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Effect of sound environment on homework performance

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Abstract

Noise may impair childhood development and education, which may have lifelong effects on academic achievement and health. Children are known to be exposed to unhealthy levels of noise at home and at school. Long term exposure to environmental noise, especially to airport noise, in schools, effect attention, comprehension, recall and recognition skills. Acute noise exposure was found to effect recall and recognition in students. Irrelevant speech, even in an unfamiliar language, interferes with serial recall skills and causes attentional distraction.

Although the studies on noise exposure of children are executed in schools, home learning environment should provide auditory comfort conditions for homework performance. In this study, the effect of various sound environments on homework performance was investigated through the duration and correctness of solving algebraic equations in multiple choice tests. High school students (17-18 years, N=32) solved quadratic equations listening to sound clips (L_{Aeq}=55 dBA): quiet (no sound), aircraft takeoff sound, continuous road traffic sound, verbal television sound, a music piece and children playing (talking, screaming, running).

Statistically, aircraft, verbal and children sounds effected homework performance, road traffic and music piece did not. Playing children sounds, which include speech, screaming and running, had a more impairing effect than speech from television, even though they had the same equivalent sound level. Participants' self-reported activity disturbance was dependent on the duration to solve the algebraic equations. The study shows the importance of sound insulation against airport noise, neighbor noise and even noise inside the home, for the academic performance of children.

Keywords

Academic performance, Activity disturbance, Neighbor noise, Transportation noise.

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1. Introduction

It is well known fact that noise may effect short-term and long-term health, cause annoyance and reduce work performance and cognition (Passchier-Vermeer & Passchier, 2000). European Union has guidelines (WG-AEN, 2006; WG-HSEA, 2002; WG-HSEA, 2004) and a Directive (The European Parliament and The Council of The European Union, 2002) on reducing exposure to environmental noise. Despite the numerous efforts, World Health Organization (2011) estimates that about 40% of the population in EU countries is exposed to road traffic noise at levels exceeding 55 dBA, which is potentially harmful to health.

Noise is considered to be a stressor and a pollutant for the whole population. Children, chronically ill and elderly people are vulnerable to noise and must be protected from it. One of the reasons of children's vulnerability is the fact that their stressor coping skills are less developed than those of adults. Another important reason is that noise may impair early childhood development and education, which may have lifelong effects on academic achievement and health (Pujol et al., 2012; Passchier-Vermeer & Passchier, 2000). Cognitive impairment is a known harmful effect of noise in children and is defined as "delayed psychomotor development and impaired performance in language skills, motor skills, and coordination, equivalent to a 5 to 10 point deficit in IQ" (WHO, 2011).

Pujol et al. (2012) investigated noise levels (L_{Aeq}) outside and inside the residences of 44 schoolchildren and associated them with familial and environmental characteristics. Outdoor noise levels depended significantly on the socio-economic status of the household. Indoor noise levels were associated with the number of children present and noise sources present in the dwelling. Indoor noise levels for the child's bedroom could go up to 65 dB, whereas it should have been about 35 dBA for a healthy bedroom or study-room environment. This study shows the severity of children's noise exposure at home environment.

There are some epidemiological studies which investigate effects of chronic exposure to environmental noise. Many studies showed that tasks involving central processing and language, such as reading comprehension, memory and attention are affected in children due to noise exposure (Haines et al., 2001a; Haines et al., 2001b; Cohen et al., 1973). Evans & Hygge (2007) presented the effects of noise on reading and memory in children. A study around Heathrow Airport with primary school children (N=236) showed a strong dose-response relationship between aircraft noise exposure at home and performance on memory tests of immediate/delayed recall (Matsui et al., 2004). Clark et al. (2013) presented six-year follow-up of students (15-16 years, N=461) who attended primary and secondary schools around London Heathrow airport. Multilevel regression modelling showed that aircraft noise exposure at primary school was associated with a significant increase in noise annoyance and with a non-significant decrease in reading comprehension at follow-up.

Evans et al. (1998) and Hygge et al. (2002) studied the effect of Munich airport's relocation on children's (9–10 years, N = 326) health and cognition. Noise exposure to airport noise was associated with problems in long-term memory and reading comprehension. Two years after the airport was closed, the problems disappeared, showing that cognition problems may be reversed if exposure is halted. On the other hand, children exposed to the relocated airport started showing the same cognition problems. Stansfeld et al. (2005) investigated cognitive performance of children (9–10 years, N = 2844), in the Netherlands, Spain and the United Kingdom, who were exposed to long-term road traffic and aircraft noise. The result was a linear dose-effect relationship between aircraft noise and impaired reading comprehension and recognition memory. No relationship was found between long-term road traffic noise and cognition. Neither aircraft noise nor road traffic noise affected attention or working memory. Belojevic et al. (2012) examined the relationships between environmental noise and school children's (7-11 years, N=311) executive functioning, which

includes decision making, working memory, and self-regulation of emotions and behaviors. It was found that executive functioning was affected by noise exposure for boys only.

There are also some experimental studies on acute noise exposure, investigating the effects on reading and memorizing new material. Memory tests are made in silence for materials that are read during noise. Participants are sampled from socio-demographically comparable schools (WHO, 2011). Hygge (2003) conducted experiments in classrooms with different noise sources and sound levels to discover the long-term recall and recognition in children (12-14 years, N=1358). Different types of single and combined noise sources (aircraft, road, rail and verbal) were presented with loudspeakers for 15 min at 66 dBA Leq (single aircraft and road traffic at 55 dBA). Children were tested for recall and recognition of a text exactly one week later. Aircraft and road traffic noise impaired recall at both noise levels. Train noise and verbal noise did not affect recognition or recall. Item difficulty, item position and ability did not interact with the noise effect.

Verbal noise sources are known to effect performance of children, which is named "the irrelevant-sound effect" or "the irrelevant-speech effect". The irrelevant-speech effect occurs when an irrelevant auditory stimuli, such as speech, impairs recall performance (Elliott, 2008). The speech may be in the relevant language or in an incomprehensible language (Hygge, 2003). Experiments in irrelevant-speech effect are mostly tested by serial recall, which is the ability to recall items or events in the order in which they occurred (Elliott, 2008). It is evident that attentional distraction is effected strongly by both irrelevant and relevant sounds in children (Elliott, 2008; Wetzel, 2015).

The studies on the performance effects of noise on children are almost always executed in classrooms (Belojevic et al., 2012; Clark et al., 2013; Evans & Hygge, 2007; Evans et al., 1998; Hygge et al., 2002; Hygge, 2003; Matsui et al., 2004; Stansfeld et al., 2005). Learning at home and doing homework is a very important part of student learning in Turkey because Turkish National Education policy suggests that education takes place not only in schools, but also at home. Student learning at home is influenced by unique characteristics of home environment and support of parents and siblings (Iflazoglu & Hong, 2012). Home learning environment should provide the necessary comfort conditions for the best homework performance and auditory comfort is one of the most important ones.

In Turkey, students study for the university entrance exam (LYS) by solving multiple choice tests at home or at after-school study centers. In this study, the effect of the sound environment on homework performance at home is investigated. The homework performance is measured by the speed and correctness of solving algebraic equations in multiple choice tests.

2. Method

32 high school students in an after-school study center with similar academic achievements were chosen for this study. All the students were 11th grade students, ages 17 to 18, and almost 60% were male. Solving quadratic (second degree) equations are part of the 11th grade curriculum. All the students were reminded on how to solve these types of algebraic equations before the experiment began.

Thirty multiple choice questions including quadratic equations which have similar difficulty level were chosen for this study. First five questions were solved in quiet. After that, equations were solved while students were exposed to noise through headphones. Each sound clip was played through for another 5-question-set. The sound clips consisted of aircraft sound, road traffic sound, verbal television sounds, a music piece and children playing sounds. The order of the sound clips changed randomly. All the sound clips had the same L_{Aeq}, 55 dBA, which is found to be the most common noise level in children's bedrooms in a study by Pujol et al. (2012). It is expected that aircraft sound is the first and road traffic is the second most impairing, within transportation sounds (Hygge, 2003). Verbal television sounds and music piece are expected to be effective

due to irrelevant-sound effect (Elliott, 2008). Sounds of children playing included verbal and footstep sounds in order to investigate the effect of siblings and neighbors.

None of the students had any hearing problems. All participants signed a consent form and they were warned to stop the test if they felt any auditory problem. The sound clips were recorded using binaural microphones (MESA BMH.I-H42 binaural headset) and adjusted to L_{Aeq} 55 dBA (Ascigil Dincer & Yilmaz, 2015; Yilmaz & Ascigil Dincer, 2016). Headphones (MESA BMH.I-H42 binaural headset) were used to listen to sound clips.

The number of correct answers and the duration to solve each 5-question-set was recorded for each student. At the end of the multiple choice test, children were asked which noise they found to be the most activity-disturbing.

Statistical analysis called MANOVA (Multivariate analysis of variance) was run to analyze the relationship between the sound clips and homework performance. MANOVA compares two or more dependent variables through sample means and runs significance tests involving individual dependent variables separately. It may present significant effects of independent variable on the dependent variables or relationships among the dependent variables. The analysis was run using IBM SPSS Statistics software.

3. Experimental results and discussion

19 of the 32 participants were male, 40.6% were female. Before the testing, 50% of the participants reported themselves to be not sensitive to noise, whereas 31.25% were somewhat sensitive and 18.75% were highly sensitive to noise in general. Table 1 shows the names, codes and explanations for the sound clips used in the study.

Participants were asked about the most disturbing sound clip they encountered in this study after the testing. The most disturbing sounds were aircraft and children playing, followed by verbal sound (Figure 1). None of the participants found road traffic noise to be the most disturbing.

Table 1. *Names, codes and explanations for the sound clips used in the study.*

Code	Name	Explanation	L_{Aeq} (dBA)
N1	Quiet	No sound	55
N2	Aircraft	Aircraft takeoff	55
N3	Road	Continuous road traffic	55
N4	Verbal	Speaking on television	55
N5	Music	Music piece with no speech	55
N6	ChPlay	Children talking, screaming, running	55

For the MANOVA analysis, the independent variable was noise type and the dependent variables were number of correct answers for each sound clip and duration to solve the 5 equations. As the independent variable was noise type, between-subject factors were the six types of noise (N1, N2, N3, N4, N5, N6) given in Table 1, with 32 samples each. Multivariate tests were run with Wilks's Lambda and the results showed that homework performance is statistically significantly dependent on noise type ($F(10,370)=2.832$; $p<0.005$; Wilk's $\Lambda= 0{,}863$; partial $\eta^2= 0.071$).

The test of between-subject effects (effects of noise) showed that noise has a statistically significant effect on both number of correct answers ($F(5,186)=4.308$; $p<0.005$; partial $\eta^2= 0.104$) and solving duration ($F(5,186)=3.195$; $p<0.05$; partial $\eta^2= 0.079$).

A Post Hoc analysis presents differences between pairs of groups, in this case between pairs of noise types. The results of the Post Hoc tests are given in Table 2.

Mean number of correct answers were statistically significantly different between (N1) quiet and (N2) aircraft noise ($p<0.05$), between (N1) quiet and (N4) verbal sound ($p<0.005$), between

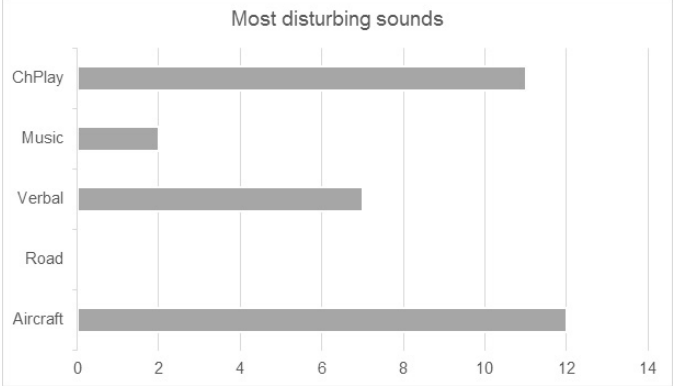

Figure 1. *The most disturbing sounds during testing.*

Table 2. *The results of the Post Hoc test for noise types, due to number of correct answers and solving duration.*

Dependent Variable	(I) Noise	(J) Noise	Mean Difference (I-J)	Std. Error	Sig.
Correct	1	2	,34*	,153	,026
		3	,06	,153	,683
		4	,47*	,153	,002
		5	,06	,153	,683
		6	,50*	,153	,001
	2	1	-,34*	,153	,026
		3	-,28	,153	,067
		4	,13	,153	,414
		5	-,28	,153	,067
		6	,16	,153	,308
	3	1	-,06	,153	,683
		2	,28	,153	,067
		4	,41*	,153	,009
		5	,00	,153	1,000
		6	,44*	,153	,005
	4	1	-,47*	,153	,002
		2	-,13	,153	,414
		3	-,41*	,153	,009
		5	-,41*	,153	,009
		6	,03	,153	,838
	5	1	-,06	,153	,683
		2	,28	,153	,067
		3	,00	,153	1,000
		4	,41*	,153	,009
		6	,44*	,153	,005
	6	1	-,50*	,153	,001
		2	-,16	,153	,308
		3	-,44*	,153	,005
		4	-,03	,153	,838
		5	-,44*	,153	,005

Dependent Variable	(I) Noise	(J) Noise	Mean Difference (I-J)	Std. Error	Sig.
Duration	1	2	-,50*	,205	,016
		3	-,03	,205	,879
		4	-,34	,205	,095
		5	-,13	,205	,543
		6	-,63*	,205	,003
	2	1	,50*	,205	,016
		3	,47*	,205	,023
		4	,16	,205	,447
		5	,37	,205	,069
		6	-,13	,205	,543
	3	1	,03	,205	,879
		2	-,47*	,205	,023
		4	-,31	,205	,129
		5	-,09	,205	,648
		6	-,59*	,205	,004
	4	1	,34	,205	,095
		2	-,16	,205	,447
		3	,31	,205	,129
		5	,22	,205	,287
		6	-,28	,205	,172
	5	1	,13	,205	,543
		2	-,37	,205	,069
		3	,09	,205	,648
		4	-,22	,205	,287
		6	-,50*	,205	,016
	6	1	,63*	,205	,003
		2	,13	,205	,543
		3	,59*	,205	,004
		4	,28	,205	,172
		5	,50*	,205	,016

(N1) quiet and (N6) playing children noise ($p<0.005$), but not between (N1) quiet and (N3) road traffic noise or between (N1) quiet and (N5) music piece. Mean number of correct answers for (N3) road traffic noise were found to be statistically significantly different between (N4) verbal sound ($p<0.05$) and (N6) playing children noise ($p<0.01$). Mean number of correct answers for (N5) music piece were found to be statistically significantly different between (N4) verbal sound ($p<0.05$) and (N6) playing children noise ($p<0.01$).

Mean duration for solving equations were statistically significantly different between (N1) quiet and (N2) aircraft noise ($p<0.05$), between (N1) quiet and (N6) playing children noise ($p<0.005$), but not between (N1) quiet and (N3) road traffic noise or between (N1) quiet and (N4) verbal sound or between (N1) quiet and (N5) music piece. Mean duration for solving equations for (N3) road traffic noise were found to be statistically significantly different between (N2) aircraft noise ($p<0.05$) and (N6) playing children noise ($p<0.005$). Mean duration for solving equations were statistically significantly different between ((N5) music piece and (N6) playing children noise ($p<0.05$).

Another MANOVA test was run by putting in the most disturbing sound as independent variable and the dependent variables as number of correct answers for each sound clip individually. Performance on the correct number of answers was not statistically significantly dependent on disturbance. A third MANOVA test with the most disturbing sound as independent variable and the dependent variables as the

duration to solve the 5 equations for each sound clip individually, showed the opposite effect. Multivariate tests run with Wilks's Lambda showed that homework duration performance is significantly dependent on disturbance ($F(18,65)=2.847$; $p<0.005$; Wilk's $\Lambda=0{,}195$; partial $\eta^2= 0.420$).

Figure 2 shows the median and standard deviation of correct answers during each sound clip. In comparison to quiet (no sound), road traffic noise and music piece did not have any negative effect on the number of correct answers. According to medians and standard deviations, aircraft takeoff, speech from television and playing children sounds had the same impairing effect, but the effect of children playing sounds was slightly more varying.

Figure 3 shows the median and standard deviation of solving duration for each sound clip in minutes. Comparing each noise clip to quiet showed that road traffic noise and music piece did not have any effect on the duration of solving 5 equations. According to medians and standard deviations, aircraft takeoff, speech from television and playing children sounds had the same prolongation effect, but the effect of children playing sounds was slightly less varying.

Figure 4 presents the boxplot for the minimum, maximum, median and quartiles of solving duration in minutes due to number of correct answers in 5-question groups when exposed to varying noise conditions. It is clearly seen on the graph that solving duration decreases as correct answers increase. This shows that homework performance, related to correctness of answers and shortness of duration, is dependent on the exposed sound and not the difficulty of the questions.

It is known that aircraft noise impairs recognition and recall (Hygge, 2003; Stansfeld et al., 2005). Road traffic noise on the other hand, was found to impair recall (Hygge, 2003), but not cognition (Stansfeld et al., 2005). In order to solve algebraic equations, both recalling the steps of solving the equations and recognition of similar equations are needed (Anderson & Krathwohl, 2001; Zanibbi & Blostein, 2012). In this study, road noise was not found to be effective in the correctness or the duration of algebraic equations, therefore it was not effecting recall or recognition. Aircraft noise on the other hand effected both correction and duration and therefore effected both recall and recognition.

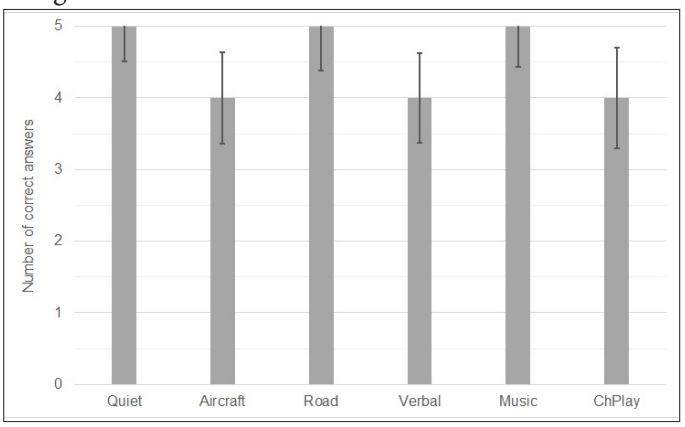

Figure 2. *The median and standard deviation of number of correct answers during each sound clip.*

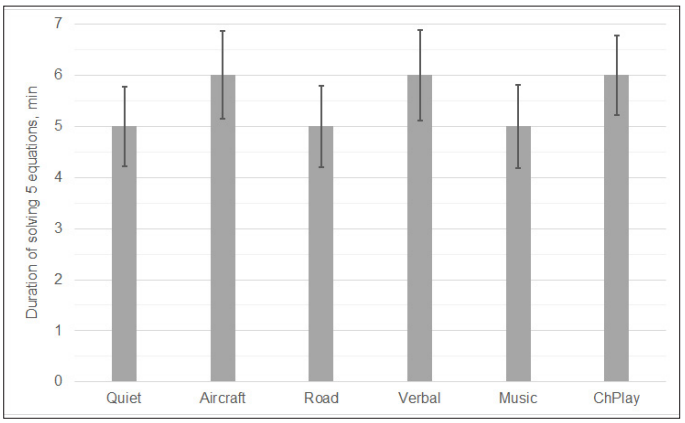

Figure 3. *The median and standard deviation of solving duration for each sound clip.*

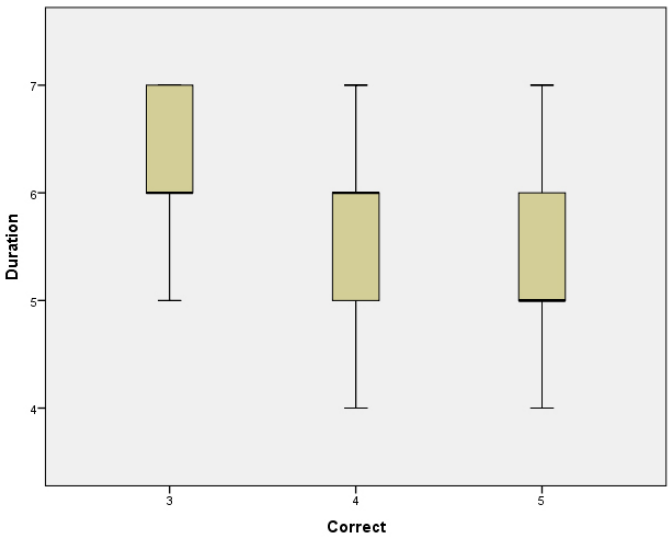

Figure 4. *Boxplot for the minimum, maximum, median and quartiles of solving duration in minutes due to number of correct answers in 5 question groups.*

Irrelevant speech effect is related to recall and attentional distraction (Elliott, 2008). In this study, speech from television and children were found to effect correctness. Duration was not effected by speech from television but it was effected by children talking, screaming and running.

4. Conclusion

In this study, the effect of various sound environments on homework performance was investigated through the duration and correctness of solving algebraic equations in multiple choice tests. High school students (17-18 years, N=32) with similar academic achievements, solved a total of 30 quadratic (second degree) equations. During each 5-question-set, they listened to different sound clips (L_{Aeq}= 55 dBA) through headphones: quiet (no sound), aircraft takeoff sound, continuous road traffic sound, verbal television sound, a music piece and children playing (talking, screaming, running).

Statistics showed that noise type is effective for both the number of correct answers and the solving duration. Mean number of correct answers in quiet environment is statistically better than mean number of correct answers for aircraft, verbal and playing children sounds. But the response to children playing is slightly more varying than the others. The correctness performances of road traffic noise and music piece are statistically better than verbal and playing children sounds. Mean duration for solving equations in a quiet environment is statistically better than mean duration for aircraft and playing children sounds. Although mean duration for verbal sound is higher than quiet, it is statistically not different. The duration performances of road traffic noise and music piece are statistically better than aircraft and playing children sounds.

Duration performance is statistically dependent on what the participants thought to be the most disturbing sound, but correctness performance is not. This proves that participants' self-reported activity disturbance is dependent on the duration to solve the algebraic equations.

In terms of transportation sounds, aircraft takeoff noise is effective in recall and recognition but road traffic noise is not. In terms of speech, speech from television and children is effective in recall and attentional distraction. Playing children sounds, which include speech, screaming and running, had a more impairing effect than speech from television, even though they had the same equivalent sound level. Music piece with no speech had no effect on homework performance.

This study proves the significance of land use planning near airports according to noise mapping. It also points out the importance of sound insulation on façade, between individual dwellings and within houses. Neighbor, television and sibling sounds are impairing to homework performance, which may be prevented with efficient sound insulation and planning. Considering that learning environment at home is almost as important as learning environment at school, noise at home is an important issue to be addressed in order to prevent cognitive impairment of children.

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