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Cognitive test performance following exposure to noise in an open-office simulation study

Søren Peter Lund, Jesper Kristiansen, Roger Persson, and Hitomi Shibuya
National Research Centre for the Working Environment, Lersø Parkallé 105, DK-2100, Denmark, spl@nrcwe.dk

Jørn Toftum, and Geo Clausen
International Centre for Indoor Environment and Energy, Nils Koppels Allé, DK-2800, Lyngby, jt@byg.dtu.dk

Objective: Noise in open-plan offices may increase mental fatigue of the employees at the end of the day. Measurements: 225 employees completed a screening questionnaire. Of these, 50 persons (33 females) who normally worked in open-plan offices agreed to participate in the experiment. All who participated completed two counter balanced experimental sessions, one with exposure to simulation of office noise (Leq=55 dB(A)) and one without noise (Leq=50 dB(A)). To simulate a workday, each session lasted about 7 hours, where the participants engaged in different computerised work tasks. Before and after each simulated workday, the participants performed different tests, including Choice Reaction Time (CRT) test, Sustained Attention to Response Task (SART) test, and a Two-Back Task (TBT) test. Results: Working in noise did not affect the number of correct trials in the cognitive test after work. Yet, there were differences in performance between subgroups that were defined with respect to the degree of disturbance to noise they experienced in their normal work conditions. Conclusion: There were no signs of increased mental fatigue during the experimental sessions. However, there were slight differences in test performance between groups reporting being disturbed by noise for more or less than 50% of the time in their normal open office environment.

1 Introduction

The most frequent complaints about open-plan office environments are background noise [1], with people talking in the background and phones ringing at vacant desks being the most annoying sources of noise [2]. Up to 60% of the occupants in the very large open-plan offices have complained about noise compared with only 6% in the cellular offices [3]. Noise in open-plan offices may reduce well-being, and occupants in such offices may even experience higher sickness absence than occupants in cellular offices [3, 4]. There is also evidence that open workplaces intensifies cognitive workload [5], and signs of physiological stress reactions to noise has been shown in a 3 hour study entailing clerical workers who performed office-like tasks [6],. This was, however, not observed in a smaller short-term study (~35 min.) with volunteers [7]. The present study was undertaken in order to test whether noise in a simulated open office environment would reduce performance and increase fatigue of subjects normally working in an open offices. To elucidate whether differences in noise disturbance during simulated office work was associated with differences in mental fatigue, test in cognitive tasks were performance before and after working in noise for a full working day. Only a limited dataset of the entire the study is presented here.

2 Materials and methods

2.1 Settings

In balanced order, subjects participated in two experimental sessions simulating an ordinary workday. On one of the sessions the participants were subjected to pre-recorded office noise and in the other sessions there was no pre-recorded noise The experiments were carried out at the Technical University of Denmark in a controlled environment that were designed to resemble an office with eight computer workplaces. Digital recordings of office noise were played from a surround sound amplifier by six loudspeakers located in pairs along three of the walls. The sound track consisted of typical office noises such as people talking on telephone, people engaged in conversations, occasional laughter, telephones ringing, fax and printer sounds, etc. A detailed description of the sound track can be found in Witterseh et al. 2004 [8]. The sound track had been re-sampled and digitized in order to support the surround effect [9]. The background sound level measured in the empty office was 42 dB(A). With subjects present but without playing the office noise it was 50.7 ± 1.2 dB(A) and with noise exposure it was 55.0 ± 1.2 dB(A). Mean sound levels included only the exposure periods and excluded the break periods when subjects moved around, talked, and the door between the office and the adjacent corridor was open. The office was mechanically ventilated with a fixed flow rate in all experiments and the temperature was controlled by a combination of radiators located along the exterior facade and the temperature of the supply air. One to eight subjects participated in an experiment at the same time and the CO2 concentration measured during the exposure time from approximately 10:00 to 15:00 hrs varied between the outdoor concentration and 600 ppm. The thermal load with subjects present in the office caused an increase in the hourly mean temperature (across all experiments) from 23.4±0.8°C (mean±sd) during the first hour to 24.4± 0.8°C during the final hour. The relative humidity was 41%±9% RH.

2.2 Participants

The selected groups of employees within the three companies first received a mail with a description of the study and an invitation to visit a web site with a comprehensive pre-screening questionnaire. They were recruited among employees working in open-plan offices in one private (bank) and two public companies (industrial injuries processing and logistics). Altogether, 225 employees completed the screening questionnaire and of these 49 persons (32 females aged 44.3 ± 11 years (mean ± sd; range 20-63 years) and 17 males aged 44.4 ± 10 years (range 28-63 years) agreed to participate in the experiments and completed both experimental sessions, while two persons only participated in one of the experimental sessions.

2.3 Noise disturbance

Noise disturbance was addresses in the pre-screening questionnaire by several items, but the one used in the analysis was the following question:

- "Are you exposed to noise that disturbs you during work?" (*1 = Never, 2 = rarely or very little, 3 = approximately ¼ of the time, 4 = approximately ½ of the time, 5 = approximately ¾ of the time, 6 = Almost all of the time*)

In the analysis, the participants were divided in two groups of approximately equal size according to dichotomizing the answers into being *disturbed less than 50% the time* (1+2+3; n=24) or *approximately 50% of the time or more* (4+5+6; n=22). Four participants did not answer this question.

2.4 Cognitive test

All the cognitive tests was administered while subjects were seated in the LAB in front of their individual desktop computer with a 14" LCD monitor and were performed using the E-Prime 2.0 computer program and E-prime PST Serial Response Boxes.

The Choice Reaction Time task (CRT) consisted of 50 trials, each with participants pushing left or right hand buttons on the response box when shown either a "0" or a"1" on the screen. Subjects were given one or more practice blocks of

10 trials to become familiar with the task. The data calculated was the geometric mean of the reaction time (RT) and number of correct responses.

In the Sustained Attention to Response Task (SART), digits were presented from ”1” through ”9” 450 times in random order and in different sizes. The participants were required to respond to the digits with a key press with the exception of the number ”3” which required no response. The 50 target digits were distributed throughout the 450 trials in a random fashion, and the all 450 trials were presented in a single, continuous block. Reaction times of all key presses relative to digit onset were collected. The primary outcome measure of the SART is the total error score, consisting of key presses when no key should be pressed (i.e. after a ”3”, a so-called ”no-go” trial: commission errors), and absent presses when a key should have been pressed (i.e. after anything but a ”3”, the so-called ”go” trials: omission errors). [4, 10, 11]. Each session was preceded by one or more practice blocks of 36 trials, four of which were “no-go” trials. The following measures of response accuracy were assessed: the number of commission errors, with a maximum of 50; the number of omission errors, with a theoretical maximum of 400 errors. The geometric mean RT in ms was calculated over correct response trials.

For working memory assessment, we used a Two-Back Task test. Participants were required to monitor a series of sequentially presented consonants and to indicate for each letter, if it was the same (a so-called “target” stimulus) or different (i.e. a so-called “non-target” stimulus) from the letter presented two times earlier. The subjects were instructed to press different buttons for each type of stimulus (i.e. “target” versus “non-target” stimuli) [12]. Each session consisted of 3 blocks of 24 stimuli presentations, where only the last 22 were used for data collection, including 8 “target” and 14 “non-target” stimuli, presented in a pseudo-randomized order. The 72 stimuli presented, including 24 “target trials” and 42 “non-target” trials”, was preceded by on or more practice blocks of 15 stimulus presentations , of which 5 were “target” trials and 8 were “non-target” trials. The data calculated was the number of correct trials and the geometric mean RT in ms for both “target” and “non-target” stimulus presentations.

2.5 Analysis

All the cognitive test sessions were examined for unsatisfactory performance of the subjects, i.e. like systematic response every at second or third presentation, and the data from these sessions was discharged. The effects of exposure to noise and time of day were estimated in repeated measures mixed models with these variables as fixed factors and the participants as random intercept. The participants were also divided in two subgroups according to their answer to the pre-screening questionnaire regarding disturbance to noise in their normal work place, i.e. being disturbed less than or more 50% of the time or more. Effects of noise disturbance were estimated in repeated measures mixed models with adjustments for age, gender and time of day. Posthoc analysis revealed differences in of the group with less noise disturbance when TBT sessions from the afternoon in a t-test were compared to the sessions in the morning. All effect estimates were adjusted for multiple comparisons where appropriate, and probability of the null-hypothesis (P) less than or equal to 0.05 were considered significant. Statistical computations were made with IBM SPSS version 20.

3 Results

Table 1 shows the number of correct responses in the cognitive test performed in the morning before start of the simulated working day in the laboratory, and again in the afternoon with and without the simulated office noise during the day. The data presented shows no differences between the performances in the cognitive test with respect to the exposure to office noise, i.e. there were no consistent differences in the performances between the cognitive tests from the days working with (~55 dB(A)) or without (~50 dB(A)) simulated office noise.

The group that reported being disturbed for more than 50 % of the work time in their ordinary work had on average a lower score (estimate: 38.9; 95% CI: 37.6 - 40.2; P=0.04) in the “no-go” trials compared to the group that reported disturbance for less than 50 % of their ordinary working time (estimate: 40.9; 95% CI: 39.5 - 42.3). Hence, the group with more noise disturbance made a higher number of commission errors in the SART test. There was also a difference between the groups in the performance in the TBT tests (estimate of >50 % of the time: 21.1; 95 % CI: 20.6 - 21.6; estimate of <50% of the time: 22.0; 95 % CI: 21.4 - 22.5; P=0.02). However, this difference in performance seems primarily to be caused by a better performance of the lesser disturbed group during the afternoon testing (see Table 1).

Table 1: Correct responses (mean ± SEM) in Choice Reaction Time task (CRT), Sustained Attention to Response Task (SART), and Two-Back Task test (TBT) performed in the morning and the afternoon on both the day with and the day without exposure to pre-recorded office noise. The participants are divided in two subgroups according to their answer to the pre-screening questionnaire regarding disturbance to noise in their normal work place, i.e. being disturbed less than or more 50% of the time or more. The figures in parantheses are the number of accepted tests for each group.

		CRT (total: n=50 trials)		SART (total: n=50 trials)		TBT (total: n=24 trials)	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
Noise	< 50 %	48.7 ± 0.3 (20)	48.5 ± 0.3 (21)	41.8 ± 1.4 (20)	40.0 ± 1.5 (21)	21.5 ± 0.4 (20)	**22.6 ± 0.4** (20)*
	> 50 %	48.5 ± 0.4 (22)	48.3 ± 0.3 (22)	39.1 ± 1.1 (22)	37.6 ± 1.4 (22)	21.5 ± 0.6 (21)	21.3 ± 0.6 (20)
No noise	< 50 %	49.3 ± 0.2 (21)	48.8 ± 0.3 (21)	41.3 ± 1.5 22)	40.4 ± 1.9 (22)	21.2 ± 0.4 (20)	**22.2 ± 0.4** (20)*
	> 50 %	48.5 ± 0.4 (23)	48.6 ± 0.4 (20)	40.5 ± 1.3 (24)	38.9 ± 0.9 (23)	21.0 ± 0.6 (23)	21.0 ± 0.6 (22)

Note : * posthoc t-test $p < 0.05$ for performance in the afternoon when compared to performance in the morning.

4 Summary

The hypothesis of the study was that the exposure to low-level of noise (~55 dB(A)) in a simulated open-office environment may induce mental fatigue, which could be detected by cognitive test of sustained attention and working memory. However, this hypothesis was not supported. On the other hand, there were slight differences in test performance between groups reporting being disturbed by noise for more or less than 50% of the time in their normal open office environment.

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References

[1] J.H. Pejtersen, L. Allermann, T.S. Kristensen, and O.M. Poulsen, Indoor climate, psychosocial work environment and symptoms in open-plan offices, *Indoor Air*, 16, 2006, 392-401.

[2] S. Banbury, and D.C. Berry, Disruption of office-related tasks by speech and office noise, *British Journal of Psychology*, 89, 1989, 499-517.

[3] J.H. Pejtersen, H. Feveile, K.B. Christensen, and H. Burr, Sickness absence associated with shared and open-plan offices - a national cross sectional questionnaire survey, *Scandinavian Journal of Work and Environmental Health*, 2011, 37, 376-382.

[4] H. Jahncke, S. Hygge, N. Halin, A.M. Green, and K. Dimberg, Open plan office noise: Cognitive performance and restoration. *Journal of Environmental Psychology*, 31, 2011, 373-382.

[5] E. De Croon, J. Sluiter, P. Kuijer, M. Frings-Dresen, The effect of office concepts on worker health and performance: a systematic review of the literature, *Ergonomics*, 48, 2005, 119-134.

[6] G.W. Evans and D. Johnstone, Stress and open office noise, *Journal of Applied Psychology*, 2000, 85, 779-783.

[7] J. Kristiansen, L. Mathiesen, P.K. Nielsen, Å.M. Hansen, H. Shibuya, H.M. Petersen, S.P. Lund, J. Skotte, M.B. Jørgensen MB, and K. Søgaard 2009. Stress reactions to cognitively demanding tasks and open-plan office noise. *International Archives of Occupational and Environmental Health*, 82, 2009, 631-641.

[8] T. Witterseh, D.P. Wyon, and G. Clausen. The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work. *Indoor Air*, 14(suppl. 8), 2004, 30-40.

[9] I.H. Robertson, T. Manly, J. Andrade, B.T. Baddeley, And J. Yiend, Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects, *Neuropsychologia*, 35, 1997, 747-758.

[10] T. Manly, I.H. Robertson, M. Galloway, K. Hawkins, The absent mind: further investigations of sustained attention to response, *Neuropsychologia*, 37, 1999, 661-670.

[11] A.M. Owen, K.M. McMillan, A.R. Laird, and E.Bullmore, N-back working memory paradigm: a meta-analysis of normative functional neuroimaging studies, *Human Brain Mapping*, 25, 2005, 46 –59.