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Listening Education

Editor: Margarete Imhof

International Listening Association

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Editor

Margarete Imhof

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Effects of background noise on cognitive performance in elementary school children

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Summary:

This study looks at how the irrelevant sound effect (ISE) affects attention processes in elementary students in a natural setting. A sample of *N* = 50 fourth graders were administered two subtests from an ecologically valid attention test (one listening and one copying task) to investigate the effect of classroom noise on attention. Results were returned with medium to large effect sizes showing that attention, and, consequently, performance was impaired in the noise condition. The pattern of results suggests that both a detrimental impact on attentional resources and interferences during information processing may contribute to the ISE. For practical purposes it is important to realize that the ISE affects the quantity of student output while error rates are not affected.

Keywords:

Irrelevant Sound Effect, Classroom Noise, Attention, Cognitive Performance, Elementary Education.

EFFECTS OF BACKGROUND NOISE ON ATTENTION IN ELEMENTARY SCHOOL

Irrelevant sound effects and school work

A growing body of literature describes and explains the irrelevant sound effect (ISE) which reflects the finding that the presence of an acoustic background, such as noise or speech, has a detrimental effect on cognitive performance in spite of the fact that subjects in the experiments were told to ignore whatever they hear in the background (Colle & Welsh, 1976; Salamé & Baddeley, 1982). Empirical research on the ISE is of interest both for theory building (e.g., on the nature of working memory), and for practical purposes (e.g., for issues of designing working environments). In the area of education, it is important to understand what the ISE means for learning processes in classrooms. Recent studies on classroom acoustics have shown that the acoustic quality of the immediate learning environment has an impact on the quality of learning (Klatte, Meis, & Schick, 2007; Spreng, 2002), especially for young children who are on their way to acquire reading and writing skills based on their listening abilities (Marx & Jungmann, 2000). However, considering the noise and sound environment in schools, we have reason to assume that the acoustic characteristics of classrooms are not always optimal for listening tasks (Mommertz, 2002; Schick, Klatte, & Meis, 1999), in spite of a high demand of various listening situations in the course of a typical day at school (Imhof, 2008).

Although the ISE has been widely researched, the problem of the extant empirical evidence is that the experimental studies have rarely been carried out under ecologically valid conditions, but rather in strictly controlled laboratory conditions in order to fine-tune and to control the characteristics of the acoustic background (Beaman, 2005; Elliott, 2002; Farley, Neath, Allbritton, & Surprenant, 2007; Klatte, Meis, Sukowski & Schick, 2007; Schlittmeier, Hellbrück, Thaden, & Vorländer, 2008). So, for instance, it has been investigated in detail in which way the ISE is affected by conditions such as speech vs. non-speech, by sound level, and continuous noise vs. changing-state noise. However, in everyday situations we typically have to deal with a hybrid noise, as for example in classroom noise which may contain some speech, some non-speech, some loud and some soft sounds, some continuous and some changing components.

In addition, the experimental tasks which had typically been used in pertaining research were very specific (e.g., mental arithmetic, serial recall of digits and words, and contained acoustically presented stimuli which are easily susceptible to distortion by noisy conditions). Klatte et al. (2007), for example, used similar sounding words as stimuli which participants had to verify by selecting one out of three pictures which represented the different objects. The acoustic stimuli differed from each other in one phoneme only (as e.g., in /bat/ vs. /but/). The observed interference may be due to the fact that the relevant and the irrelevant signal compete for the same acoustic processing resources (see also Hughes, Vachon, & Jones, 2007; Schlittmeier, Hellbrück, & Klatte, 2008). Typically, stimuli used in the experiments on ISE were computer-paced, so that the participants' resources for attentional control were somewhat alleviated compared to a situation in which they would be required to self-regulate attention and to actively direct attention to the relevant stimuli and to wall out the irrelevant background, as would be the case in a self-paced task.

Schlittmeier et al. (2008) have added to the research on how background noise interferes with specific types of cognitive tasks based on the assumption that they require different amounts of short term memory or working memory capacity. The authors found that background noise disturbed verbal serial recall and mental arithmetic, but not verbal-logical reasoning performance. It remains an open question, however, if the specific cognitive processes pertaining to the task or the unspecific aspects of a task, such as attention, are affected by the acoustic background.

Another concern in this context is the developmental aspect. It has consistently been observed that the extent to which ISE has a detrimental effect on performance changes with age (Beaman, 2005; Elliott, 2002). In particular, it has been found that from about third or fourth grade on the ISE appears to be less pronounced when acoustic targets are to be detected against irrelevant sound (Elliott, 2002; Klatte, Sukowski, Meis, & Schick, 2004). However, it is not known at what cost the irrelevant sound is suppressed while attention is focused on the relevant information.

It is also not known, if the detrimental effect of irrelevant sound or background noise is still visible when it is associated with highly familiar and well-habituated situations as the classroom and classroom noise (Cowan, 1995). It might very well be that the everyday exposure to classroom noise is perceived in an attenuated manner and that the habitual behavior overrides or walls out the potential disturbance. Classroom noise may even mask more acute sounds and, as a consequence, increase performance. The positive effect of classroom noise on children with special needs had been demonstrated in an experiment by Zentall and Shaw (1980) who found that children with an attention deficit hyperactivity disorder displayed both normalized behavior and performance in a noise condition as compared to (relative) silence.

Thus, the issue of ecological validity of ISE studies and the issue of which aspects of a task are affected by the ISE were driving our research. Following up on the work by Klatte et al. (2007), we stated a research question which we broke down into two research hypotheses:

RQ: Does classroom noise as acoustic background have an impact on attention which is an unspecific aspect of cognitive performance?

H1: Classroom noise as acoustic background has an impact on attention; this will show in the performance in a listening task which requires mental storage of orally presented verbal information.

H2: Classroom noise as acoustic background has an impact on attention; this will show in the performance in a copying task which requires mental storage of visually presented verbal information.

Method

Sample

The sample for this study included a total of 55 students from two complete classes of in fourth grade (*M* = 9.62, *SD* = .57 years), 24 of them girls. The classes were suggested by the school principal, because the teachers were interested in the study and willing to cooperate. The school was in central Germany in an urban, middle-class, generally well-to-do environment. Three students had a bilingual family background but based on their general classroom performance – they had successfully mastered three grades of instruction in German – it was safe to assume that they had sufficient language skills to understand the instructions. Six students were known to be diagnosed with dyslexia. In the light of the research questions, this age group seemed to be appropriate because they had mastered the basic skills which are needed to solve the experimental tasks and since there is evidence that fourth graders do have a good control of irrelevant sound as opposed to younger students (e.g., Klatte et al., 2004).

Experimental Variation

To test the effect of background noise, a within group repeated measures design was realized (Creswell, 2002). We created two conditions, one of which included the presentation of pre-recorded background noise. The recording was made during an individual seat work period in the class. A special microphone was used to capture the surrounding noise in a realistic manner (microphone ITT, recorded by M-Audio Music Track 24/96). The recordings were burned on a CD and were played from a Philips CD recorder using four loudspeakers (SOLTON Music, EC 12/80, 80 Watt) which were placed in the four corners of the classroom to make sure that the sound was equally distributed across the room. In the experimental condition with background noise, the sound level was kept at 65 dB(A) which would be the typical sound level in the classrooms. For the control condition without background noise, the room was not totally silenced, but sources of acoustic distractions were minimized. The room was prepared by closing the windows, by putting potential sources of noise out of the way (e.g., backpacks, by attaching felt on the chairs to keep the noise low). During the test administration, the sound level was measured (VOLTACRAFT, Type 33-2050) for a treatment check and it was found that the sound level was at 40 dB(A).

Experimental Tasks

To study the effects of background noise on attention, we chose the TAC (*T*esting Battery for the *A*ssessment of *C*oncentration) published by Kurth and Büttner in 1999, because it contained standard tasks for this age group and does not require specific prior knowledge. Since the subtests had been validated to measure attention and to be demanding in terms of short term storage, we found them appropriate for use to test the hypotheses on the effects of background noise. The test can be considered as ecologically valid, because it builds on well-practiced tasks which are frequently used in elementary school instruction. The TAC comprehends a listening test, a timed copying task, and number problems. For the purpose of our experiment, we selected the verbal tasks, i.e., the listening task and the copying task, because the entire test battery would take about 45 minutes to administer which seemed to be too much of a load for the purpose of one single study. The authors report satisfactory reliability scores for the sum scores of the listening (r_{tt} = .88) and the copying subtest (r_{tt} = .96) and the error rates of the copying test (r_{tt} = .64) (Kurth & Büttner, 2004). The test scores were shown to correlate substantially with teacher ratings of student attention skills (r = .59). Correlations between measurements of working memory and the listening task were very low for elementary students (r = .05) so that it would be safe to say that the test primarily measures attention and is independent of working memory in this specific target group (Kurth & Büttner, 2004).

For the copying task, the students had to rewrite a short story from a master to their own sheet. The task is self-paced in a way that the students may proceed at their own personal speed. The two stories prepared for the TAC were titled "The bear and the two hoodlums" which was 19 printed lines long with 196 syllables, and "The oak tree and the reed" which was 22 printed lines long with 141 syllables. According to the test manual, the texts were equal in difficulty. The task is time-limited at a maximum of 10 minutes. During copying, the students were instructed to start writing in the next line on the signal "stop – new line please" given by the test administrator in 2-minute intervals. In line with the test instructions, the number of syllables which were copied and the error rate were recorded as indicators of attention.

The listening task was presented as an oral story in which a total of 31 animal names were mentioned. The children were instructed to attend to the animal names and to retain as many as possible. They were not allowed to take notes during listening. The story had been tape-recorded in order to avoid spontaneous changes (e.g., mispronounciations, changes in loudness, and repetition). After completion of the story, the children received a ruled sheet of paper and had 5 minutes to write down all the animals which they were able to recall. A second story was created along the same principle as the original to avoid verbatim repetition of the target items in the second testing.

Design and Procedure

All students were tested twice and the two test conditions were presented on two consecutive days. The order of test conditions was balanced across the two classes to control for sequence effects, so that one class worked without background noise first, followed by a testing session with background noise the next day. The other class worked in reverse order of conditions. All tests were administered between 9.30 and 11 a.m. to avoid effects of low vigilance due to the time of the day. Two student teachers who had been visiting with the classes for a couple of weeks prior to the experiment instructed the tests. They were careful not to use the term "test" in order to relax the situation and to reduce test anxiety as much as possible. It was still pointed out that the students should try their best at the tasks. In an exploration subsequent to the testing administration, we wanted to verify if the students had worked on the tasks with the expected motivation. After the students had completed the test tasks, they filled in a short questionnaire to verify their motivation.

Results

Descriptives

The tests were evaluated by two individual teaching students. Before processing the data, we sorted out the tests of those children who reported in the exploration that they had not liked the task and that they had not made an effort to do their best. This way, we wanted to control for confounding effects of a lack of motivation on the performance. For the listening task, this applied to five out of the 55 students, for the copying task we had to take out 13 tests. In addition, the tests of six students who were known to be diagnosed with dyslexia were also excluded from further processing. This procedure left the tests of 36 students in the sample. The data were processed using SPSS for Windows 15.0. The descriptive results for both parts of the test are presented in Table 1.

Table 1

Means and Standard deviations of the test results in the experimental tasks in the condition without background noise and with background noise.

	M	*SD*	N
Listening Task:			
Number of items recalled			
without background noise	16.29	3.35	50
with background noise	13.14	3.65	50
Copying Task:			
Number of syllables copied			
without background noise	120.11	33.58	36
with background noise	103.44	27.79	36
Percentage of errors			
without background noise	4.21	4.13	36
with background noise	4.55	4.25	36

Performance with and without background noise in the experimental tasks

As can be seen in Table 1, the performance deteriorates in terms of quantity in the condition with background noise. The number of items recalled from the listening subtest and the number of syllables copied in the copying subtest were lower in the condition with the surrounding noise. Paired t-tests revealed that the differences are statistically significant in both cases; number of items recalled in the listening test: t (df = 49) = 6.74, $p < .001$; number of syllables copied: t (df = 35) = 5.11, $p < .001$. Given that a small effect size is .20, a medium effect size is .50 and a large effect size is .80 (Aron, Aron, & Coups, 2006, p. 259), the effect size in the current study was large for the listening task (Cohen's *d* = .90) and medium for the copying task (Cohen's *d* = .54). The proportion of spelling mistakes relative to the number of copied syllables did not differ across conditions as shown in Table 1 (t (df = 35) = -.51, $p > .05$). This means that both hypotheses which we had stated can be accepted, and that we found evidence for a substantial performance decrement both in the listening and in the copying task. Since the experimental tasks were used as indicators for attention capacity, the results need to be viewed in combination to respond to the research question. From the evidence brought forward in this study it can be concluded that classroom noise depletes the attentional resources of elementary students and may entail a decrease in output quantity and cause an increase in effort required to maintain the quality of the work.

Interpretation and Discussion

The aim of the current study was to investigate the ISE in an ecologically valid environment and to describe its impact on attention as required for the cognitive school tasks in elementary grades. The performance in an attention test battery was significantly impaired by medium to large effect sizes in the testing condition in which recorded classroom noise was played as a background sound. This result supports the findings from previous experimental work in laboratory settings when detrimental effects of irrelevant sound on cognitive performance were described. We have reason to believe that naturally mixed noise which contains speech and non-speech, continuous and changing elements, has an effect on how well students can use their attentional resources. Although we used their own classroom noise which should be familiar to the students, habituation could not entirely make up for the detrimental effects. It might very well be that the decrease in performance might have been more acute with an unfamiliar background noise.

According to the results, the performance impairment consisted mainly of a reduced output quantity while the error rate remained stable. The students produced less work in the same amount of time. Assuming that the students probably expended the same amount of attentional resources during this time, we can draw the tentative conclusion that they depleted more resources to maintain the overall quality of the work.

The results of the current study are in line with previous findings from laboratory studies with a comparable age group concerning the ISE (Beaman, 2005; Klatte et al., 2007). Beaman (2005) discusses two explanations for the ISE: It may be due to involuntary capture of attentional resources or, alternatively, it may be attributed to a confusion at the level of encoding, storing or recalling representations. The results of the current study are not sufficient to shed light on the question at which level the detriment might be operating. This study cannot contribute to the question what kind of cognitive processes would be affected.

According to our data and effect sizes, both mechanisms could contribute to the effect, because we found that attention was generally impaired in both tasks, and that this impairment was more salient in the listening task which involved competing signals in the acoustic modality than in the copying task which used the visual modality. This makes sense because it is plausible to assume a stronger effect when there is a direct interference at the stimulus level. However, in order to better understand and explain the causes of the performance impairment, a measure of working memory should be included in future studies.

Strictly speaking, this study would need to be replicated with a larger sample of students. It would specifically be of interest to take into account individual differences in the susceptibility to the ISE (Elliott, 2002) and to investigate in more detail how the reported effect might vary across age groups and ability groups. Since we had a large number of students who dropped out of the experiment due to a lack of motivation, we would be well-advised to take a look at possible systematic self-selection effects in further studies. It might very well be that the effect is even stronger in children with special reading and writing problems or in children who have not yet automatized the underlying skills to the same degree as their classmates.

The choice of the experimental tasks from a testing battery on concentration seemed to be appropriate, because the children in the sample performed at a level which was appropriate for the age group. The results might be flawed by the fact that a second set of test items had to be created for the purposes of the current study and that this set has not specifically been validated. However, the results look plausible and in line with what could be expected.

Also we think that for further studies the experimental conditions ought to be realized in several different levels. The condition which we named “without background noise” still contained noise at a sound level of 40 dB(A). The question remains if even lower sound levels would be associated with further improvement of performance or if there is a limit to the beneficial effects of the absence of sound. Further research should certainly take into account that there might be students who actually benefit from the classroom noise due to their special learning needs (Zentall & Shaw, 1980).

As it is, however, the results have implications for educational practice. The current pattern of results suggests that teachers might not at first recognize the detrimental effects of irrelevant sound, because it does not appear in the quality of the work. Teachers may easily overlook or not notice that the children might need to expend more effort to maintain the quality of their work and that their output decreases in terms of quantity. However, if our results hold, we have reason to say that the acoustic conditions in the classroom affect the attentional processes underlying school word and, therefore, that acoustic aspects need to be considered both for the planning of classroom equipment and for planning and conducting instruction.

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Teaching listening in the classroom

Title: Basketball and Gorillas: Using Visual Cognition Research to Introduce the Concepts of Limited Capacity and Attentional Focus

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Grade level: Undergraduate

Keywords: Limited Capacity, Attention, Schema, Information Processing

Listening Practice:

Course title: suitable for any course that has a unit devoted to listening, social cognition, or information processing; this activity has worked well in both large (N = 237) and small (N = 23) classes.

Course level: adjustable

Goals: To illustrate the concepts of attentional focus and limited information processing capacity

Type / Aspect of listening in focus: Attention and processing

Description: It is a well known fact that individuals are limited capacity information processors (Imhof, in press). That is, we cannot pay attention to all information available in our environments. This is true for visual stimuli as well as auditory stimuli (Cutler & Clifton, 1999), so understanding the concept of limited capacity is vitally important for students of listening. Similarly, when individuals focus attention to some aspect of a situation, other aspects of that situation are neglected. Situational elements that are not attended to and consciously processed may be vitally important for subsequent judgments and decisions; thus, an ability to choose relevant objects of attention is important for competence in listening. This activity is designed to illustrate the limited capacity of human information processing and the potential consequences of attentional focus. Although the development of this activity is my own, the copyright for the video used in the activity is owned by Daniel Simons of the University of Illinois Visual Cognition Lab; the video should be purchased from Viscog Productions to use in the classroom. You can view the video at://viscog.beckman.illinois.edu/flashmovie/15.php but this version is not supposed to be used for instructional or other purposes.

Preparation and Procedures: This activity should be conducted prior to students being exposed to concepts such as limited capacity, selective attention, selective exposure, barriers to effective listening, or other general cognitive aspects of the listening process. Begin by making three sets of instructions. Provide for enough of each instruction type so that each student is given one instruction and an equal number of each instruction is distributed. When students arrive to class, hand them one of the following:

1. You are about to watch a video that shows several people tossing basketballs. Your task is to pay attention to those individuals wearing a WHITE shirt. More specifically, you are to count the number of times they pass their basketball to other people wearing WHITE shirts. You will be asked for your answer at the end of the video. The person coming closest to the actual number of tosses will win a prize.
   While watching the video please remain silent. Do not talk to anyone but pay close attention to the people in the WHITE shirts and their passing the basketball to others in WHITE.

2. You are about to watch a video that shows several people tossing basketballs. Your task is to pay attention to those individuals wearing a BLACK shirt. More specifically, you are to count the number of times they pass their basketball to other people wearing BLACK shirts. You will be asked for your answer at the end of the video. The person coming closest to the actual number of tosses will win a prize.
   While watching the video please remain silent. Do not talk to anyone but pay close attention to the people in the BLACK shirts and their passing the basketball to others in BLACK.

3. You are about to watch a video that shows several people tossing basketballs. These people are wearing either a white or black shirt and are tossing a basketball to other people with the same color shirt. Your task is simply watch the video. Don’t pay attention to any one group of people. Instead, shift your attention around to all individuals.
   While watching the video please remain silent. Do not talk to anyone but pay close attention to all aspects of the video.

Once students have read and understood the instructions, show the video "Gorilla/Basketball" available from Viscog Productions, Inc (.viscog.com). This video portrays six individuals (three in white shirts and three in black shirts) passing two basketballs back and forth. The individuals in white shirts pass their ball to other individuals in white shirts, and the same is true for individuals in black shirts. Some students will focus on the white shirt team, some on the black shirt team, and some will not be instructed to focus on a particular color and to just watch.

About halfway through the approximately 30 second video, a person dressed as a black gorilla walks from the right of the screen to the middle of the basketball throwers, beats its chest, and walks off the screen to the left. Student who have been told to focus their attention on the individuals with white shirts do not see the gorilla, whereas students focusing on the black shirts and students instructed to simply watch all see the gorilla (which is plainly visible on a second viewing of the video to the entire class).

After showing the video twice (the second time to prove to the students focused on the white shirts that a gorilla did, indeed, walk across the screen), the class discussion can focus on implications of limited capacity and attentional focus on the process of listening. Although discussion should differ depending on student comments and the particular lecture material to follow the activity, it is important to explain the reason for an inability to see the gorilla for those focused on white shirts. Specifically, individuals focused on white shirts ultimately blocked out of their attentional focus anything black in color. This results in sustained inattentional blindness of the gorilla for these students. In other words, white-shirt-focused students were selectively attending to a small part of the visual field which caused them to be unable to attend to other aspects of that field. The instructor is also encouraged to ask students how this might apply to listening specifically and to engage in a discussion about the potential consequences of this phenomenon.

Tips and Debriefing:

1. Mirroring the research using the "Gorilla/Basketball" video, there are some students assigned to attend to the white shirts that do, in fact, see the gorilla. Anecdotal evidence from my own classes suggests that most of these students were not putting forth maximal effort to only focus on the basketball passes, and some indicated a suspicious with the activity at the forefront. Depending on whether white-shirt-focused students notice the gorilla, the discussion can lead to interesting speculation and possible avenues for future research about individual and situational differences that predispose some individuals to attending to more of their environments than others.

2. I suggest making sure students do not share what is on their sheets with other students. Perhaps wait until all students are seated and class is stated to hand out the instructions and make it clear that each student should read his or her sheet without sharing with others.

Assessment: Certainly, attentional blindness found solely through the visual channel is not directly transferable to the context of listening. Even so, this activity seems to be a good antecedent for a discussion of limited capacity and attentional focus and their implications for listening. Certainly similar activities that use a range of auditory and visual (and combined) stimuli are welcomed improvements to this.

References:

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