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## **Noise Stress in Classrooms**

*August Schick, Maria Klatte, Markus Meis*

*Institute for Research into Man-Environment-Relations and  
Graduate School Psychoacoustics,  
University of Oldenburg (D)*

### **SUMMARY**

An analysis of German and international reference works shows that classroom acoustics have been sadly neglected worldwide. This is just as true for German as for other countries. In the United States, however, classroom acoustics has become increasingly important. From all parts of the world, values for noise levels are being reported which are no longer permissible in industrial and commercial places of work. That means: while parents are protected at their places of work, their children are expected to endure such conditions for years. The investigations also show that children suffer from learning difficulties under such stressful conditions. On occasions these can even lead to children doing significantly worse in tests in their noisy classrooms than under quiet conditions. Our report summarizes the verifiable difficulties children have when learning to read and speak in noisy surroundings. Today there appears to be justification for the assumption that poor performance at school has, to a great extent, to be put down to the inadequate ergonomic conditions found in schools. Noise caused in schools themselves together with the dreadful acoustics are mainly responsible for that.

## DESCRIPTION OF THE PROBLEM AND THE CURRENT STATE OF RESEARCH

An investigation was made into the noise stress among children in various situations under various stress conditions. In order to make the degree of reliability of our analysis clear, we divide the studies up in accordance with the following aspects.

**Studies into the effects of noise among adults:** Unfortunately children were always excluded from largescale studies into the effects of noise. For this reason Mills' review (1975) had to do without any statements about the effects of noise on children who were able to hear normally owing to the lack of investigations.

With regard to the question of performance, research into stress and its effects has mainly so far dealt with the effects of noise in industrial and commercial places of work (Smith and Jones 1992). In these studies adults were the focus of research. A number of investigations however, dealt with those tasks and stress conditions which are similar to those at school, for example the working conditions of office workers and shop salespeople who are subjected more to medium noise levels (Nemecek 1983, Sust 1987, 1989).

Studies by Battmann and Schönpflug (1986), Krenauer and Schönpflug (1980), Kuhl and Schönpflug (1974), Müller, Schönpflug and Stöber (1990), Schönpflug (1984, 1986, 1987, 1993), Schönpflug and Battmann (1982, 1987), Wieland and Schönpflug (1980) also show similarity with tasks from school situations. Sust not only published a very comprehensive study of reference work on this problem but also carried out investigations of her own in which she was able to show that even at 50 dB(A) average noise level disruptions occur when tasks are demanding: "When wide-ranging information has to be taken in, stored, related, assessed, recalled and/or the work is done under pressure or for performance assessment, decision times are extended, the amount of information is reduced, the error rates increase." (Sust

1989, p. 2). Such situations are comparable with those at school at least with regard to noise stress and tasks.

The following conclusions can be drawn from the comprehensive laboratory studies on the effects of noise on mental performance (see Smith and Jones 1992):

- Monotonous, simple and routine tasks such as choice reaction and vigilance tasks are not impaired by noise under 95 dB(A).
- In the case of complex tasks based on speech processing procedures in working memory, noise effects (measured by the effects of artificially produced broadband noise) are provable from sound levels of 70 to 80 dB(A). Among other things, these effects consist in the narrowing of the attentional focus, which, for example, is expressed in the recourse to the simplest, most primitive solution strategies, in the inflexible, rigid application of these strategies and in the concentration on the dominant, primary parts of the task, while neglecting secondary parts.
- The disruptive effects of background noise depend only to a small degree on its volume. Rather, it depends on the type of noise. In general, a continuous broadband noise presented at a moderate level will have no negative effects on performance; indeed it may well exert a positive effect on performance and well-being, as it partly masks disturbing noises (colleagues' conversations, telephone ringing) (Loewen and Suedfeld 1992). On the other hand, time-varying noises such as speech, music or the clattering of a typewriter-keyboard cause a fall in performance even at low levels (Smith 1985).
- The phonological short-term memory, a subsystem of working memory specialized for the temporary storage of speech-based information, has proved to be particularly susceptible to negative sound effects. A great many of investigations confirm the massive, disruptive effect of time-varying sounds on tasks relying on this system (e.g. Klatter and Hellbrück 1993, Klatter, Kilcher and Hellbrück 1995, Jones 1995). The disruptive effect

is known under the name of "Irrelevant Speech Effect" (ISE), as it can particularly be observed with background noises containing speech. It occurs at very low sound levels (from about 45 dB(A)) and is also caused by languages which are completely foreign to the people affected. Consequently, the effect cannot be put down to attention distractions caused by the contents of the text, or to alterations in activation due to volume. Rather, speech sounds appear to access the short-term memory directly and automatically and to interfere with the units to be memorized at that time. The ISE cannot be influenced intentionally, and even after a long time of exposure it does not become less, i.e. no habituation takes place (Hellbrück, Kuwano and Namba 1996).

- On the basis of a number of recent investigations (particularly some longitudinal studies which have been conducted very convincingly from a methodological point of view), the phonological short-term memory is ascribed an important function in the acquisition of one's mother tongue, literary language and a second language (Gathercole and Baddeley 1993, Baddeley, Gathercole and Papagno 1998). It must, therefore, be assumed that these basic performances are very susceptible to the disruptive effects of irrelevant speech. Consequently, children of nursery schools and primary schools are mainly affected. Unfortunately, corresponding investigations are not yet available.

**Studies into the effects of noise among children in domestic everyday environment:** There is a number of investigations which focus on the noise stress among children and young people of school age. These were concerned with stress caused by road traffic, aircraft noise, trams, trains, aeroplanes and low-level flights in domestic everyday life. The question here is: What are the consequences of such chronic stress for school achievement and behaviour at school in general?

As noise stress in the home can be a chronic form of stress, these results will always have to be included in the final interpretation of school achievement and other form of behaviour in the classroom. Part and parcel of this is probably the increasing consumption of tranquillizers among children, as Knipschild found at Amsterdam Airport.

A further example: Ando (1988), who conducted very largescale studies with children at Osaka Airport, suspected that the development of the brains of the elementary schoolchildren he was investigating, in particular the specialization of the different halves of the brain towards individual functions, was delayed by the constant stress caused by aircraft noise. He was able to show (1987) that music and aircraft noise disrupt in different ways, depending on the type of task involved. Music proved to be detrimental to performance, for example, in arithmetic tasks which - according to the author -are like music processed by the left half of the brain. The assumptions concerning functional brain asymmetries which underly this interpretation are surely too simple, but nevertheless this example shows: it is easier to explain school performance when the chronic stress experienced outside school is taken into account.

The many individual investigations which have been carried out at the two airports in Munich must be mentioned, too. This group of researchers has also published important investigations into the physiological changes caused by noise stress. The main focal point was cardiac-circulatory-stress, the vegetative and hormonal quantities (Evans, Hygge, Bullinger 1995).

**Stress caused by traffic noise among children at school:**

There are investigations involving whole school classes who suffer stress at school itself from road traffic, aircraft noise, trams, trains, aeroplans and low-level flights. The results of these studies have been summarized in a number of surveys (Evans 1998; Schick 1990; Meis 1998). Noise stress from adjoining roads seems to be decreasing continually, particularly because since the fifties schoolbuildings in the Former West Germany have been constructed facing away from roads for safety reasons: We personally

know of many more schools in the Former East Germany which suffer greatly from road traffic noise. Schuschke and Rudloff (1994), Rudloff and Schuschke (1993) described the refurbishment required at schools in the Magdeburg area and came to the conclusions: "In the Federal Republic of Germany there are no limits for traffic noise in existing streets. In schools exposed to noise in a city, acoustic tests were carried out which showed the need for measures to reduce noise and the need for action on the part of lawmakers for premises in particular need of noise protection. The acoustic impact of traffic noise in schools built on disadvantageous sites leads to average sound levels over 60 dB(A) during lessons in the classroom. Reference is made to the necessity of taking into consideration short-term fluctuations in the noise level because of the greater effect of disruption and stress of such fluctuations. One possibility of considering these level fluctuations is proposed by the calculation of an effective noise level (Wirkpegel), which reflects the disruptive sound adequately. This measurement procedure appropriately complements the otherwise usual evaluation of sound events by solely giving the equivalent mean sound level  $L_{eq}$ ."

**Hearing impairments among children and young people:** In the last ten years, a number of papers have appeared in which considerable hearing impairments were diagnosed among children and young people. Costa, Hellström and Axelsson (1990) showed that 15 % of all the students attending a Swedish vocational school suffered from hearing impairment, even though they had not been subjected to noise at their place of work. Taking Nelsson's (1997) data as a basis for comparison, we must assume that in Germany there are between 5 % and 10 % of children in every school class who suffer from occasional and chronic hearing impairment. Children with hearing impairment, who as a rule attend normal schools, have frequently been the subject of investigations which we are not including in our analysis, because the requirements made of room acoustics are even higher than for people with normal hearing. We are only taking those papers into consideration when they contain data about children with normal hearing as well.

The helpful survey on classroom acoustics made by Ruhe (1998), although mainly intended for work with hearing-impaired people, may in the same way acquire significance for those with normal hearing abilities. Fuchs and Zha (1996) use a number of examples to explain some of the basic problems of classroom acoustics, and point out that improved acoustics are often not accepted by the users, who virtually have to learn to become accustomed to the new acoustics.

In the following analysis we have excluded all the papers which fall into one of the above categories, because above all we have restricted ourselves to verifiable facts from investigations close to schools. We have restricted ourselves to the noise stress experienced by schoolchildren and teachers in the self-imposed conditions of school and lessons. In doing so, we wish to avoid the reproach of having transferred conclusions from non-school investigations to the school situation rashly and without authority.

### **THE SELF-IMPOSED CONDITIONS OF SCHOOL AS A SOURCE OF STRESS**

The educationist, Rost (1979) entitled one of the chapters in his book on child-rearing "We can no longer play down the damage noise does to health." In 1980 Ritterstädt, Reimer & Kastka analyzed the acoustics of 16 classrooms; 25 % of all teachers felt themselves as annoyed by noises. Our experience gained from enquiries and visits to schools during teacher training proves that both teachers and schoolchildren suffer from the noise they in parts cause themselves in classrooms and corridors. In every school class there are children with attention disorders who continually cause noise and make teaching impossible (cf. Zoellner 1985 for handicapped school children). They run around aimlessly, call out for no reason and throw things about in order to draw attention to themselves. Such findings are described in clinical psychotherapy as a syndrome of Attention Deficit Disorder-Hyperkinesis (ADD-H) - with regard to noise chiefly by Zentall und Shaw

(1980), Zentall und Meyer (1987), Lucker, Geffner und Koch (1996). We are using these observations as an opportunity to make another thorough scientific investigation into this question and to work out a factual report. In the December issue of the magazine, "Beispiele. In Niedersachsen Schule machen" the health of school-teachers was discussed. It was striking that not one of the articles dealt with noise stress, which is why we think it all the more important to mention.

In schoolclasses in Germany today you will find that up to 50 % of the children are foreigners with only a limited knowledge of German. These children are disadvantaged when hearing their own and the foreign language when speech is submerged in noise. Our analysis shows, however, that there are no investigations into this, only individual observations and reports of teachers' experience. We consider such investigations to be very important.

Piper und Szymanek (1998) as teachers' representatives complain about the complacency shown by the Ministry of Education which has been aware of the problems for a long time. They point out that the Laws on Safety at work have been valid for school since 1973. Besides, in 1996 the Law on Protection at work, based on European regulations, came into effect (Szymanek 1998). In this respect teachers also have a right to work and health protection measures. Kuehs (1993) made an ergonomic checklist which included noise. Scheuch dealt with noise stress suffered by teachers from a psychiatric point of view, and Wochnik's (1990) contribution deals with the difficulties experienced by teachers who are hard of hearing - a problem which may frankly be regarded as taboo. Ingo Titze, the Director of the National Center for Voice and Speech at the University of Iowa, estimates the number of teachers with voice disorders in the USA at 3.1 million. In the United States, teachers form the main group of patients with voice disorders. The English textbook of Jones (1995) which aims to put eco-psychological ideas in school organization and school buildings into practice deals with room climate and light along with noise. Whereas Bronzaft (1997) describes noise in educational facilities as being a worldwide problem, the public takes hardly any notice of it. A glance at the current discussion on in-service teacher

training courses shows that stress factors such as noise and room climate receive little attention. A report by Tacke (1998) does mention noise, but that is all. In this respect we have the opportunity to supplement the current sociopsychological-clinical analyses by the noise factor. The way in which room climate acts in combination with lighting and room acoustics appears to have been investigated in the workplace but not in the Kindergarten and other educational facilities (Duke 1998). We see our research as being confirmed by the summary presented by Helmke and Weinert (1997, p. 97), who maintain: "In comparison to the social conditions and socio-psychological forms of behaviour in the classroom, the physical context factors are frequently underestimated or completely ignored."

### **NOISE EXPOSURE OF CHILDREN AND TEACHERS AT SCHOOL**

**Schoolbuildings and architectural acoustics:** In Germany, the guidelines and requirements for architectural acoustics are regulated by various norms. In German Industrial Standard (DIN) 4109 (Noise protection in structural engineering, in part specified by the states with particular requirements made of airborne insulation of building parts used in schools and comparable educational establishments), DIN 18041 (audibility in lecture halls, small to medium-sized rooms), DIN 18032 (sport halls, halls for gymnastics, games and multipurposes). However, as DIN 4109 has existed as a draft for nearly thirty years, during which time it has seen many alterations, it is safe to assume that schools do not meet the acoustical guidelines. Measurements taken in Berlin revealed as much as 76 dB(A) Leq over a period of eight hours in a first-year primary school class. In comparison: the regulation governing places of work provides a limit of 55 dB(A) where, in the main, intellectual work is carried out. That is why as long ago as the 1970s in programmes such as "The human school" the Ministries and teachers' organizations pointed out the inadequate acoustical situation

in the classroom. Löwe, one of the founders of paedaudiology in Germany, complained in 1990 about the acoustical state of classrooms with their overlong reverberation times. In 1997 Sennheiser, the German fabricator of audio equipments, measured in classrooms following mean sound levels: without children 42,5 up to 46,6 dB, in classrooms with children: 75 dB (5 and 6 years old), 65,3 dB (primary school), 64,5 dB (11-16 years). The measured values and observations reported here are not based on systematic enquiries. A literature analysis of the Data Bank "Environmental Planning, Urban Development, Housing, Buildings and Construction" of the IRB in Stuttgart revealed only a few small publications on ideas for new school-buildings: they describe a number of model schools in brief and in general, but they do not contain any empirical data about noise (Andersch 1992; STERN 1991; Wagner 1990; Solingen 1987; Bildungszentrum Barnettstrasse 1995; Graf 1995; Staatliches Gymnasium Neufahrn 1994). The following survey of research activity will therefore confirm a research deficit in Germany.

DeJoy (1983) summarized in a general paper the results of various American studies, which show that in many cases noise is detrimental to children's school achievement and their cognitive development. The speech-related functions are particularly affected. Brooks, Du Bois, Lubman, Nixon, Pearsons, Schaffer, Soli and Sutherland (1998) published a report on the state of classroom acoustics in the USA. At the International Congress of Acoustics many researchers from the Architecture Technology Research Center, Florida, report about state of the art: Siebein et al. 1998; Gold et al. 1998; Crandell et al. 1998; Herrwagen und Khiati 1998). According to this, under sponsorship of the Acoustical Society of America a working group of acousticians, audiologists, educators and psychologists, published a draft of standards and guidelines with which the inadequate acoustics of many American schools are to be overhauled. Picard and Bradley (1997) report that as a rule the optimal values for intelligibility are exceeded by 4 up to 38 dB(A). "The aim is to remove the acoustical barriers to learning that prevent students of all ages from reaching their full potential. Good acoustics is central to classroom learning

and is therefore vital to every knowledge-based society... Poor acoustics is the single most common environmental complaint affecting many millions of children in the U. S. Legislation known as the American with Disabilities Act (ADA) that has stimulated a need to accommodate large numbers of students with hearing, learning and language disabilities into 'mainstreamed' classrooms. Such classrooms require improved acoustical conditions for speech communication." (p. 191). In 1997 the American government spent \$ 12.8 Billion on schoolbuildings. Unfortunately, it is not known how much is payed for a better acoustics. The cost of overhauling the acoustics of a classroom is estimated at between \$ 2.000 and \$ 8.000. The government has declared this major project to refurbish schools one of ist most important aims. Noise appears to be the main cause of most complaints. Nixon (1999), an architectural acoustician, stated that 99 % of all communication problems were caused by faulty acoustics. While we may appreciate that he is exaggerating, nevertheless it shows the amount of importance attached to good school acoustics in the USA today. A survey of practical hints on the acoustical design needed in classrooms with children of normal hearing ability, including the setting up of allround loudspeaker systems is offered by Berg et al. (1996), Crandell and Smaldino (1994), Easterbrooks (1998), Anderson (1997), Green et al. (1996), Palmer (1997, 1998), Ross (1992) and Knirk (1992).

Bowden (1980) showed that handicapped children have greater difficulty in understanding stories that are told in background noise (cafeteria situation and talking children) than have children with normal hearing. Schulz (1981) reported similar results for German children. Schoene (1981) was able to replicate the same findings for a sample of children with learning diffiiculties. Numerous investigations confirm that both mentally handicapped children and those with hearing impairment have greater difficulty with tasks they are unable to hear properly.

Hétu, Truchon, Gagnon, Bilodeau (1990) report on the situation at Canadian schools. They questioned teachers from six schools with fifty classrooms about noise; "...many teachers considered noise to be detrimental to their work, in particular, interfering with

speech. Noise in an educational setting has many detrimental effects that may have significant psychological and physical impacts on both children and teachers. Noise problems may be even more acute for people with special problems, be they perceptual, socio-emotional, or cognitive."

Josserand and Occelli (1989) describe the situation at French schools and the programme set up by the French government. They report on values of up to 70 dB(A) in classrooms. In vocational schools 95-100 dB(A) are not unusual.

In the Netherlands Houtgast (1981) looked into the question of noise in classrooms; he concentrated on speech intelligibility and developed his RASTI-Method of measuring room acoustics easily and in a standardized way. This procedure has been adopted worldwide.

Airey, MacKenzie und Craik (1998) presented a major study on the stress experienced by schoolchildren and teachers in England. They reported on stress levels of up to 100 dB(A). In 60 primary schools they registered the speech comprehension of the schoolchildren and were able to achieve considerable improvements in performance by improving room acoustics (Mackenzie and Craik 1999). Airey (1999) and Mackenzie (1998) summarize their results in a survey and compare the guidelines of individual countries.

Blake and Busby (1994) presented values for New Zealand primary school beginners. They examined fifty schools with 106 classrooms and 149 teachers. An average signal-to-noise-ratio of 6 dB(A) emerged. As such values are too small, they conclude their reports by commenting: "The acoustic conditions in the majority of classrooms studied were unacceptable."

In Spain, diverse groups investigated the classroom acoustics: Delgado, Perera und Santiago (1993) examined the acoustics in classrooms, and the remarkable thing about their work is that they measured speech intelligibility from every single seat in the room. Another group (Garcia, Romero, Garcia and Arana 1989; Romero and Garcia 1992; Garcia, Garcia and Romero 1993; Romero, Garcia and Garcia 1992) dealt with noise stress in schools in the province of Valencia. They were particularly interested in the sources of the noise and therefore also registered the noise levels

on the outer walls of classrooms. They interviewed teachers to find out to which sources they mainly ascribed the noise. The teachers believed that the main source was in their own and neighbouring classrooms.

Seballos, Costabal and Matamala (1993) examined the acoustics in classrooms in Chile and their effects on the learning and behaviour variables of schoolchildren between the ages of 7 and 18.

Kryukova and Abramchuk (1991) measured values of over 75 dB(A) Leq in the recess halls in White Russian school centres with between 1800 and 2200 students, making it impossible for them to relax. The schools should be made smaller.

Sone and Kono (1990) registered the individual noise stress experienced by people of different professions in the Japanese cities of Tokyo, Sendai and Nagoya. They showed that teachers in Nursery schools and primary schools, together with nurses, suffer the greatest stress.

Niu (1990) investigated the cognitive capabilities of Chinese primary schoolchildren in classrooms ranging between 42 dB(A) and over 55 dB(A). Without exception the differences in performance were significantly in favour of the quiet classrooms. Wang (1987) published suggestions for the acoustics overhaul of classrooms in China.

Benesova, Brunclikova, Dohnal and Synkova (1988) subjected schoolclasses to noise and found that children who lived in quieter residential areas were more resistant to noise than noise-stressed children. That means: when schoolchildren are subjected to a permanent over-stressed situation at school, this can lead to a reduction in their school performance.

In Poland, a working group centered around Koszarny has been dealing with acoustics in schools for a number of years (Koszarny and Jankowska 1995,1996). In the recess halls of primary schools they measured a noise level of 86 dB(A), in secondary schools it was 9 dB(A) less. They believe that a desirable sound level can be achieved in classes with up to 25 children. If the number exceeds 30, values 3 dB(A) higher must be expected. They report on an average stress value of 80 dB(A) among primary schoolchildren,

where by the State Schools reach as much as 85 dB(A), while the Private Schools record 72 dB(A).

**Impairment of the speech and auditory functions:** At school, communication is above all speech-based; which is why speech intelligibility is of outstanding importance. In addition, sound does not only block out the "functional noise" speech, but also masks the cognitive functions and operations in which speech is involved directly and invisibly.

Intelligibility depends on the room acoustical conditions: we perceive directly what someone says to us from a distance of about 60 cms; when we, as listeners, hear at a distance of over 60 cms, we perceive speech increasingly weakly, i.e. the reflecting properties of the room and the objects in it further or impede intelligibility. Normal schoolchildren, children with central and peripheral hearing disorders and foreign children are affected by inadequate intelligibility.

One of the early works on impairment by noise when learning the sound distinctions between words was written by Finitzo and Tillman (1978). In their study, not only children with hearing impairment but also those with normal hearing had problems. These findings have been confirmed again and again over the years.

Geffner, Lucker and Koch (1996) also investigated the ability of auditory discrimination between words. They compared children between the ages of 7 and 12 both with and without disorders of hearing discrimination performance. The children with disorders were, in addition, decidedly overactive. They were not examined at school but in the clinic. The stressful noises (meaningful speech, meaningless speech, and the noises in a cafeteria) were, however, common at school. Whereas there were no differences between the groups under conditions of quiet, the discrimination performance of the hearing-impaired children deteriorated under "speech noise". That means the omissions become really effective because of the noise stress. The authors were thus able to replicate the earlier findings of Nober (1973, 1975).

At the instigation of the interdisciplinary working group at the Federal Environmental Agency, Spreng (1994) delivered a report

on the state of research into the noise-induced impairments of communication between normal hearing people. He goes into the dependency of speech intelligibility on the level of disruptive noise, the frequency/time composition, the structure of the room (reverberation), the distance between the speaker and the listener, the binaural and visual additional information, the speech intensity, speech distortions and variations in articulation and speech velocity. Special emphasis is laid on the stress suffered by speaker and listener due to noise, which particularly affects infants, young children, children with hearing impairments and schoolchildren.

**Impairment of social and motivational functions:** Since the investigations carried out by Glass and Singer (1972) and Cohen and Lezak (1977), we have known that noise reduces contact and the willingness to help - which poses a not inconsiderable problem for kindergartens and schools.

Evans (1998) summarized the main results of this research work in a survey. It shows that schoolchildren suffering from noise stress are more difficult to motivate, and they give up more easily when tasks become more difficult. These effects have been proved both for short periods of exposure, of half an hour's duration, and for chronic noise stress. In many cases, the phenomenon of helplessness appears to be perfectly verifiable. Evans therefore speaks of "noise avoidant learning". He mentions (p. 316) a number of occasional observations and in particular the study made by Wachs (1987) who observed disorders in the development of achievement motivation among babies caused by permanent daily noise stress in the home. Although this is not a school situation, it reveals the sensitivity of children to "moderate" noise stress.

## ARE THERE PRACTICABLE WAYS OF DEALING WITH IMPAIRMENT OF SPEECH INTELLIGIBILITY?

Andersson (1994, p. 1006), Berglund and Lindvall (1995), Madell (1990), Pekkarinen and Viljanen (1990), Viljanen and Pekkarinen (1993), Fuchs and Zha (1996), Ruhe (1998) all suggested ways of making improvements despite the lamentable state of classroom acoustics. They put together a list of important conditions required for a good acoustical situation in a classroom, and the WHO-report (1993) adopted it:

- no disturbing reflections and an appropriate room structure.
- a short reverberation time  $\leq 0,6$  s in the octave bands 125 to 4000 Hz. The octave band of 125 Hz is especially important for schoolchildren with hearing impairment because they are particularly sensitive in the deep frequency range. This is also a reason for the use of the C-evaluated sound level. Children react to overlong reverberation time more sensitively than adults (Yacullo and Hawkins 1987).
- Andersson reports from studies by Crandell (1993) and Crandell and Smaldino (1994), that even people with only a slight hearing loss of about 10-15 dB(A) have considerable greater intelligibility problems than normal hearers. A lot of normal hearers suffer from such hearing impairment, for example, when they have a cold. That is why Andersson recommends an reverberation time of not more than 0,4 s. Crandell (1997) published a new comprehensive study in which he related the room acoustical parameters of the room and material structures with various parameters of speech communication. These studies can be used as a basis for the acoustical overhaul of classrooms today.
- Berglund and Lindvall propose an reverberation time of less than 1 s for school assembly rooms and cafeterias. Unfortunately, according to the reports of various authors, these requirements are seldom fulfilled.

- as a background level a low  $L_{eq} \leq 30$  dB(A) and  $\leq 50$  dB(C). This value is laid down in German DIN 4109 but is certainly not often put into practice. Ruhe (1998) refers to Table 4 of DIN 1946-2, which distinguishes between high and low guidelines: in the one case 35 dB(A), in the other 40 dB(A).
- In American kindergartens and schools, transmission systems are being tried out among classes with normal hearing ability, in order to facilitate speech intelligibility, because the distance between the functional signal "speech" and the background noise is becoming greater. Of course, such systems are also used in Germany for lessons with children who have hearing impairment.

"Ordinary everyday speech is completely intelligible at an interference noise level of  $L_A$  45 dB and is still moderately intelligible at levels up to  $L_A$  55 dB. Speech expressed with raised intonation can be easily understood at an disturbing noise level of up to  $L_A$  65 dB" (Lazarus, Lazarus-Mainka und Schubeius 1985). However, the raised intonation is exhausting over a long period.

Assuming that a normal teacher's voice is 60 dB(A), according to the Lombard Law he has to speak at a volume of at least 70-75 dB(A). Lazarus, Lazarus-Mainka and Schubeius (1985), Lazarus-Mainka, Schubeius, Hörmann and Lazarus (1983), Lazarus-Mainka, Lazarus, Hörmann and Schubeius (1981) have described the difficulties resulting from this: "The speaker articulates more slowly, the numbers of pauses increases, longer pauses are made between the sentences. Furthermore, the statements become simpler, less information is given." Not only the teachers who are speaking become tired, but also the schoolchildren who are speaking and listening.

Amazi und Garber (1982) report on investigations in which the Lombard-Effect causes children who are learning to speak to tend to reach the volume of people living around them, they almost overcompensate. Unlike adults, they are not able to modify the volume according to the task. Planners drawing conclusions from

this can say: in rooms in which speech intelligibility is important, the basic noise level should not exceed 35 dB(A).

Andersson also describes the difficulties a speaker in a room has: he hears himself but does not know how his listeners perceive him. As the speaker orientates himself in accordance with his own hearing impression, he often underestimates his intelligibility when the reverberation times are very short. To compensate for this, he raises his voice unnecessarily. Andersson proposes that the speaker should occasionally listen to another speaker from the back of the room, in order to confirm himself of the good intelligibility. The children in Amazi and Garber (1982) study also seem to orientate themselves mainly in accordance with their own hearing impression. Andersson and Bronzaft (1981) were able to use relatively simple means to improve the room acoustics in classrooms (e.g. absorbers made of various materials). The effects on speakers and listeners were decidedly positive and beneficial. The sound absorbing measures even led to an improvement in children's reading performance.

## **EFFECTS ON KINDERGARTENS AND DAY-NURSERIES**

**Effects on children:** As the individual hearing functions, pre-speech capabilities and speech capabilities of children develop very early, they require special attention with regard to their fostering and possible impairment. Allen, Wightman, Kistler and Dolan (1988) were able to show that the ability to distinguish frequency develops further in the child's third year.

Maxwell and Evans (1988) investigated the inadequate room acoustics of a day nursery as a significant source of disturbance. After acoustical improvements had been carried out, the children were able to improve their performance in early reading, learning numbers and their speech ability.

In German speaking countries it was mainly the medical service of the former German Democratic Republic which looked into the noise stress experienced by children in crèches (Bartsch,

Berger, Neumann 1984; Neumann, Berger, Bartsch 1985; Grosch, Niebsch und Schneeweiss 1983; Hoffmann 1983).

**Effects on the Staff:** At the 74th Annual Conference of Ear, Nose and Throat Specialists in Oldenburg, Berger reported on 8 hours of noise stress at 78 dB(A). The kindergarten teachers feel most disturbed. The children feel disturbed most of all when they are playing. Nilsson (1998) examined school teachers and kindergarten teachers in Denmark who had gone into an audiological clinic for treatment for tinnitus and loss of hearing due to noise. As no convincing causes could be established, measurements were taken in the kindergartens. These revealed a Leq of 80-85 dB(A) during working hours. This means that they were working under noise conditions for which hearing protection would be recommended in an ordinary industrial firm. Such developments led to demands by Werner (1998) to include noise nuisance in kindergartens and schools today in the total acoustical stress that people experience.

Sala, Airo, Lain, Olkinuora, Pentti and Suonpää (1998) examined the speech stress and susceptibility to voice disorders of 200 teachers from 25 day centres for children. This Finnish study was carried out very thoroughly from both a clinical and a psychological point of view. The disorders were mainly caused by inadequate acoustics in the rooms and by the necessity to speak more loudly than normal over long periods.

## FURTHER IDEAS

- Schools are beginning to rediscover the value of silence again (Spranger 1957; Guardini 1957) which plays a central part in Steiner's and Montessori's concept of education (cf work by Buddemeier 1990). Paulus (1998) reported on the "Network of Healthy Schools" on the occasion of the Conference to Reduce Noise in Europe. Rivlin and Weinstein (1984) summarized results of research into school climate from three different points

of view: school is a place to learn, to live together and to develop psychologically. Surroundings free from noise stress appear to be an important precondition for the realization of these aims. Among other books on educating people to appreciate silence, Claussen (1997), Israel (1989) published a work based on his own experience of creating a quiet, learning intensive atmosphere to combat increasing noise stress in the primary school. Six essays in the Westermann Educational Series (1984) suggested more comprehensive ways of teaching and learning in peace (Bertelsmann 1984; Bergk 1984; Heidemann 1984; Hofmannsthal 1984; Meckling 1984). As part of a teaching project, Keunecke and Häußler (1996) made use of the direct stress caused by traffic noise in order to combat it. Hammerschmidt's (1997) schoolchildren even developed sound proof materials against traffic noise. More and more books on survival in kindergartens, schools and the home are appearing more and more frequently (Essa 1995; Tubbs 1992; Lauth, Schlottke and Naumann 1998; Heitkaemper 1995).

- A completely quiet school is surely not regarded as ideal; on the contrary, the increase in freedom in learning has necessarily led to an increase in noise. Approaches which particularly foster creativity maintain that children must be allowed to make a noise (cf Edwards and Springate 1995 on the concept of creativity). But just because of this, the room acoustics should not intensify, but muffle and moderate this natural sound level.
- In Switzerland the Ministry of Health is carrying out a campaign involving the media called "All Ears" to prevent and sensitise people to self-produced noise. In this connection, investigations by Miller (1982), Miller and Zalensky (1982), Miller and Shannon (1984) seem to us to be pointing the way. In the early eighties they dealt with the question, which factors do schoolchildren and students believe to determine their own learning. Schoolchildren were to be made aware of the conditions that disturb their learning and distract or attract their attention. When schoolchildren had to consider whether they should ascribe people's performance rather to noise than the strength of

interests, kindergarten children and primary school children attached greater importance to noise than did older children. Kindergarten children, according to Holmes (1991) regarded a noisy situation as a sign of games and free time. Altogether, with increasing age noise stress was cited as being less significant for learning than the other physical factors. These experiments are not simply comparable with the actual stress investigations we have described above; learning situations were presented only in the form of stories. Altogether, however, the work shows that noise was not subjectively ascribed the harmful role that we as enlightened researchers into the effect of sound would have wished. This finding corresponds to the results of investigations into the public's generally low degree of noise consciousness. Accordingly, it is not surprising that even those affected do not regard improving the acoustical situation as being of great importance. There are, however, a number of teaching experiment to draw schoolchildren's attention to the way they are affected in discos and at rock concerts and to sensitize them to noise. Fruth (1989) drew up a list of suggestions for parents on how schoolchildren could protect themselves against noise. Stracke (1982) discussed the topic of concentration and quietness with his classes; Noack (1982) and his secondary school pupils carried out experiments with noise, and a similar approach was made by Olson (1995). Wagner (1995) dealt with noise in a cross-disciplinary project on questions of health and work. And Zoellner (1985) tried out a unit on noise stress with schoolchildren with special educational needs.

- Similar activities are planned by the Federal Center for Health Education in Cologne. Chermak, Curtis, Seil and Anthony (1996) describe a Learning Programme with which they tried to win over schoolchildren to protect their hearing. We shall not go into that at this point, because we have discussed "noise consciousness" and motivation to bring about less noisy behaviour in greater detail in other publications.

- Dunn (1983, 1987) assumed that every schoolchild lives in his own individual learning environment: When demands are placed on schoolchildren by particularly difficult tasks, the need to form it in their own way increases: individual preferences and personal styles concerning loud music are part of this. Dunn even developed an instrument to categorize this learning style. Hodgkin and Wooliscroft (1997) took up Dunn's ideas about learning style and laid out classrooms in accordance with acoustical and ergonomic considerations. Handelsman (1978) went down a similar path when she compared the reading performances of Grade 3 children under different noise conditions in the classroom, environmental noise with white noise, environmental noise with playground noise, and environmental noise mixed with music. This study was different from other investigations in that Handelsman assumed that noises activate to produce better performance when they are presented in combinations. No differences in performance were observed between the individual conditions. The author even suggests training schoolchildren to learn under different noise conditions. Shimozono (1995) looks at white noise in the form of splashing seawater, applying these techniques in the main to children with learning difficulties. The research of Zentall and Shaw (1980) and Johansson (1983) was also guided by the arousal theory. Investigating the effects of noise, it seems, one must be prepared to see that noise not only reduces performance but can also promote it to a certain extent.
  
- Schuschke and Rudloff (1994) criticise the concept of the energetic summation and the Leq and the resulting inadequate reflection of the stress effects by the measuring values. They propose to use the effective noise level in terms of a Takt-Maximal-Pegel of noise (i.e. effect-oriented time-interval maximum level) among school stress. "With regard to the WHO Health Definitions, noise stress ought to receive great attention both in methods of measuring and the assessment procedures. Modern measuring technology makes the registration of a great number of additional parameters of a sound

event possible, for example, its dynamics, the top values and the maximum and minimum sound level. With the aid of a model effective noise level the authors explain how additional stress-effective parameters can be taken into consideration when assessing sound" (p. 49).

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