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Noise in Schools – Causes and Reduction

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Noise in Schools – Causes and Reduction

H.-G. Schönwälder, J. Berndt, F. Ströver, G. Tiesler

1 Noise Situation in Educational Facilities

In educational facilities people teach and people learn. This gives rise to sounds which are a nuisance, which disturb and which are perceived as noise. This is claimed to be a major stress factor by about 80% of those teaching in, for example, schools¹. The project² "Noise in Education Facilities – Causes and Reduction" funded by the Federal Institute for Occupational Safety and Health in Germany dealt with this problem. Alongside a review of the actual noise situation, possibilities were investigated as to how this stress factor can be countered. The education facilities here are represented by regular schools (4 primary schools and 1 school of the German secondary level I in the public school system), their teaching staff, male and female, and by pupils in the age groups of about 6 to 16. The rooms in which educational or training processes are implemented as well as their acoustic features play a role in the noise development. In all these schools sample class rooms were taken (N=30) and their room-acoustic features were examined (reverberation times, speech intelligibility index). In addition all the noise-related events in a total of 565 teaching periods in the 1st to 10th years were registered by, in each case, 2 observers; at the same time the intensity of the noises arising in the teaching-learning process were continuously recorded using sound level measuring instruments.

Noise arising in education institutions only rarely attains the high intensity which can result in hearing damage after many years of exposure. A rating level – the average noise level during working time – of 85 dB(A) and above was not verified in the course of our investigations, although findings obtained in woodwork and metalwork shops in occupational training facilities indicate that even such intensity levels can arise occasionally in education facilities; but they are not the rule. Rather it is "noise of medium intensity" which teachers perceive as disturbing in work situations and which has to be classified as stress-inducing. It contributes to the stress spectrum for people working in education institutions and hinders them in the optimum performance of their tasks.

In this study average sound levels of between 60 and 85 dB(A) were measured in schools during teaching, as the example of a day profile in Figure 1 shows. These are sound levels which partly surpass by a factor of several times the sound intensities which work scientists recommend for informative activities, for example office work. SUST AND LAZARUS (1997)³, however, demand that in rooms used for education purposes basic sound levels and reverberation times must even be substantially lower than for other mental activities (for basic sound levels by 30 – 45 dB(A)) and for reverberation times (by 0.4 secs). The crucial fact is that education processes are often mainly based on the medium of verbal-auditive communication, on speaking (informing and explaining) and on listening (understanding and processing). It is this medium that is impaired most or even partially rendered ineffective by interfering noises.

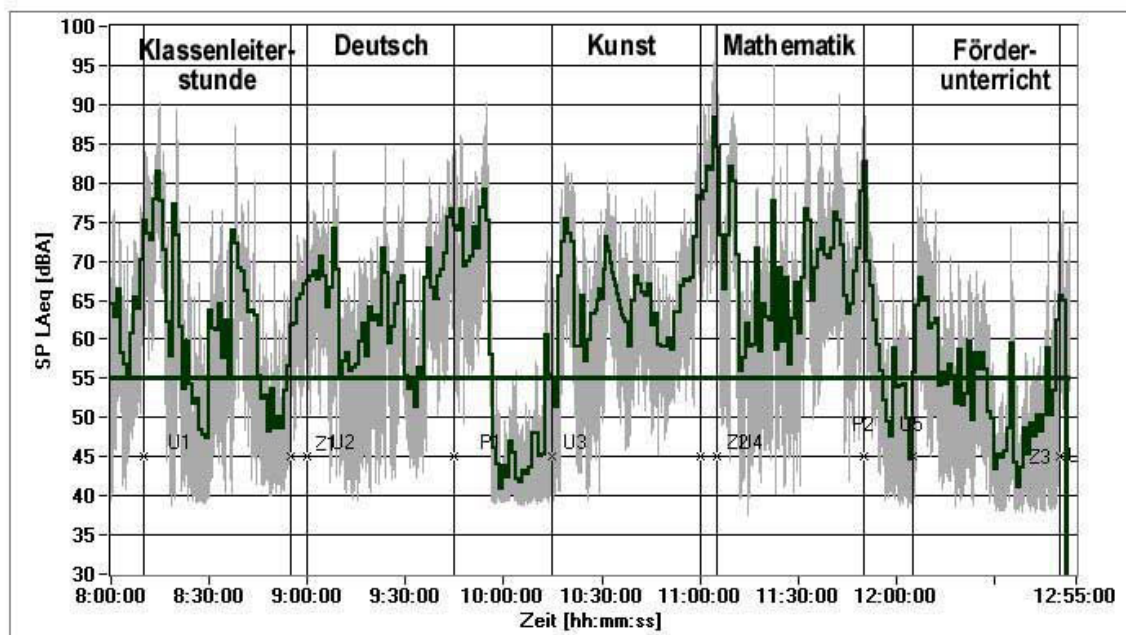


Fig. 1 Day profile of sound level in a 1st year class

Klassenleiterstunde – Class teacher period, Deutsch – German, Kunst – Art, Mathematik – Mathematics, Förderunterricht – Special instruction

The faultless transfer of information assumes optimum room-acoustic conditions; they can be assessed on the basis of the *reverberation time of sound signals* and the *speech intelligibility of spoken texts*, calculated as the *speech intelligibility index* (STI). Deficient room acoustics quickly lead to a rise in the noise level due to the insufficient absorption of interfering noises and to the incomplete "counter-productive" attempt to avoid errors of comprehension by raising the voice.

The consequences are defective communication, interference with cognitive processes, greater effort of speech, raised stress perception and hence, in the final analysis, superfluous exhaustion. The results of teaching and learning are impaired. Defective room acoustics were encountered in the majority of the 30 classrooms examined in 5 schools in Bremen and North Rhine-Westphalia (Germany).

The observations made in the present study indicate a clear age dependence of the intensity of noises in lessons within the age range examined of 6 to 16: younger age groups are louder than the older ones. For the adolescent group it can be assumed that their attention is directed more towards the learning process than is the case with those who have just started school, a part of whose energy (including their vocal energy) is devoted to assertion in the learning group (pecking order). The effects of the social behaviour of pupils and of the noise level they help to cause on learning processes can be estimated, for example, using the laboratory studies of SCHICK et.al. (2003)⁴.

Effects on the noise situation in a learning or working group were made very clear by the finding obtained in the primary schools involved in this study; the staff here differ very much in the way they handle behavioural problems (Fig. 2).

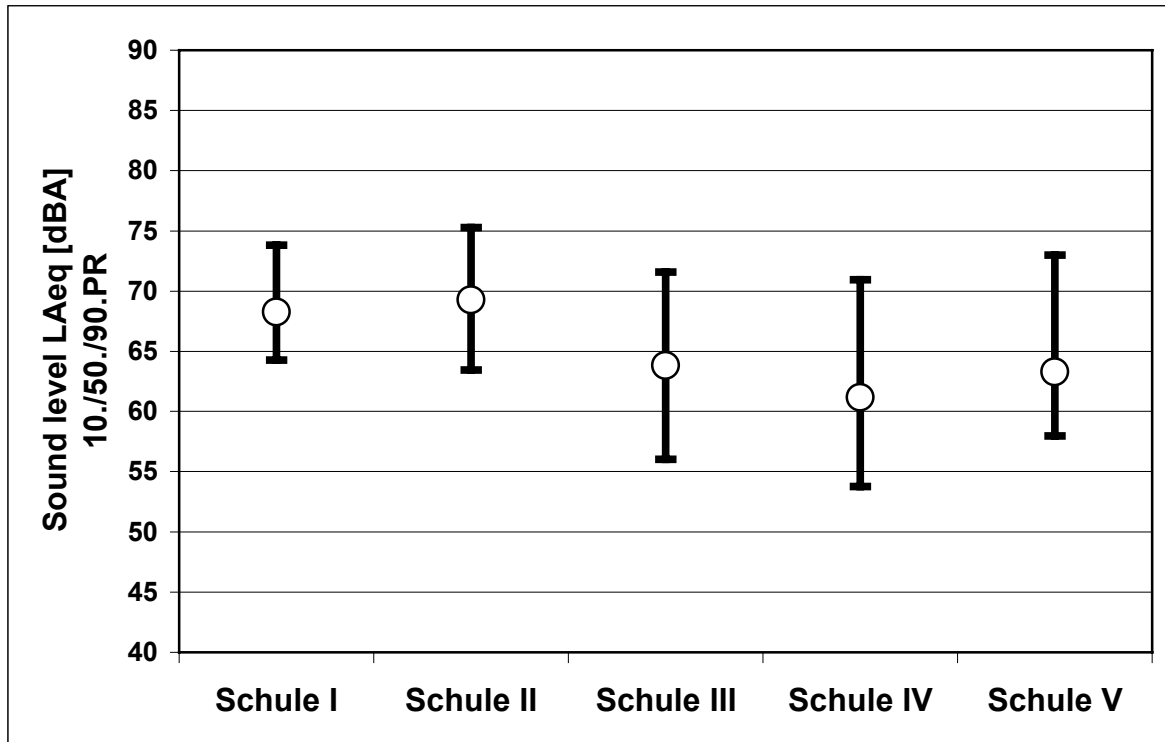


Fig. 2 Average sound level in all lessons observed in the schools involved in the study. Median values (circles), 10th percentile (beams downwards) and 90th percentile (beams upwards). The schools I, II, III and V are primary schools, school IV is a central secondary level I school

Here the "quiet" schools (III and V), which concentrate on the "learning of social behaviour" from the very first day at school are in contrast to the "loud" schools (I and II), where there is no uniformly applied approach to behaviour control (including "noisy" behaviour). Because of the limited number of classes observed, the conclusion is illustrative.

The structural and "pedagogical" intervention measures taken in the study show the effects both of the room acoustics on behaviour and the significance of modified behaviour for the noise situation in lessons.

2 Improvement of Room Acoustics

The refurbishment measures taken on the acoustics in three classrooms testify to the improvement of the reverberation time and speech intelligibility in a number of ways. The reverberation times measured in these rooms before the refurbishment did not even satisfy the requirements of the old DIN 18041⁵, whereas after refurbishment they even met the conditions for the integrative schooling of children with impaired hearing (Fig. 3).

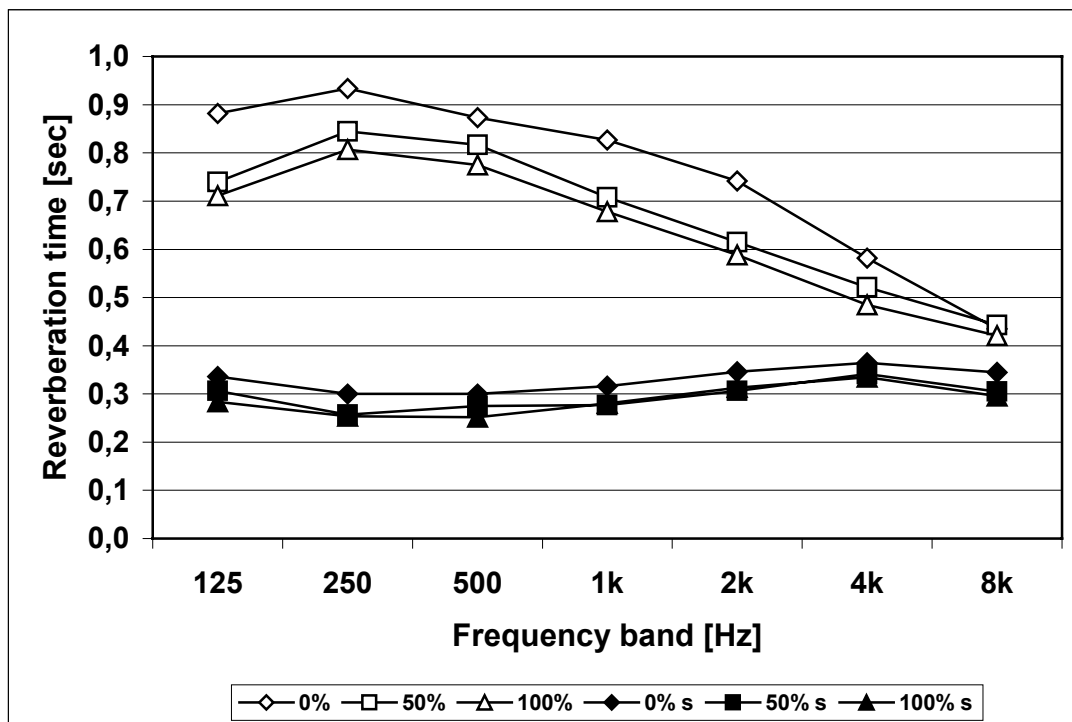


Fig. 3 Reverberation times before and after refurbishment: Class C

As a consequence the speech intelligibility is rated as "very good" in the form of the calculated STI after refurbishment in all three rooms, in contrast to "satisfactory" previously.

The improvement in sound absorption in the class room means in physical terms a reduction of the sound level by a maximum of 3 dB(A); the reduction actually measured of 6 to 8 dB(A) is due to the interaction between the improvement in speech intelligibility and the resulting social conduct of the pupils. "If everything is quiet, I don't need to speak so loudly", according to students. This perception is confirmed by a teacher, who, after they had moved into the refurbished class room, claimed: "I have

the feeling that I'm standing in front of a new class". By this she did not mean the class room, but the pupils.

The refurbishment examples make clear how important good room acoustics are for the noise situation during lessons. In the "loud" school there is a substantial reduction in the average sound level in lessons of approximately 6 dB(A), while in the "quiet" school the reduction is only approximately 3 dB(A), (Fig. 4). In both schools, however, the basic noise level drops by about 6 dB(A), which contributes to a substantial improvement in the signal-to-noise ratio.

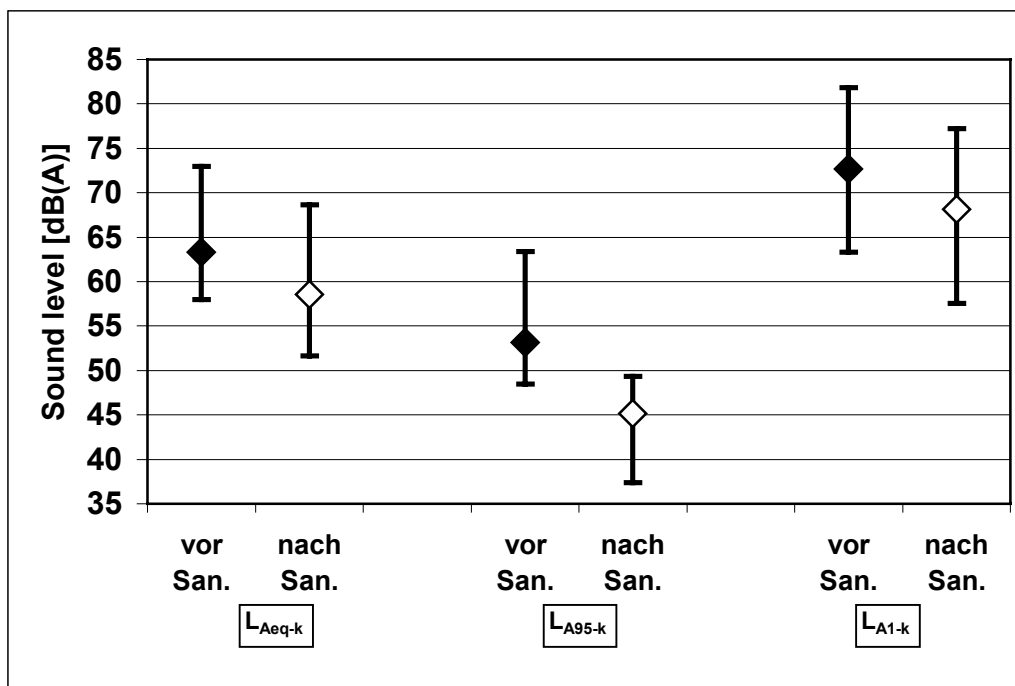


Fig. 4 Lesson sound level before and after refurbishment in Class C, median values, 10th (bar downwards) and 90th percentile (bar upwards)

3 Pedagogical Intervention to Reduce Noise

The background noise levels in nearly all lessons were substantially in excess of the values 30 – 40 dB(A), which were those given as recommended maxima for mental work related to imparting information, for example in class rooms (DIN EN ISO 11690 Part1, DIN 18041)⁶. Once again the principle is "the quieter the better". In terms of the demands involved, classroom teaching must be classified as a highly difficult cognitive activity both for pupils and for teachers. The noise levels we measured during lessons must therefore normally be described as too high! Clear differences

were ascertained between individual lessons, schools and, not least, even between individual schools with similar room acoustics.

3.1 Pedagogical Approaches to Noise Reduction

The primary school III, described as "quiet", fulfils a certain model function. In a forward-looking extended project (integration of pupils with special needs; integration of pupils with foreign mother tongue and from other cultures), the educationally very active and committed staff there developed and introduced, together with the headmaster, a systematic behavioural training with new school entrants and began this years ago.

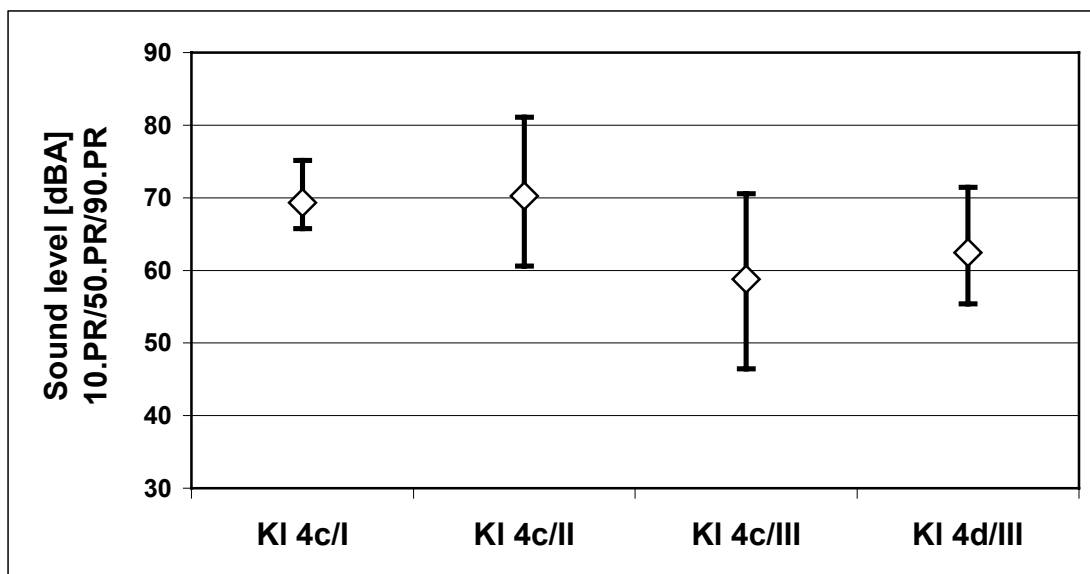


Fig. 5 Class room teaching sound levels in four 4th-year classes from 3 primary schools. Median values, 10th (bars downwards) and 90th percentile (bars upwards)

The approach works with visual and acoustic signals and with controlling behavioural rituals, which are practised with the pupils and are applied and maintained by all members of staff. A major portion of these rules, which were introduced on entry into the schools and then continuously practised, are concerned with noise reduction or noise avoidance. The differences are shown in Figure 5 taking the example of the 4th-year class.

The same applies with regard to a primary school in a neighbouring federal state (school V), where a strikingly low noise level was measured despite unfavourable room-acoustic conditions in the only class observed. Observation of lessons and questioning revealed that in this class systematic training of noise-avoiding modes of behaviour was conducted during the lesson. In this class the noise level was so low that it was tacitly feared the sound refurbishment instigated because of the room-acoustic conditions would bring about hardly any change or no change at all in the noise situation during lessons. This expectation was refuted; even under these conditions the refurbishment led to a clearly evident improvement not only in the room-acoustic data, but also in the sound level during lessons.

3.2 Noise Reduction through Education and Optical Indication of Noise Level

A further test of the "pedagogical" influence on the noise situation during lessons was conducted in two classes of the 2nd and 4th years in primary school II: this school is conspicuous because of its relatively high noise level; here an external test leader dealt with the subject of "ear and hearing" in a teaching unit of five periods in each case. Rules for noise avoidance were agreed and practised; this also included the appropriate reaction to indication of the sound level by the SoundEar introduced as a signal transmitter (this device works on the traffic light principle with the signal colours green, amber and red, which are changed as a function of the sound level in the class room; the switching thresholds can be freely selected). At the end of each hour a reward was given if the behaviour aimed at and agreed was kept to. Before and after this teaching experiment the teaching was observed in both classes for a week and during the lessons the sound level was recorded continuously. The procedure was agreed in consultation with the teachers.

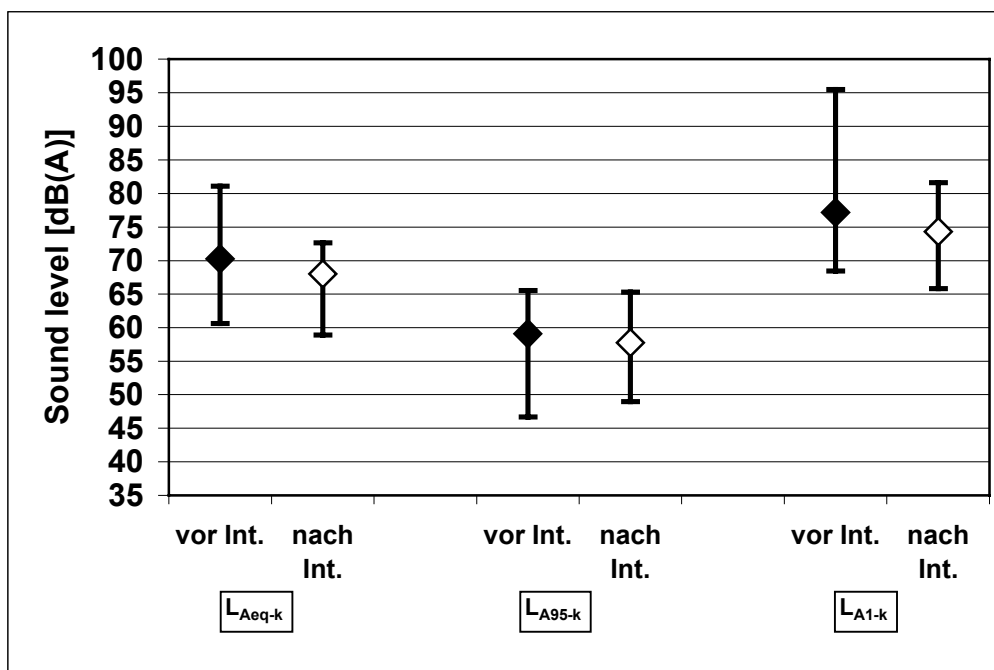


Fig. 6 Sound level in lessons (average, minimum and peak values) before and after implementation of the intervention project. Median, 10th (bars downwards) and 90th percentile. Class E (4th year)

This intervention test also had a noise-reducing effect (Fig. 6), but it was very small in one of the two classes. This was attributed to the short time for the test, to its late implementation years after school entry and to the fact that the cooperation of the respective teacher was ensured, but not that of the whole staff.

4 Significance of the Intervention Measures

Four different noise reduction measures were monitored with the methods used in the project (continuous recording of sound level, observation of lessons) over one week before and after their implementation:

- acoustic refurbishment of two class rooms
- long-term pedagogical intervention to reduce noise
- long-term pedagogical intervention plus room refurbishment
- education, practise of rules, optical signal transmission by the SoundEar.

For all four measures noise reduction effects could be verified to differing degrees; this is understandable since all measures take effect at different points in the process of noise development and its propagation.

The most important "noise generator" in education institutions is the human voice. It is possible to achieve a situation where, during lessons, only that is said that is necessary for the teaching and its accompanying processes (including social ones), and if a situation is also achieved where what has to be said is said quietly, the teaching noises will decline in frequency and intensity; it gets quieter. Here is where the pedagogical (more accurately, social-pedagogical) approaches of the two "quiet" primary schools take effect: pupils learn only to speak when it is required and then only quietly; teachers react to this because they can also speak more quietly. In both schools it gets quieter: the noise reduction already sets in in the phase of noise emergence. It has an effect even if though the room-acoustic conditions are not ideal.

The noises produced mainly by speaking actually only last a few seconds. They persist for longer if their "reverberation" continues beyond the necessary degree because they are not absorbed, but are reflected by the surfaces and the ceiling in the room. What is spoken encounters the remains of what is still in the room from what was said previously. The reaction is that speaking becomes a little louder and then even louder... There thus arises a higher sound level in a "reverberating" room with longer reverberation time than in a sound-insulated room with substantially shorter reverberation time. At this point the "room-acoustic refurbishment" comes into play; it prevents traces of the noise that has already developed from remaining for a disproportionately long time and then building up on the way described: It is not necessary to boost the speaking volume. This effect was observed directly in school V: during teaching what was happening in the lesson in all class rooms could clearly be followed from the corridor; only from the refurbished class room was it not possible to hear anything of the lesson in progress.

When both measures coincide, it can be expected that there will be a reinforcement of the individual effects. This was confirmed in school V, which was one of the "quiet" primary schools from the very beginning, and in which it was possible to reduce the noise level again during lessons after the class room concerned had been refurbished. In terms of "teaching acoustics" it would therefore certainly be necessary to recommend that both measures be applied simultaneously. Whether the pupils have learned to be quiet or not, both adults and younger users of education institutions

and those employed there only avoid the great effort of having to speak loudly and the problem of restricted speech intelligibility by means of optimised room acoustics. Improved teaching acoustics help ensure that errors and shortcomings in the teaching/learning process are avoided. They facilitate the following:

- improved information transfer
- less interference with cognitive processes
- lower strain on the teacher's voice
- reduced fatigue
- enhanced attentiveness.

The requirement which can be concluded from this must be to integrate the room acoustics as early as the planning stage of rooms for educational institutions. If this is done from the beginning, there will arise practically no extra costs for an acoustically optimised learning environment. There are similar circumstances regarding general structural refurbishment. Higher costs are incurred mainly due to the subsequent installation of absorption surfaces.

The behavioural attitudes that pupils bring into the school and into lessons are a further variable in the process of noise generation. This would suggest that younger pupils produce more noise and older ones less. Although not recorded in detail, some characteristic features of different schools are striking. School V, which is "quiet" despite unfavourable room acoustics, is located in a solid middle-class/academically dominated urban district in a small Westphalian town. The location of the "quiet" school III in Bremen can certainly be described difficult in social terms (a so-called "hotbed " school), but the composition of the student body displays perceptible differences from the "louder" school II with quite similar conditions in terms of structure and room acoustics. With the measurability of sound level it is possible to allocate clearly the terms loud and quiet, but this feature depends not only on room-acoustic parameters and the social-pedagogical skill of teachers. When pupils come from very different ethnic origins (including those exhibiting different noise patterns), cultures and language areas, when they form ethnically defined groups which are in competition and conflict with one another, it will probably be difficult to interest them in noise and to motivate them to adopt noise-reducing modes of behaviour. It may be that

teachers then have to apply mainly disciplinary measures; this should not be underestimated under such conditions.

5 Noise and Stress for Teachers

Lessons are a common working situation for learners and teachers. High basic sound level demands of teachers at least a raised vocal volume through to shouting. One concern here, but not the only one, is irritation of teachers' vocal chords: higher sound levels during lessons also signalise disturbed communication, require corrective reactions (disciplining) and deflect attention away from the actual goals of the lesson.

Disproportionate and avoidable ambient sound is a stressor. This can be verified by objective measurement as well as by verbal statements based on subjective perception. How this stressor acts depends on the physical properties of the sound (intensity, frequency etc.), on the conditions of the situation in which it arises and on the noise sensitivity of the persons making the judgement. If it has a sufficiently high and enduring intensity (rating level of 80 dB(A) and above), the risk of hearing damage is demonstrated. But even at low intensity typical stress reactions are demonstrated on a physiological level, e.g. reactions of the cardio-vascular system or the hormone system.

What is more difficult to classify is the "noise of medium intensity" such as is characteristic of education institutions. A direct effect, for example on bodily organs and systems, can normally be discounted; this noise tends to act more on people's mental processes. It is perceived, interferes with the intake and processing of "more important" sound events, i.e. ones which are more significant for people, and it hinders (or completely prevents) understanding of such sound events. It annoys, places a burden on the processes of attention control, renders concentration more difficult and may prevent relaxation and sleep. People who experience such noise in situations requiring concentration and attention feel they are no longer up to the demands which they would be able to cope with under different conditions. They react with irritation, anger and annoyance. The "stress hormones" (adrenalin and noradrenalin,

cortisol) are produced in greater quantities; blood pressure and the frequency of the heartbeat rise, the organism's level of excitation increases. It becomes more difficult and more strenuous to fulfil requirements, and fatigue processes intensify the problem.

Even so, it would be difficult or impossible to prove that "noise of medium intensity" makes people "sick" if one considers these stressors alone. But if one considers that many other stress-inducing factors are operative simultaneously in educational institutions (conspicuous behaviour, learning difficulties, lack of a sense of responsibility, problems with willingness to work and make an effort, and much more), then the phenomenon of "noise" contributes to the exposure and stress on teachers together with such causes; it is responsible with other factors for the fact that education institutions cannot fulfil their mission in the way that can be expected of them. Premature wear, including burn-out, which may end in leaving the profession can be explained among other things by high noise exposure.

Noise as one among many stress factors plays a special role in that it is named by a noticeably large number of teachers as a stress factor and at the same time methods are known by which it can be successfully combated. "Pedagogical" noise control is also free and would not only make it easier for teachers to concentrate on the more important aspects of their mission, but also create improved learning conditions for pupils. High sound levels are present to a disproportionate extent in educational institutions, and they are avoidable, as the present study has shown. The fact that successful refurbishment of the room-acoustic situation and its effect on the behaviour of pupils is perceived is documented by comments from teachers. The latter would "prefer to teach only such classes" and they feel as though they are "standing in front of a new class".

6 Adult Education Institutions

When adult education institutions are being discussed, the institutions concerned are mostly evening institutes, academies, vocational colleges, universities, institutions for political or vocational further and in-service training etc. Such institutions have a lot in

common with schools: there are teachers (professors, lecturers, trainers, master craftsmen or simply: qualified specialists) who work in the field in which the institutions operates, who have special skills, and there are the learners (students, pupils, apprentices etc.), who want to acquire qualifications in this field.

In such institutions speaking and understanding of speech as the medium of the teaching-learning process again plays a central role. To this extent the standards for ergonomic (including acoustic) features of the teaching-learning environment are similar to those in schools. In all probability the requirements for reverberation times and speech intelligibility have to be interpreted somewhat less strictly because the adult brain has numerous routines to fill in gaps in speech comprehension; because adults are aware of their own shortcomings in learning processes and have learnt to handle them and because they have experience in how to develop concentration and attention.

The learning steps in the school are evidently smaller and more elementary from an adult point of view, especially for younger age groups. But for children these steps often approach the limits of comprehensibility and performance and occasionally surpass them. Measured in terms of the "cognitive development age", the cognitive requirements for schoolchildren and for adolescents in the school years appropriate to their ages are very high, often extremely high. Under these circumstances the requirements for the learning conditions must also be very high: adults can also improvise, children and adolescents all the less, the younger they are. Furthermore, in schools (of the conventional kind) the subjects to be learnt are specified, not freely chosen. Children and adolescents are intrinsically motivated to learn by virtue of their curiosity, and their emotionally and intellectually stimulated interest; but they are motivated in real terms by pressure and compulsion, by reward and the promise of reward.

Adults involved in institutionalised educational processes are in a fundamentally different situation from that of children and adolescents: often they have chosen the subject (topic, goal) of an educational process themselves from many alternatives. They more frequently intrinsically motivated through their life plan, by goals they hope to achieve with a successful education phase, and by the insight that they have

acquired in the relationship between educational processes and life competence. But this is only true in an "ideal" world where people have the choice from a wide range of alternatives and it assumes creativity, the willingness to work hard, a sense of responsibility and willingness to co-operate, things which many adults also lack.

In both cases noise is a typical factor that can hinder learning processes. Many adults know this and attempt to create a noise-free environment in learning situations. Children first have to recognise this relationship, and since they are often the ones (as a group) who make the noise for the reasons mentioned, they also have to learn how to behave without generating a lot of noise. If this process is not stimulated and initiated by adults, it can take years, years of less effective learning. Even many students who are young adults seem not yet to understand that the lecturer can only speak when they have stopped.

It would be possible to take other examples than that of noise to depict the ergonomic problems arising in "informative" or "mental" work, or in processes of education and training. Complaints about noise in educational institutions are often heard, and they are increasing in our world as it gets steadily louder. A lot less is said or written about the poor quality of classroom chairs (as compared to the ergonomically optimised, multiple-positioning, gas-sprung office chairs at desks and computer workstations for adults), about poorly ventilated class rooms as compared to ideally air-conditioned offices. The ergonomics of educational institutions, which was an important subject of scientific study⁷ in the 19th Century under the heading of "school hygiene", has become a forgotten subject, along with many of its results and insights which have retained their validity.

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⁶ DIN EN ISO 11690, Teil 1: Akustik – Richtlinien für die Gestaltung lärmarmen maschinenbestückter Arbeitsstätten; Teil 1: Allgemeine Grundlagen; Berlin, Beuth Verlag, 1997

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