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Znanstveni empirično-raziskovalni prispevek

The influence of traffic noise on children's work efficiency while using a computer at school

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Abstract: One of the consequences of new technical innovations is noise. It represents a considerable problem especially as traffic noise in urban areas. It deteriorates intellectual work in educational institutions and can, among other things, have a substantial effect on personality development. Taking this facts into consideration we started a research presented in this paper. Our aim was to establish what is the influence of traffic noise on the efficiency of pupils when working with computer, which has become an extremely popular learning tool. We prepared different tasks that require increased attentiveness and tasks that require a certain activity of pupil's memory. Investigating the influence of traffic noise we used the Signal Detection Theory and methods for testing short-term memory. Results of the research, conducted in artificial working conditions show that mental work defined within the frame of intellectual activities and memorizing during these activities is in a negative interdependence with noisy environment. This means that pupils can succumb to the pressures of the working environment when using a computer. Unfortunately, this can consequently negatively effect their health and work efficiency.

Key words: job performance, noise effects, students, computer assisted instruction

Vpliv prometnega hrupa na delovno uspešnost otrok pri uporabi računalnika v šoli

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Povzetek: Posledica hitrega razvoja številnih tehničnih iznajdb je tudi hrup. Ta predstavlja, še posebej kot prometni hrup v urbanih naseljih, velik problem. Poleg ostalega ogroža tudi intelektualno delo v izobraževalnih ustanovah in ima nezanemarljiv vpliv na razvoj osebnosti. Upoštevajoč ta dejstva, smo se lotili študije, ki jo v prispevku povzemamo. Raziskati smo namreč hoteli, kolikšen vpliv ima prometni hrup na uspešnost opravljanja delovnih nalog učencev s pomočjo vedno aktualnejšega učnega pripomočka - računalnika. V ta namen smo pripravili naloge, ki so zahtevale povečano pozornost učencev pri delu in tudi takšne, ki so zahtevale določeno spominsko aktivnost. Pri proučevanju problema smo se naslonili na teorijo detekcije redkih signalov ter postopke testiranja kratkoročnega spomina. Rezultati, dobljeni v umetno ustvarjenih delovnih pogojih, nakazujejo, da so mentalno delo učencev v sklopu intelektualnih aktivnosti ter pozornost pri teh aktivnostih, v negativni odvisnosti s hrupnim okoljem. To pa pomeni, da lahko učenci tudi ob uporabi računalnika kot učnega pripomočka podležejo obremenitvam delovnega

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okolja. Žal se lahko to posledično negativno izraža tudi v zdravstvenem smislu ter v delovni uspešnosti.

Ključne besede: delovna uspešnost, hrup, učenci, učenje z računalnikom

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Although we try to make work and time spent at school as friendly and pleasant as possible we don't always achieve this goal. The environment which we live in is getting more and more polluted. This is caused by the enormous speed of the industrial and traffic development as well as other "civilization needs". In this way the natural environment is greatly threatened by human's aggression towards primal natural resources. Human race exploits these resources in its belief that it is creating optimum living and working conditions. In this process of development even the educational institutions are affected by this aggression and schools are therefore becoming increasingly threatened. Pupils and teachers are constantly under the influence of numerous pressures which divided into bio-mechanical, sensory, energetic and psychological (Rohmert, 1984). Among things that induce these pressures noise is definitely one of the strongest. Noise also represents one of the basic causes for complex medical problems especially in industrially high developed countries (Brown, Chan & Chan, 1985; Romero, Garcia & Garcia, 1992). At the same time noise represents one of the negative factors of otherwise pleasant sound-perceptible environment. If we try to analyse the influence of noise on pupils in general we can emphasize the fact that noise exerts influence on different levels: physiological and psychological level. When investigating the first level - physiological, previous studies focused mostly on investigating pulse rate and blood pressure (Neus, Ruddel, Schulte & Von Eiff, 1983; Regecova & Kellcrova, 1995). Karsdorf & Klappach (1968) have comparatively soon found out that pupils attending schools in quiet school districts have no problems with their blood pressure. On the other hand, pupils, especially boys attending schools in urban areas have a high blood pressure. Recent studies determine noise as a factor which causes symptoms of stress with pupils (Bullinger, Hygge, Evans, Meis & Mackensen, 1999; Ewans, Lercher, Meis, Ising & Kofler, 2001; Ising, Babisch & Kruppa, 1999).

When investigating the psychological level (cognitive field) researchers have focused mostly on the influence of noise on attentiveness at work, memorizing and speech perception. Kyzar (1977) states that traffic noise around schools influences attentiveness at work, especially when writing written tests and also performing other, motor exacting tasks. Attentiveness is also disturbed with children who live in the urban areas exposed to traffic noise. At school these children have much greater difficulties with concentrating and focusing on their studies and in average they attain lower results. Noise also has a considerable effect on memorizing and it was established that noise is especially distracting when pupils are working on more difficult tasks (Hygge 1993).

A lot of studies show that noise is damaging to health and causes beginnings of many illnesses. Researchers used to believe that noise only damages hearing organs but studies nowadays show that the effects of noise are much more extensive. Besides the direct and damaging effect on a person, noise indirectly influences the results of work in the direction 'the louder the noise, more distinctive the influence'. Especially traffic noise with its level of noise pollution is highly damaging (Nelson, 1987). Extreme volume of noise undoubtedly distracts and hinders the work of teachers and pupils. It obstructs normal communication (Crook & Langdon, 1974; Ko, 1981; Sargent, Gidman, Humphreys & Utley, 1980).

Researchers have made many studies on the influence of noise on the learning process directly at schools and indirectly in laboratory studies (Cohen, Evans, Krantz & Stokols, 1980; Cohen, Evans, Krantz, Stokols & Kelly, 1981; Evans & Lepore, 1993; Green, Pasternack & Shore, 1982; Houtgast, 1981; Maxwell & Evans, 2000; Moch-Sibony, 1984; Sanz, Garcia & Garcia, 1993). Unfortunately most of these studies were investigating the influence of aircraft noise on the learning process. There were comparatively few studies done in the direction of investigating the influence of traffic noise on school work or investigating noise influence on a specific occupation. We, too, tried to find certain answers within this field.

Method

Participants

We tried to establish the influence of working environment on pupils' work efficiency. We concentrated on two kinds of tasks - computer tasks that require increased attentiveness and tasks that require a certain activity of pupil's memory. The research, conducted in artificial working conditions investigated a sample of 20 male pupils aged between 13 and 14 who often use computers in their work. The parameters of noise (two levels: optimal-normal and increased-maximal noise level) were combined with other pressures of the working environment, namely lightening (three levels: low-minimal, optimal-normal and increased-maximal lightening of working environment) and climate (three levels: low-minimal, optimal-normal and increased-maximal climate burden expressed in effective temperature – ET (Table 2)). These parameters were the elements of study in the context of the entire research.

Instruments

Monotonous work operations are connected with the perception of certain "rare" signals which are bound to a longer time period and mean a basis for research on attentiveness at work. In the first part, investigating the influence of traffic noise on attentiveness we used the Signal Detection Theory (Baker, 1959; Mackworth, 1957; Swets, Tanner & Birdsall, 1961). Such attentiveness can change relatively quickly in

interdependence with numerous factors and we can measure it relatively well with a specially designed computer programme. This programme has been especially made and adjusted to special test needs. The programme demand was for the pupil to carefully monitor a certain trail of a "carriage" on a monitor during the whole time of the research. The "carriages" moved across the monitor in different time intervals and with different speed. According to the position of the cargo on the carriage the pupils had to determine which carriage would tip over because of the incorrect arrangement of the cargo. The pupils' task was to detect the carriage which might tip over with an answer "Yes", and the carriages which have an intermediate and accurate load with an answer "No".

The monitoring of such monotonous tasks was also conducted on a computer where the number of »Commissions« as the false signal determined by the user, and the number of »Omissions« as the correct signal. A simultaneous analysis showed also a number of correct and false detections and determined the sensitivity and criterion for each of the four sequences of the whole experiment. The final result of the measuring was calculated on the basis of a random choice of the number of stimulations for the analysis.

Another important factor within the frame of investigating the influence of working environment on the work with a computer were the tasks which were connected to memory work tasks. The latter are apparent in the practice whenever mind activity is necessary at use of computer – this is consequently connected to logical reactions as a part of work process. Scientific results show that on the level of an instant reaction the short-term memory is present in the first phase. The short-term memory continues into the Long-term memory in the process of logical linking. Therefore, in the second part, when investigating the influence of traffic noise on performing memory exacting tasks on a computer we used methods for testing short-term memory (Fujsaki, Mizuno & Tanaka, 1972; Hunt & Elliot, 1980; Watkins, 1975; Woodworth, 1938). A part of such research was also another computer programme which demanded a recollection of random chosen numbers of the pupil. Before the real measurement, each user was tested by an experimental programme which defined the size of a random number series. Each repetition with no mistakes and no time stopping was considered as a correct one. The final result of this experiment shoved the level of dependence of the user's organism on the recollection of numerical series which could also be memorized as logical linking.

Procedure

In the research 20 pupils were tested in 18 different working combinations in performing two tasks (Table 1). The total number of tests was therefore 720.

The parameters of noise, lightening and climatic conditions were set on the basis of similar tests performed in computer classrooms of 60 different schools across Slovenia. The results we got were later used for parameters' setting under artificial conditions (Table 2).

Table 1: Combinations of the working conditions in the research.

No.	Noise	Effective Temperature	Lighting
1	L_{opt}	ET_{min}	E_{min}
2	L_{opt}	ET_{opt}	E_{min}
3	L_{opt}	ET_{max}	E_{min}
4	L_{max}	ET_{min}	E_{min}
5	L_{max}	ET_{opt}	E_{min}
6	L_{max}	ET_{max}	E_{min}
7	L_{opt}	ET_{min}	E_{opt}
8	L_{opt}	ET_{opt}	E_{opt}
9	L_{opt}	ET_{max}	E_{opt}
10	L_{max}	ET_{min}	E_{opt}
11	L_{max}	ET_{opt}	E_{opt}
12	L_{max}	ET_{max}	E_{opt}
13	L_{opt}	ET_{min}	E_{max}
14	L_{opt}	ET_{opt}	E_{max}
15	L_{opt}	ET_{max}	E_{max}
16	L_{max}	ET_{min}	E_{max}
17	L_{max}	ET_{opt}	E_{max}
18	L_{max}	ET_{max}	E_{max}

Table 2: Average values of noise, lighting and thermal working environment.

Values	Noise	Climate		Lighting
		RH=50% and	v=0,3 m/s	
	L (dB(A))	**T (°C)**	**ET(°C)**	**E(lx)**
MIN.	-	18	15,3	120
OPT.	35	24	20,5	350
MAX.	65	30	25,6	1000

ET* - Effective Temperature (°C)
T - Air Temperature (°C)
L - Noise (dB(A))
E - Lighting (lx)
MIN. - Decrease values
OPT. - Normal values
MAX. - Increase values

* Effective temperature (ET) was intended to equate varying combinations of temperature, humidity, and air movements in terms of equal sensations of warmth or cold (McIntyre, 1980). For example, an ET of 21°C characterized the thermal sensation of 21°C temperature in combination with 100 percent humidity. Equal thermal sensations (ET= 21°C) can also be achieved with other (higher) temperatures in combination with other (lower) humidities (such as 27°C with 10 percent humidity).
For Effective temperature (ET) the formula is:

$$ET = 37 - \frac{1}{0{,}68 - 0{,}14.\frac{RH}{100} + \frac{1}{1{,}76 + 1{,}4.v^{0{,}75}}}.(37 - Ta) - 0{,}29.Ta.(1 - \frac{RH}{100}) \ (^{\circ}C)$$

RH ... Relative Humidity (%); v ... Air Movement (m/s); Ta ... Air Temperature (°C)

Pupils in these conditions performed the aforementioned tasks. Results were processed with adequate statistical analyses. Therefore we used the variation analysis for the first phase. In order to get the factors of work efficiency we used multiple regression analysis. In the continuation of this paper we are going to limit ourselves to the results obtained from the inestigating the noise.

Results and discussion

Experimentally we confirmed our anticipations that sound environment significantly influences the performing of monotonous and memory exacting tasks when using a computer at school. In the first part, investigating the influence of traffic noise on attentiveness we used the Signal Detection Theory (Baker, 1959; Mackworth, 1957; Swets et al., 1961). With the help of this theory we analysed various possible pupils' reactions while working on a computer. These were:

- confirmation of the false signal in a task (Commission);
- omission of the correct signal in a task (Omission);
- correctly detected signal in a task (Correct) and
- correctly omitted signal in a task (Omitted).

The results (Table 3 and Figure 1) show that pupils in conditions of increased sound pressure achieve lower results within the criterion *confirmation of the false signal in a task Commissions* (M = 5,09, SD = 4,24) and *omission of the correct*

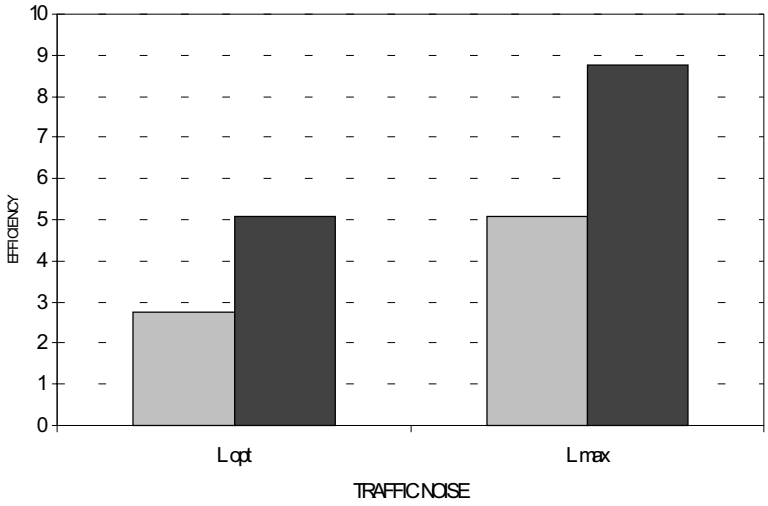

Figure 1: Graphic representation (Commissions = brighter bar, Omissions/Traffic noise = darker bar).

Table 3: Results of values of individual research criteria.

Commission - CONDITION	confirmation of the false **CAUSES**	signal in a task *M*	*SD*	*SS*	
L opt.	180	2,73	3,22	1851,20	
L max.	180	5,09	4,24	3216,58	
SOURCE	*SS*	*df*	*MS*	*F*	Significant
Between groups	499,38	1	499,38	35,28	0,000
Within groups	5067,78	358	14,16		
Omission - CONDITION	omission of the correct **CAUSES**	signal in a task *M*	*SD*	*SS*	
L opt.	180	5,08	4,59	3763,75	
L max.	180	8,75	5,78	5973,75	
SOURCE	*SS*	*df*	*MS*	*F*	Significant
Between groups	1210,00	1	1210,00	44,49	0,000
Within groups	9737,50	358	27,20		
Correct - CONDITION	correctly detected **CAUSES**	signal in a task *M*	*SD*	*SS*	
L opt.	180	101,50	12,39	27479,00	
L max.	180	98,47	12,13	26330,80	
SOURCE	*SS*	*df*	*MS*	*F*	Significant
Between groups	828,10	1	828,10	5,51	0,019
Within groups	53809,80	358	150,31		
Omitted - CONDITION	correctly omitted **CAUSES**	signal in a task *M*	*SD*	*SS*	
L opt.	180	101,54	9,60	16482,64	
L max.	180	99,72	6,43	7410,11	
SOURCE	*SS*	*df*	*MS*	*F*	Significant
Between groups	298,84	1	298,84	4,48	0,035
Within groups	23892,76	358	66,74		
Memory CONDITION	**CAUSES**	*M*	*SD*	*SS*	
Lopt.	180	7,28	0,75	99,95	
L max.	180	6,76	0,76	102,30	
SOURCE	*SS*	*df*	*MS*	*F*	Significant
Between groups	24,33	1	24,33	43,06	0,000
Within groups	202,25	358	0,57		

signal in a task - Omissions (M = 8,75*, SD* = 5,78*),* compared to pupils who work in undisturbed sound environment *($M_{Commissions}$* = 2,73*, SD* = 3,22*)* and *($M_{Omissions}$* = 5,08*, SD* = 4,59*)*. The differences in these two examples are statistically significant (p = 0,000). Similar results (Table 3 and Figure 2) appear in the analysis of the criterion *correctly detected signal in a task - Correct* (p = 0,019) and *correctly omitted signal in a task - Omitted* (p = 0,035). As seen clearly on Figure 2, the number of correct detections and correct omissions is considerably lower when pupils work in a noisier environment.

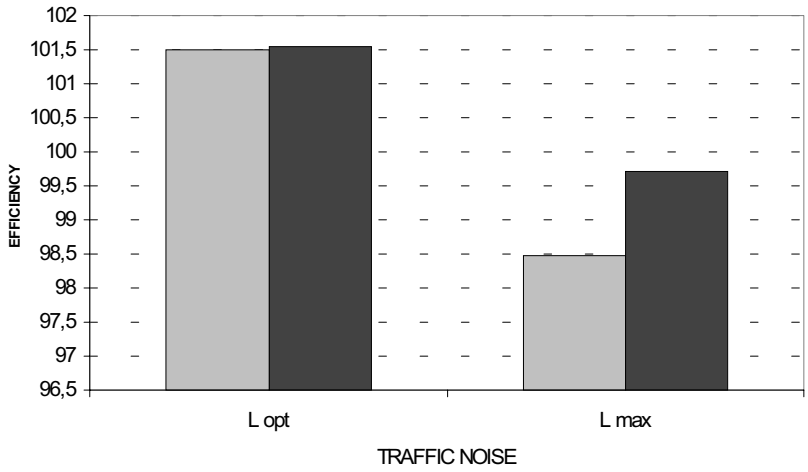

Figure 2: Graphic representation (Correct = brighter bar, Omitted/Traffic noise = darker bar).

The results of the research therefore show that the efficiency of performing monotonous computer tasks varies dependently on sound-working environment. These results also confirm the findings of Hambrick-Dixon (1986) that attentiveness of children living in urban areas who are exposed to traffic noise is disturbed. At school these children are significantly more cursory and achieve on average worse results. We can conclude that with increased noise in computer classrooms at school a decreasing of work attentiveness and therefore work efficiency appears.

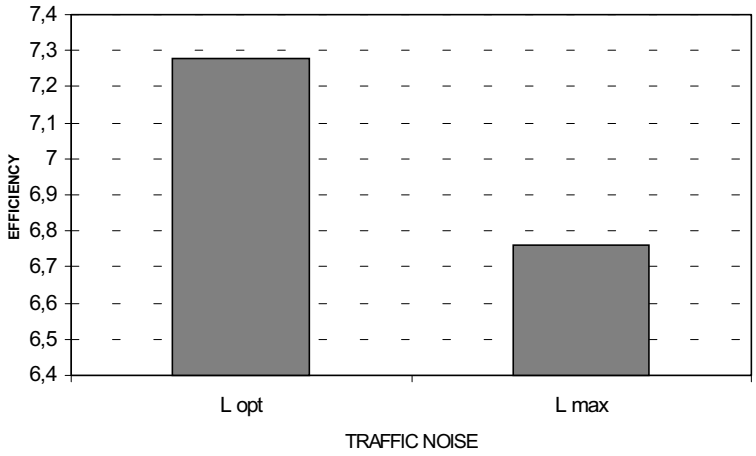

Figure 3: Graphic representation (Memory task/Traffic noise).

In the second part, investigating the influence of traffic noise on performing memory exacting tasks on a computer we got similar results. We used methods for testing short-term memory which have roots in the research of aforementioned authors (Fujsaki et al., 1972; Hunt & Elliot, 1980; Watkins, 1975; Woodworth, 1938).

Table 3 and Figure 3 show a difference in work efficiency in performing memory tasks on a computer, namely a difference between optimal - normal *(M = 7,28; S.D. = 0,75) (e.g. schools outside urban areas)*, and extreme - increase *(M = 6,76); S.D. = 0,76) (e.g. schools in urban areas)* values of traffic noise. The influence of noise is statistically significant (P = 0,000). Our findings are in agreement with the findings and declarations of Weinstein (1977), who ascertains that noise between 65 and 70 dB(A) already damages work memory. He also adds that noise over 85 dB(A) effects work efficiency in a destructive way when the work tasks have a higher perceptive level. Globally for a successful work in a classroom the optimal noise level should be between 47 and 52 dB(A), with frequency points between 57 and 65 dB(A).

Conclusion

Our research adds another stone to the mosaic of such reflections. With our study we have established and confirmed different anticipations of the problem noise represents in school districts and urban areas (e.g. Sanz et al., 1993). The influence of noise is reflected especially in pupils' responses to individual school tasks. Our research concentrated on tasks performed by computers which are becoming more and more used at schools. Looking at different studies we can also assume that similar influence can be expected on other educational fields at school.

A number of aforementioned studies (Cohen et al.,1981; Green et al., 1982; Houtgast, 1981; Koszarny, 1978; Moch-Sibony, 1984 and others) implicate that mental work within the frame of intellectual activities and memorizing during these activities is in a negative interdependance with noisy environment. This environment formed by contemporary traffic elements represents a big distraction to intellectual work. A young person is therefore already in his early ages (childhood) threatened by pressures of the working environment which can damage his health as well as his successfulness (Bullinger et al., 1999; Ewans et al., 2001; Ising et al., 1999). Therefore protection of young people against noise deserves and should be given more attention.

We have to realize that we are not up to date only when we are working on a computer. We are also up to date when we are able to harmonize the use of computer with the working environment. Why don't we start doing that at schools, with children?

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