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Studying for an exam in an open-plan study environment: Does background noise impair performance?

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ABSTRACT

Students in higher education work for a large part of their time in rather noisy open-plan study environments (OPSEs). A recent field research has shown that almost 40 percent of the students were 'much' to 'very much' disturbed by background noise while working in an OPSE. Moreover, the students indicated that they were very disturbed by the background noise when they were studying for an exam. Although the influence of background noise on different cognitive tasks has been shown in many studies, little is known about this student task. Therefore, the aim of this work is to analyze the influence of background noise on the 'studying for an exam' task in an OPSE. For this experiment a set of tasks was developed to simulate 'studying for an exam'. As output measures, the performance of students was measured while performing the simulated studying task in different realistic background sound scenarios. These sound scenarios varying in background speech and room acoustics were developed using computational acoustic modelling of an existing OPSE and applying auralization with student voices. In the current paper the research design and first results of the experiments are presented.

Keywords: Open-plan study environment, Studying, Background speech, Task performance, Disturbance

1. INTRODUCTION

New learning methods in higher education have led to a diversity in learning environments for students. Not only classrooms but also informal learning settings such as open-plan study environments (OPSEs) become increasingly important (1). An OPSE is a learning environment meant for students to work on their individual and group tasks (2). In addition to newly designed OPSEs, a growing number of former libraries has been converted into OPSEs due to advanced digitalization (3). A study with 500 students, equally divided over 5 OPSEs, has shown that 64 % of the students was disturbed by the background sound from which 38 % of the students was much to very much disturbed (2). Despite the importance of OPSEs and the high percentage of noise-disturbed students there are no recommendations for the acoustic requirements of those environments.

This field study on OPSEs (2) has shown that students are mostly disturbed by background speech while performing cognitive tasks such as reading, writing and studying for an exam. A developed construct to clarify disruption of cognitive tasks by background noise is called the "Duplex-Mechanism Account of Auditory Distraction"(DMAAD) (4, 5). This theory describes two mechanisms responsible for disruption of cognitive tasks by background noise: 'attentional capture' and 'interference of processes'. When we consider irrelevant background speech, disruption by attentional capture arises from sudden or abrupt changes in a speech signal like AAABAAA, or by specific information in the speech, like for instance your own name. This suddenly changes, or specific information can cause interruption of the focus task. The other mechanism: interference of processes, occurs if the unintended processing of the background speech interferes with the intended processes of the focus task. For instance, if students perform a semantic task it will interfere with the unintended processing of background speech which is also a semantic process (6). More intelligible and meaningful background speech will interfere more with a semantic task like reading or writing then less intelligible and less meaningful background speech (7, 8, 9, 10).

The intelligibility of background speech can be influenced by the room acoustics of an OPSE, as a more reverberant room will reduce intelligibility through reflections and due to the increase of the sound level of other background sounds that mask the speech signals (11). Therefore, a good room acoustic design of an OPSE is a key factor in creating a comfortable and productive learning environment.

In the earlier mentioned field study on OPSEs (2), students indicated 'studying for an exam' to be the most disturbed task they perform in an OPSE. Preparing an examination is a complex task and although there is a great variety of examination formats and topics, exams in higher education share a common basic characteristic, they should require higher order thinking skills and encourage greater conceptual understanding (12). A frequently used model to describe a classification of cognitive skills is Bloom's taxonomy (13, 14). This taxonomy contains six categories of cognitive skills with increasing complexity: knowledge, comprehension, application, analysis, synthesis and evaluation. A later revision of this taxonomy changed the categories in more skills-based levels: remember, understand, apply, analyze, evaluate and create (15). Therefore, when students in higher education prepare for an exam they do not only have to remember and understand knowledge but also be able to apply, analyze, and evaluate that knowledge. ‘Creating’, the highest cognitive level in Bloom's model is generally tested in (multidisciplinary) projects.

In this experiment the influence of the background speech on 'studying for an exam' in higher education will be investigated by using a set of assignments testing higher cognitive skills. We hypothesize that the intelligibility of background speech will have a negative influence on studying performance and will be correlated with the perceived disturbance of the students.

2. MATERIALS AND METHODS

2.1 Participants

Until now 33 students recruited from Avans University of Applied Sciences took part in the experiment. The students (13 female and 20 male) were between 17 and 26 years old (mean=19.9). The students received an internet voucher or student credits as compensation for participation. For the complete experiment 60 students will be recruited (based on a power calculation).

2.2 Background sound scenario's

Four background sound scenarios were developed, one quiet scenario (reference) and three scenario's containing background speech. The background speech scenario's varied in intelligibility. They were constructed by auralizations based on computed impulse responses of two room acoustic models, both variations of an existing OPSE at the Eindhoven University of Technology. The computational modelling and auralization was performed using Odeon (version 12.12). From the original model of the existing OPSE a more sound absorbing scenario was taken by applying sound absorbing materials instead of the real materials such as carpet on the floor, an absorbing ceiling and perforated panels on the walls. Additionally, a more reverberant scenario was taken by applying sound reflecting materials such as linoleum on the floor, a concrete ceiling and walls of unperforated panels and concrete. Furthermore, the number of talkers in the background varied. This resulted in the following sound scenarios:

Table 1 – Background speech scenarios.

Sound Scenario	Reverberation	Background Speech	Sound Level L_{Aeq} Background Speech
A&3T	Absorbing (T_{30}=0.6s)	3 Talkers	41 dB(A)
A&14T	Absorbing (T_{30}=0.6s)	14 Talkers	54 dB(A)
R&14T	Reverberant (T_{30}=2.3s)	14 Talkers	64 dB(A)

The background speech consisted of stories of students about their studies, hobbies and work, recorded in a sound absorbing room and convolved with the binaural impulse responses calculated by Odeon. The quiet sound signal (Q) in the control condition was a pink noise signal with the same sound level as the background noise measured in the existing unoccupied OPSE (30 dB(A)).

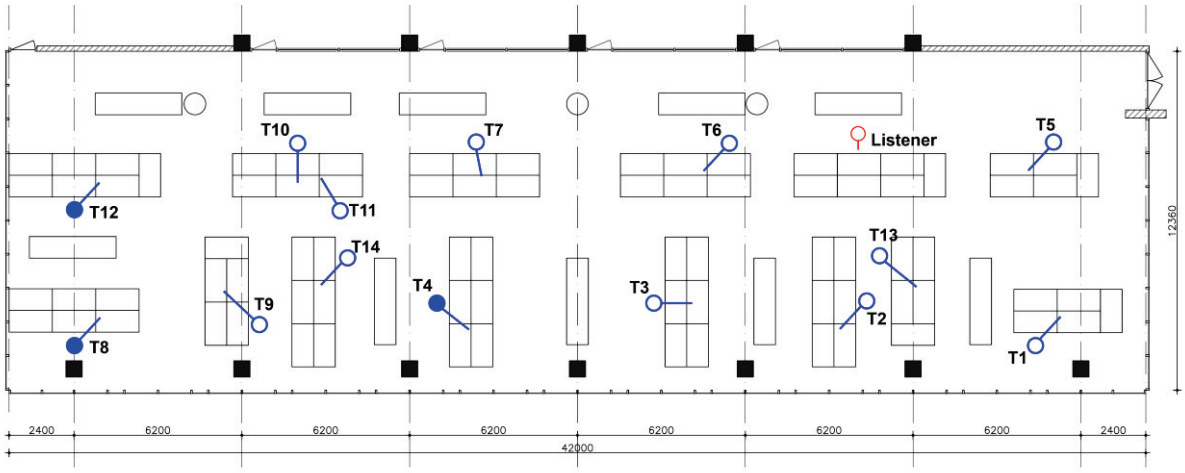

Figure 1 – Floor plan of the modelled OPSE. Positions of receiver (Listener) and fourteen sound sources (Talkers), with the lines indicating the listening and talking direction. Dimensions in mm.

2.3 Task: studying for an exam

The task 'studying for an exam' was simulated by a set of assignments. At first students were instructed to study an informational text about which they were to be examined later. The texts were selected from 'The State Exams Dutch as a second Language (NT2)' which are the national language proficiency exams for non-native adult speakers, who want to start a study at a Dutch University or want to work in the Netherlands. The selected texts were all the same length and were tested to have a similar level of complexity in a pilot study.

To simulate the time gap and diversion from the topic between studying the comprehensive reading text (studying for an exam) and answering the questions about the text (doing an exam), which is the case in a real study situation, a time interval and extra activities were introduced. The chosen tasks were all up to the standard of a beginning bachelor student. One assignment was to judge conclusions drawn from two statements on validity, a so-called syllogism or formal logical test (16). A well tested set of syllogisms, developed by Making Moves B.V. (2019), was used. Subsequently, students were asked to solve mental arithmetic problems. Finally, the subjects had to answer questions about the informational text they had been studying at the start of the experiment.

The set of assignments covered all levels of higher order thinking, in accordance with Bloom's revised taxonomy (15): remembering (reading comprehension, mental arithmetic), understanding (reading comprehension syllogism, mental arithmetic), applying (mental arithmetic), analyzing (reading comprehension, syllogism, mental arithmetic) and evaluating (reading comprehension, syllogism). No ‘creating’ elements were included in the assignments, the highest level of cognitive tasks in Bloom's taxonomy. This choice was made to reduce the duration and complexity of the experiment.

2.4 Design

A within-participants design was used with repeated measurements. Three different sound scenarios with varying intelligibility of the background speech were used (Table 1) and one quiet reference sound scenario. The sound environment in the scenarios was varied by changing the reverberation time and the number of background talkers in the OPSE. As dependent variable the performance of 'studying for an exam' was measured by the number of right answers to the comprehensive reading test. Furthermore, perceived disruption of the participants was measured by a questionnaire after each set of tasks. The questionnaire was based on ISO/TS 15666 'Acoustics - Assessment of noise annoyance by means of social and socio-acoustic surveys' (17).

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2.5 Procedure

The experiment was split up in two parts divided over two days due to the length of the whole experiment. At the first day, the set of assignments (Table 2) was tested once as a proof in a shortened version, and two times for two sound scenarios. The second day the set of assignments was tested for two sound scenarios.

After a short introduction from the experimental researcher, the participating students started the experiment. The test location was a small quiet two-person room meant for audio editing with no window, located at Avans University of Applied Sciences. Students worked individually on a laptop wearing a headphone (Sennheiser HD 380 PRO) throughout the whole experiment. Instructions about the assignments and procedures were given on the laptop screen. Start and stop instructions were also given by a voice signal through their headphone. The students were asked to study a text which was printed on paper and they were told that they had to answer some questions about the text later in the experiment. They could use a pen and marker during their study activity. After the set time (Table 2) they had to put the text including all their notes in a closed box. All assignments (the syllogism, mental arithmetic, questions about the text, and perception questionnaire) were announced on the laptop screen and after pushing the ok button the time clock and assignment were started on the laptop. The elapsed time was shown on the screen, so the students knew how much time there was left to perform their assignment.

Table 1 – The order and duration of the assignments in the experiment.

Assignment	duration proof test [minutes]	duration test [minutes]
1. Studying text	3	6
2. Syllogism	3	4
3. Mental arithmetic	3	4
4. Questions text 1	2	4
5. Questionnaire	2	2

The assignments were presented in the same sequence to all participants. The four sound scenarios were played on the participants headphones' in a counter balanced sequence using a Latin Square design. The proof set and the first two sets of assignments were done at the same day, the students had to take a short break after the first two sets. The first-day experiments took about 75 minutes for each participant in total. On the second day the students only performed two sets of assignments, a short pause in between the assignment sets. After the last set they also filled in a questionnaire about their noise sensitivity (18). The second-day experiments took about 60 minutes for each participating student.

3. FIRST RESULTS

These first results are based on experimental results of 33 participants (target=60 participants). For this conference paper the assignment to study an informational text (assignment 1, Table 2) and answering the questions after a time gap (assignment 4, Table 2), as well as the perceived disturbance (assignment 5, Table 2) are analyzed and reported.

3.1 Performance

The performance of the 'studying for an exam' task was measured by the number of correct answers on the ten questions about the text. Figure 2 shows the study performance for the four sound scenarios.

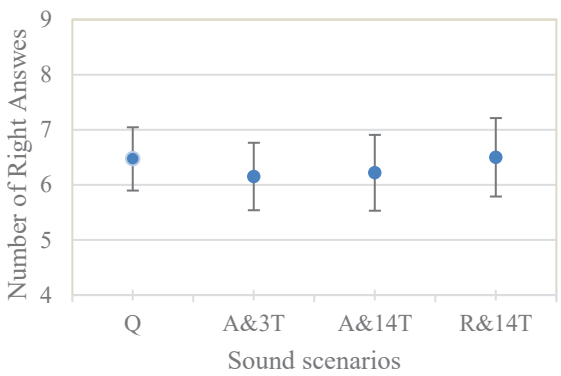

Figure 2 – Mean values (n=33) of performance of the 'studying for an exam' task with different background sound scenarios: Quiet (Q), Absorbing OPSE and 3 talkers (A&3T), Absorbing OPSE and 14 talkers (A&14T), Reverberant OPSE and 14 talkers (R&14T).

A repeated measures analyses of variance (ANOVA) across the four sound scenarios revealed no significant effect of the sound scenarios on 'studying for an exam' performance (p=0.869).

3.2 Disturbance

The perceived disturbance of the 'studying for an exam' task was measured by a questionnaire at the end of every assignment set. Figure 3 shows the perceived disturbance for the four sound scenarios on a 5 points scale.

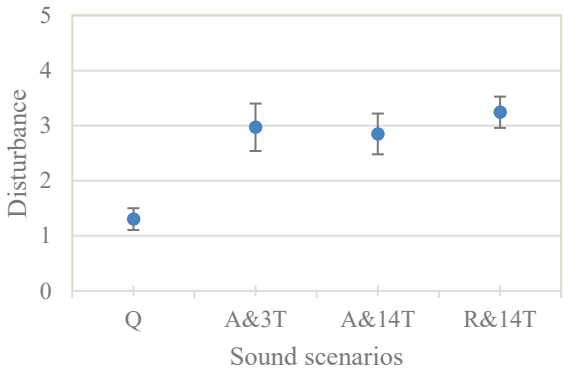

Figure 3 – Mean values (n=33) of the perceived disturbance (n=33) during the 'studying for an exam' task with different background sound scenarios: Quiet (Q), Absorbing OPSE and 3 talkers (A&3T), Absorbing OPSE and 14 talkers (A&14T), Reverberant OPSE and 14 talkers (R&14T).

A repeated measures analyses of variance (ANOVA) across the four sound scenarios revealed a significant effect of the sound scenarios on perceived disturbance (p=.0001). Post-hoc T-tests with Bonferroni adjustment showed significant differences between the quiet condition and the three other background speech conditions. The differences between all other conditions were not significant.

4. DISCUSSION and CONCLUSIONS

The first data of this experiment does not support our hypothesis: ' the intelligibility of background speech will have a negative influence on the performance of studying and will be correlated with the perceived disturbance of the students '. Although Figure 2 shows the highest performance when the background speech is the least intelligible, the scenario with a high reverberation time and 14 talkers, and the lowest performance when the participants are exposed to the most intelligible background speech scenario, the absorbing OPSE with 3 talkers, the differences between the means are not

significant. Figure 3 shows the participants to be most disturbed by the sound scenario in which the background speech is least intelligible, the reverberant OPSE with 14 talkers. The students are the least disturbed in the quiet situation without background speech. The sound scenario with the highest intelligible background speech, the absorbing OPSE with 3 talkers, is not significantly more disturbing than the other sound scenario with background speech.

So far, only 33 participants performed the experiment, half of the statistically required subjects, so there is no definite proof to reject the hypothesis. Further acquisition and analysis of data will be necessary. We plan to continue the detailed analyses of a total number of 60 participants in the near future.

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