dBA (n=266) and children exposed to noise level LAeq, 8 h <55 dBA (n=263). The examinees were schoolchildren of 10-11 years of age. We used a self-reported questionnaire for each child - Anxiety test (General Anxiety Scale) and Attention Deficit Disorder Questionnaire intended for teachers to rate children's behavior. We used Mann Whitney U test and multiple regression for identifying the significance of differences between the two study groups. RESULTS: School children who lived and studied in the residential-administrative-market area were exposed to noise levels above WHO guidelines (55 dBA), and school children who lived and studied in the suburban residential area were exposed to noise levels below WHO guidelines. Children exposed to LAeq, 8 h >55 dBA had significantly decreased attention (Z=-2.16; p=0.031), decreased social adaptability (Z =-2.16; p=0.029), and increased opposing behavior in their relations to other people (Z=-3; p=0.001). We did not find any correlation between socioeconomic characteristics and development of psychosocial effects. CONCLUSION: School children exposed to elevated noise level had significantly decreased attention, and social adaptability, and increased opposing behavior in comparison with school children who were not exposed to elevated noise levels. Chronic noise exposure is associated with psychosocial effects in school children and should be taken as an important factor in assessing the psychological welfare of the children.

•Stansfeld SA. Aircraft and road traffic noise and children's cognition and health: a cross-national study. *Lancet,* 2005, 365: 1942–49.

•van Kempen EE et al. Children's annoyance reactions to aircraft and road traffic noise. *J Acoust Soc Am.* 2009, 125(2):895-904.

Di jmsf o!boe!opjt f ! JNQBJSFE!DPHOJUJPO

NVOJDI !BJSQPSU!
TDI PPMQFSGPSNBODF

- Dmpt vsf !pgpme!bjsqpsu!pqf ojoh!pgof x !bjsqpsu
- Ef gjdju !jo!mpoh.uf sn !n f n psz!boe!sf bejoh! bspvoe!pme!bjsqpsu
- Jn qbjsn f out !ejn jojt i !x jui jo!3!zf bst !bgu f s! bjsqpsu!dmpt f e
- Tbn f !jn qbjsn f out !ef wf mpq!jo!of x !hspvq! pgdi jmesf o!x jui jo!3!zf bst !pgof x !bjsqpsu! pqf ojoh

VT!Usbot qpsubujpo!Tf dvsjuz! Ben jojt usbujpo

I zhhf T-!Qtzd pmTdj/!)3113*24)6*;57:

When an old airport was closed down in Munich, deficits in long term memory and reading in children exposed to the old airport improved within 2 years of the airport's closure and the associated decreased noise exposure. Interestingly, the children exposed to noise from the new airport replacing the old began to have the same deficits in long term memory and reading that were seen in the children exposed to the old airport—also within 2 years.

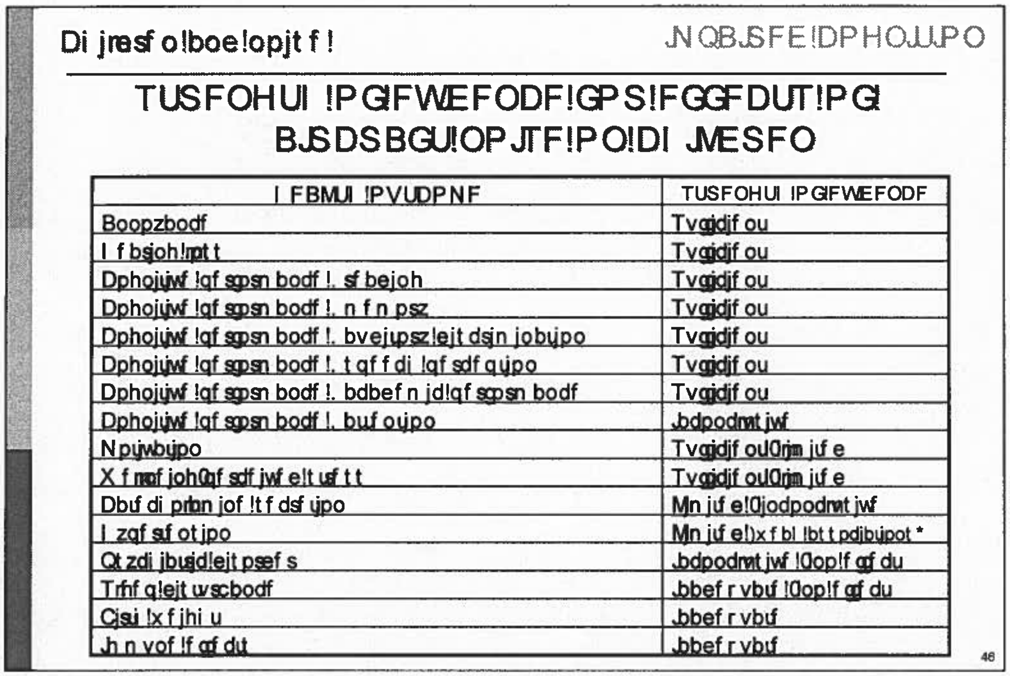
Reference:

•Hygge S. et al. A prospective study of some effects of aircraft noise on cognitive performance in schoolchildren, *Psychol Sci.*, 2002, 13(5):469.

Before the opening of the new Munich International Airport and the termination of the old airport, children near both sites were recruited into aircraft-noise groups (aircraft noise at present or pending) and control groups with no aircraft noise (closely matched for socioeconomic status). A total of 326 children (mean age = 10.4 years) took part in three data-collection waves, one before and two after the switch-over of the airports. After the switch, long-term memory and reading were impaired in the noise group at the new airport. and improved in the formerly noise-exposed group at the old airport. Short-term memory also improved in the latter group after the old airport was closed. At the new airport, speech perception was impaired in the newly noise-exposed group. Mediational analyses suggest that poorer reading was not mediated by speech perception, and that impaired recall was in part mediated by reading.

Picture:

• *US Transportation Security Administration*



Here is a brief summary slide examining the weight of the evidence for health outcomes in children from aircraft noise. We are indebted to Dr. Stephen Stansfeld (Queen Mary, University of London) for kindly lending us this and many of the previous slides for this project. This slide highlights the clear associations in children between annoyance, hearing loss and impaired cognitive performance and excess noise. The lower categories are still in need of investigation.

<<READ SLIDE>>

Dijmesfo!boe!opjtf!

FGGFDUT!PG!OPJTF!PO!UIF!GFUVT

- Hspxui!sfubsebujpo
  - ó Pddvqbujpobm!fyqptvsf!pg!uif!npuifs!up!opjtf
  - ó Fowjsponfoubm!opjtf!vomjlfmz!up!dbvtf!fggfdut- cvu!fyqptvsf!up!dispojd!mpx.eptf!opjtf!sfrvjsft!npsf!tuvez
- Ifbsjoh!jnqbjsnfou
  - ó Qpttjcmf!fggfdut

49

There are several paediatric populations which may be at increased risk of harm from noise. The fetus is one in which there is some evidence that occupational exposure to a pregnant woman may result in growth retardation and/or hearing impairment. Little is known about the effects of non-occupational noise on fetal development, and further studies are needed.

Reference:

•American Academy of Paediatrics, Committee on Environmental Health. Noise: a hazard to the fetus and newborn. *Pediatrics.* 1997, 100:724-727.

Di jmsf o!boe!opjt f !

FGGFDUT!PG!OPJTF!PO!JOGBOUT

Qsf .uf sn !boe!gvmmuf sn !cbcz

- Fyqpt f e!up!ïOf pobubmhbuf ot jwf !Dbsf !Vojuï!)OJDV*!opjt f
  - Qsf .uf sn !cbcjf t !i bwf !jn n bu/sf !i f bsjoh!pshbot !0t zt uf n t
- Bewf st f !opjt f .joevdf e!f ggf dut !po!ui f !qsf .uf sn !cbcz
  - I f bsjoh!jn qbjsn f ou qpt t jcmf!f ggf du
  - Tmf f q!ejt uvscbodf t ;!bx bl f ojoh-!t mf f q!ejt svqujpo
  - Pui f st ;!dszjoh

4:

Babies who are born pre-term or require intensive care in hospital are exposed to large amounts of noise from incubators and busy hospital settings. Furthermore, this noise may be continuous, 24 hours/day.

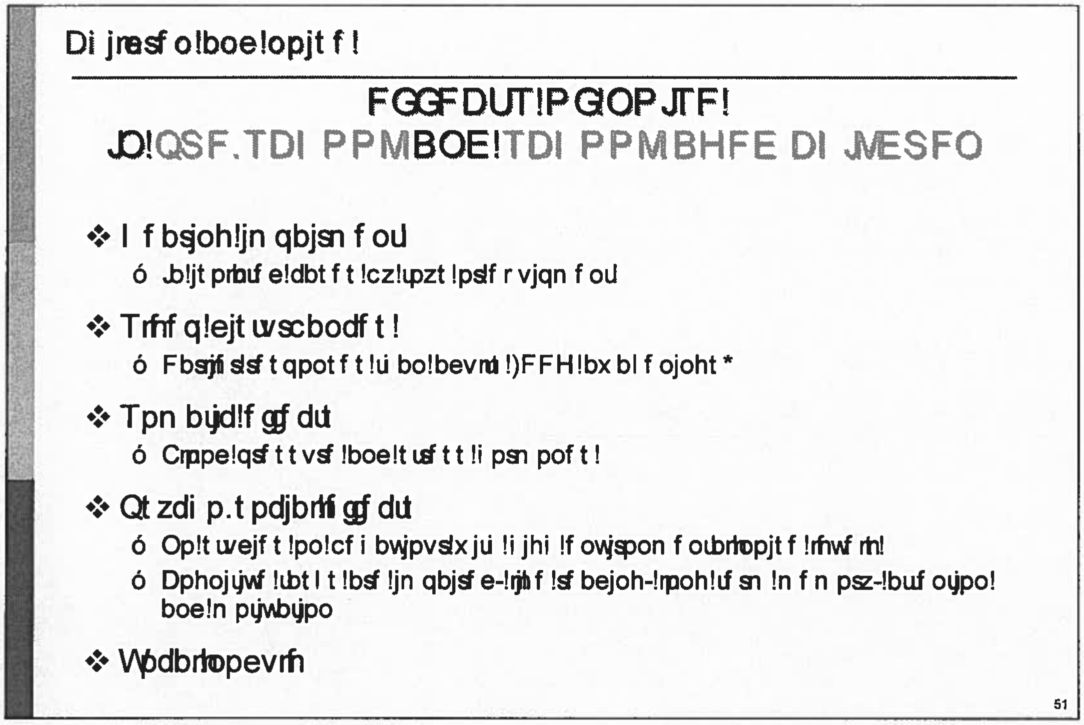
They are exposed to "Neonatal Intensive Care Unit" (NICU) noise (60 - 90 dBA max. 120 dBA) and noise inside the incubators (60 – 75 dBA max. 100 dBA). Pre-term babies must cope with their environment with immature organ systems (auditory, visual and central nervous system). These last stages of maturation occur, in part, during the time the pre-term child is in an incubator or neonatal intensive care unit (NICU).

References:

•Brandon DH. Effect of Environmental Changes on Noise in the NICU. *Advances in Neonatal Care*, 2008, 8(5):S5-S10

•Milette IH, Carnevale FA. I'm trying to heal...noise levels in a pediatric intensive care unit. *Dynamics*, 2003, 14:14-21.

The literature demonstrates clearly that most intensive care units exceed the standard recommendations for noise levels in hospitals, and that high noise levels have negative impacts on patients and staff. The purpose of this study was to evaluate the level of noise in a PICU and compare it to the recommendations of ternational bodies. We outline recommendations to promote the awareness of this problem and suggest strategies to decrease the level of noise in a PICU. The orientations of these strategies are threefold: 1) architectural-acoustic design, 2) equipment design and, most importantly, 3) staff education.



51

EEG: electroencephalogram

<<READ SLIDE>>

Children raise their voices and risk developing hoarseness and vocal nodules because of noise and relative overcrowding. The number of children screaming so much and so loudly that their voices are damaged and require treatment increased in Denmark during the 1990s. Noise in schools and day care institutions results in boys' voices getting hoarse and girls' voices squeaky. Children with vocal nodules can be difficult to understand and risk losing their voices altogether. Other children become so tired of screaming or of trying to make themselves heard that they give up saying anything at all and, for example, do not raise their hands in class. If children give up speaking, their voices do not develop properly and language learning is not reinforced.

References:

•Boman, E. The effects of noise and gender on children's episodic and semantic memory. *Scandinavian Journal of Psychology, 2004, 45:*407 –416.

•Bowen C. *Vocal nodules and voice strain in pre-adolescents*. 1997 (members.tripod.com/Caroline_Bowen/teen-nodules.htm, accessed November 2009).

•Clark C et al. Exposure-effect relations between aircraft and road traffic noise exposure at school and reading comprehension: the RANCH project. *Am J Epidemiol.* 2006, 163:27-37.

Transport noise is an increasingly prominent feature of the urban environment, making noise pollution an important environmental public health issue. This paper reports on the 2001-2003 RANCH project, the first cross-national epidemiologic study known to examine exposure-effect relations between aircraft and road traffic noise exposure and reading comprehension. Participants were 2,010 children aged 9-10 years from 89 schools around Amsterdam Schiphol, Madrid Barajas, and London Heathrow airports. Data from The Netherlands, Spain, and the United Kingdom were pooled and analyzed using multilevel modeling. Aircraft noise exposure at school was linearly associated with impaired reading comprehension; the association was maintained after adjustment for socioeconomic variables (beta = -0.008, p = 0.012), aircraft noise annoyance, and other cognitive abilities (episodic memory, working memory, and sustained attention). Aircraft noise exposure at home was highly correlated with aircraft noise exposure at school and demonstrated a similar linear association with impaired reading comprehension. Road traffic noise exposure at school was not associated with reading comprehension in either the absence or the presence of aircraft noise (beta = 0.003, p = 0.509; beta = 0.002, p = 0.540, respectively). Findings were consistent across the three countries, which varied with respect to a range of socioeconomic and environmental variables, thus offering robust evidence of a direct exposure-effect relation between aircraft noise and reading comprehension.

•Jessen B, Ruge G. Skolebørn skriger sig syge [Schoolchildren scream until they get sick]. *Berlingske Tidende,* 2000:26.

Di jmesf o!boe!opjt f!

FGGFDUT!PG!OPJTFá /!
B!X PSE!BQBSU!GPS!UFFOBHFST""

- Qpuf oujbmt pvsdf t !pgi f bsjoh!jn qbjsn f ou
  - óOpjt z!upzt -!gjsf dsbdl f st -!cppn .cbst - n vt jdbmjot usvn f out -!pui f st
- Ejt dpui f r vf t !boe!qpq!dpodf sut !
  - óFyqpt vsf !t jn jmbs!up!pddvqbujpobmf yqpt vsf t !
  - óVt f !pgn vt jd!i f beqi pof t
- Mpt t !pgi f bsjoh!n bz!hp!voef uf duf e!gpsln boz!zf bst !bgf sldi spojd! f yqpt vsf !up!i jhi !mfwf mt!pgopjt f
- Jodsf bt f e!sbuf t !pgbeplmft df oui f bsjoh!jn qbjsn f oujo!mbt u4!ef dbef t
- Qspuf dujpo!of f ef e!gspn !ui f !t ubsu
  - óCf !jot usvduf e!up!vt f !qf st pobmi f bsjoh!qspuf dujpo
  - óOpujpomz!bu!x psl !cvu!bmtp!bu!uf di ojdbmboe!qpmzuf di ojd!t di pprnt

52

<<READ SLIDE>>

Noise is associated with youth. Often, teenagers' exposure is constant. Prolonged exposure can lead to a transitory loss of 10-30 dB for several minutes after the noise ceases. Frequency of exposure, personal variability, and age of exposure determine the pattern of the damage.

Music occurs outside of the major frequencies of the human voice and over exposure to loud music causes loss of discrimination at low frequencies which may not be detected without formal testing for years. "Walkman" equipment is designed for emissions not higher than 80 dB, but the combination of an immature hearing system and a prolonged use may cause cumulative damage. Technology can be modified to bypass factory-imposed limitations and result in very loud music/noise exposure. Loss of concentration because of the focus on the music, in the presence of a potentially dangerous situation, makes a young person more vulnerable to accidents.

Teenagers should be instructed to use personal hearing protection as soon as they start being exposed to high noise levels, not only at work, but also at technical and polytechnic schools. If noise-abatement measures are not taken, good hearing will not be preserved and noise-induced tinnitus will not be prevented. The extent of hearing impairment in teenagers, caused by occupational noise exposure, and exposure at technical and polytechnic schools is unknown.

There are insufficient numbers of studies on somatic, psycho-social and behavioural effects of noise in teenagers.

References:

•Axelsson A. et al. Early noise-induced hearing loss in teenage boys. *Scand Audiol,* 1981:10: 91–96.

•Baig LA. et al. Health and safety measures available for young labourers in the cottage industries of Karachi. *J Coll Physicians Surg Pak, 2005, 15:380.*

•Fontana AM. et al. Brazilian young adults and noise: Attitudes, habits, and audiological characteristics. *International Journal of Audiology*, 2009, 48(10):692-699

•Plontke SK et al. The incidence of acoustic trauma due to New Year's firecrackers. *Eur Arch Otorhinolaryngol,* 2002, 259:247-52.

•Ryberg JB. A national project to evaluate and reduce high sound pressure levels from music. *Noise Health,* 2009, 11(43):124-8.

•Segal S. et al. Inner ear damage in children due to noise exposure from toy cap pistols and firecrackers: a retrospective review of 53 cases. *Noise Health,* 2003, 5:13-8.

•Vogel I et.al. Young People's Exposure to Loud Music. A Summary of the Literature. *Am J Prev Med,* 2007, 33(2):124-133.

Di jmesf o!boe!opjt f !

QSFWFOUJPO BOE!JOUFSWFOUJPO

- Npsf !sf t f bsdi !of f ef e-!f t qf djbmmz!jo!wvmof sbcmf!hspvqt
- Qsf wf oujwf !bdujpo!
  - Opjt f !i bt !up!cf !dpouspmmfe!bu!u f !t pvsdf
  - I f bsjoh!qspuf dujpo!ef wjdf t !bsf !b!mbt u!sf t psu
- Di jme!i f bsjoh!dpot f swbujpo!qsphsbn t
- Fevdbujpo!boe!ejt t f n jobujpo

54

Future research:

•Effects of noise on cognitive functions.
•Effects of noise on children's sleep.
•Magnitude/significance of noise annoyance.
•Children's perception and risk perception.
•Settings: home, schools, hospital, day care centres.
•Teenagers' attention when driving and listening to loud music.
•Effect of non-audible noise.
•Identification of more vulnerable groups!
•Intervention programs/best practices for preventing harmful effects.

Preventive actions

Noise has to be controlled at the source by:
•Reducing.
•Enclosing the vibrating surfaces.
•Placing sound absorbers and other protections.
Hearing protection devices are a last resort!

Child hearing conservation program

•Noise monitoring where children live, study and play.
•Hearing protection programs diffusion for teachers and parents.
•Vibration detection and protection.
•Protection of the pregnant woman.

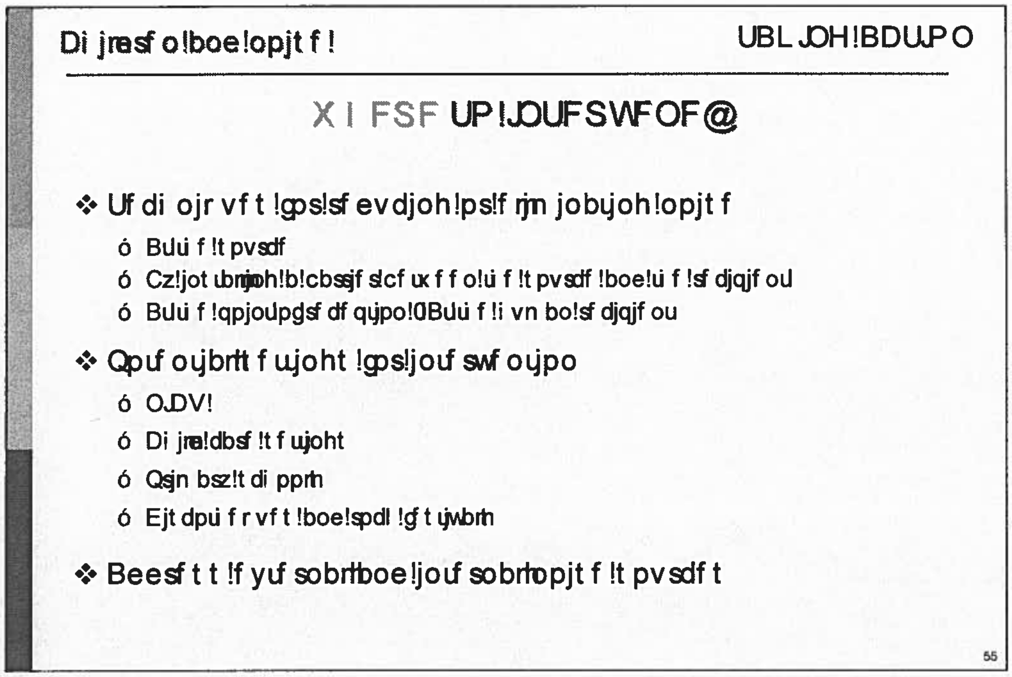
Education and dissemination

References:

•Folmer RL, et al. Hearing conservation education programs for children: a review. *J Sch Health.* 2002;72:51-7.

Prevalence of noise-induced hearing loss (NIHL) among children is increasing. Experts have recommended implementation of hearing conservation education programs in schools. Despite these recommendations made over the past three decades, basic hearing conservation information that could prevent countless cases of NIHL remains absent from most school curricula. This paper reviews existing hearing conservation education programs and materials designed for children or that could be adapted for classroom use. This information will be useful as a resource for educators and school administrators and should encourage further development, implementation, and dissemination of hearing conservation curricula. The overall, and admittedly ambitious, goal of this review is to facilitate implementation of hearing conservation curricula into all US schools on a continuing basis. Ultimately, implementation of such programs should reduce the prevalence of noise-induced hearing loss among children and adults.

•Moeller. Environmental Health, *Harvard University Press,* 1992.



<<READ SLIDE>>

Identified potential settings for intervention

1.NICU

2.Child care settings : more and more children stay in various child care settings. These play an important role in the initial stages of children beginning to establish their basic education.

3.Primary schools : primary school children often spend long periods of time in one classroom, and a noisy room can adversely affect the occupants of that room.

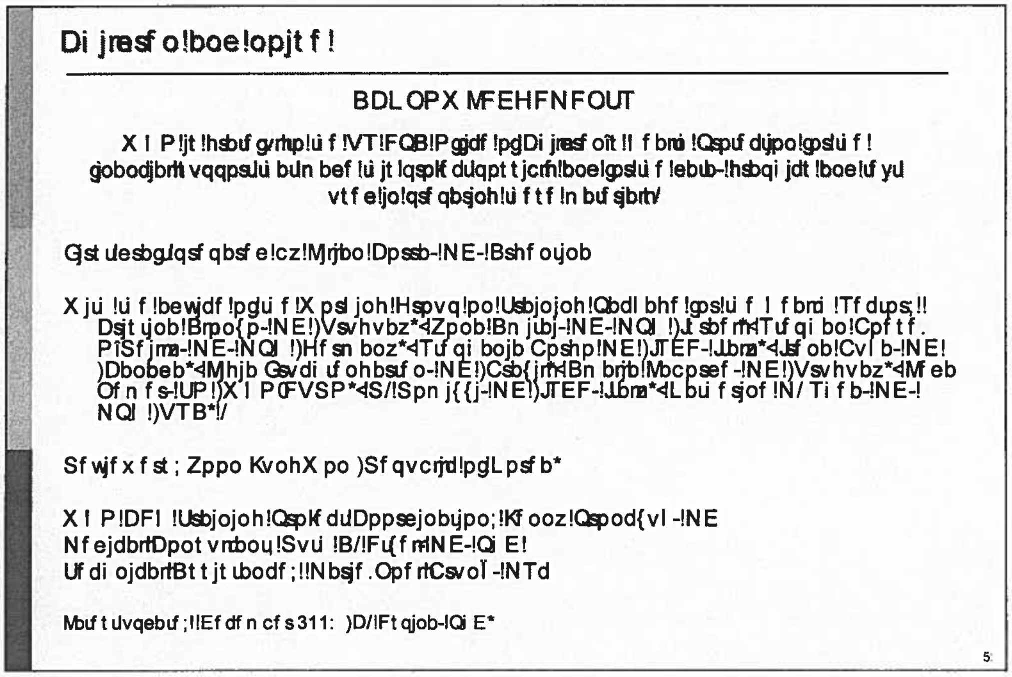
4.Discotheques and rock festivals : the noise level can be very high in discotheques, often resulting in tinnitus or a temporary threshold shift among patrons. Many major cities have festivals, and many of the noisier attractions inevitably appeal to younger people.

References:

•Bistrup M.L., Keiding L., ed. (2002). Children and noise - prevention of adverse effects. *Copenhagen, National Institute of Public Health* (also available at www.niph.dk).

•Byers JF, et al. Sound level exposure of high-risk infants in different environmental conditions. *Neonatal Netw.* 2006, 25(1):25-32.

PURPOSES: To provide descriptive information about the sound levels to which high-risk infants are exposed in various actual environmental conditions in the NICU, including the impact of physical renovation on sound levels, and to assess the contributions of various types of equipment, alarms, and activities to sound levels in simulated conditions in the NICU. DESIGN: Descriptive and comparative design. SAMPLE: Convenience sample of 134 infants at a southeastern quartemary children's hospital. MAIN OUTCOME VARIABLE: A-weighted decibel (dBA) sound levels under various actual and simulated environmental conditions. RESULTS: The renovated NICU was, on average, 4-6 dBA quieter across all environmental conditions than a comparable nonrenovated room, representing a significant sound level reduction. Sound levels remained above consensus recommendations despite physical redesign and staff training. Respiratory therapy equipment, alarms, staff talking, and infant fussiness contributed to higher sound levels. CONCLUSION: Evidence-based sound-reducing strategies are proposed. Findings were used to plan environment management as part of a developmental, family-centered care, performance improvement program and in new NICU planning.



We are indebted to Dr. Stephen Stansfeld (Queen Mary, University of London) for kindly lending us slides for this project.