# Restoration at work: effects of different sound exposures

H. Jahncke

The University of Gävle, Faculty of Engineering and Sustainable Development, S-801 76 Gävle, Sweden, helena.jahncke@hig.se

## INTRODUCTION

Open-plan offices are increasingly more common as work-environments for employees. There are, however, concerns about the effects of noise on cognitive performance and health in these office-designs (see reviews by Navai & Veitch 2003; Oommen et al. 2008; Rashid & Zimring 2008). There are also studies indicating that noise (such as irrelevant speech) decreases performance (e.g. Haka et al. 2009; Schlittmeier et al. 2008; Sörqvist et al. 2009), and enhance stress (Evans & Johnson 2000).

There are good reasons to expect that the impacts of noise in an open-plan office vary not only with the types of noise and the layout of the office, but also with characteristics of persons exposed to noise. One such variable is their degree of hearing impairment. In Sweden more than 10 % of the population has some hearing impairment and among them more than half are in working age (HRF 2008). However, no studies to the author´s knowledge, have systematically addressed how hearing impaired persons' cognition is affected by open-plan office noise.

If office noise has a negative effect on both hearing impaired and normal hearing persons, one important task is to find ways to attenuate the negative outcomes. However, research on restorative environments has so far paid little attention to how environmental sounds might affect restorative processes (Alvarsson et al. 2010). Studies of restoration have mainly shown that nature environments are restorative to be in or to look at when cognitively fatigued (e.g. Berto 2005; Hartig et al. 1996). These studies focused on the *visual* perception of the environment and not on the *sound* conditions per se. There are, however, some results indicating faster and more complete restoration (according to both performance and physiological measures) for participants exposed to nature movies with environmental sounds, in comparison to those exposed to other environments including sounds (Laumann et al. 2001, 2003; Ulrich et al. 1991). Some studies have also shown a restorative advantage of natural versus urban settings in field conditions that included the sounds typical of each type of environment (Berman et al. 2008; Hartig et al. 1991, 2003).

Khalfa et al. (2003) have also shown the restorative effects of positive sounds only. They compared recovery from sitting in silence with listening to soft music, and found that music promoted faster decline in salivary cortisol, measured after 15 minutes into the relaxation period. However, no studies (to the author's knowledge) have investigated whether positive nature sounds by themselves can promote restoration and ensuing cognitive performance.

The aim of our first study (A) was to investigate how noise in open-plan offices affects cognitive performance and acute stress, and whether it is possible to promote cognitive restoration with exposure to pleasant sounds and film-clips of pleasant nature environments (during a 7 minutes break) after having been exposed to aversive sounds. I.e. we hypothesized more precisely the following expected order of restorativeness: a nature movie with nature sounds (positive stimuli for two senses), just nature sounds (positive stimuli for one sense), silence (no stimuli) and noise (negative stimuli).

In the second study (B) we also examined whether these effects differ between hearing impaired and normal hearing persons and investigated the restorative effects of a longer (14 minutes) break.

Due to lack of space, only the effects of the restorative break on performance and stress will be presented here (i.e. not the effects of noise during the work period).

METHODS – EXPERIMENT A

## Design and participants

We designed an experiment with two acoustic environments (low noise, high noise) varied within subjects and four restorative conditions (nature movie, nature sound, silence, noise) manipulated between subjects.

The participants were 47 normal hearing and normal seeing persons recruited from the University of Gävle (27 female; mean age = 26). Participants were randomly assigned to conditions and participation in all the three sessions was compensated with 990 Swedish crowns.

## Research setting and noise conditions

The research was carried out in an office laboratory (63 $m^2$) at the University of Gävle. The eight workstations were separated with 1.43 meters high screens and each cubicle was 1.24 meters wide.

The noise used in the experiment was recorded in four positions in a real open-plan office in Sweden. From the multi-channel recordings one hour of office noise was extracted and edited and reproduced in the test room by eight loudspeakers, two at each wall, and one subwoofer. Two noise conditions were designed, one with high- and one with low noise level. In the high noise condition, additional phone and sound signals were added to the office noise. The noise was reproduced with an equivalent A-weighted sound pressure level ($L_{Aeq}$) of 51 dBA in the room. In the low noise condition the office noise, including the additional phone and sound signals, was low pass filtered which reduced $L_{Aeq}$ in the room by 12 dBA to 39 dBA.

## Restoration conditions

After two hours of work in office noise the participants went through a restoration period for seven minutes at their desk with headphones on. There were four different restorative conditions: see movie clips of rivers and hear river sounds, listen to the river sounds without movie clips, sit in silence, or continue to listen to the office noise from the high noise condition.

## Measures

We used several different cognitive tasks to measure the effects of noise and cognitive fatigue/restoration (see Figure 1 for an overview of the tasks and their order). Perceived tiredness and motivation were measured with a questionnaire (SOFI) developed by Åhsberg et al. (1995). The measures of the participants stress hormone levels were obtained through urine (catecholamines) and saliva (cortisol) samples. All measures used in Experiment A are further described in Jahncke et al. (2011a, b).

| Section 1 | Premeasures and Relaxation | | | | Noise treatment | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Urine sample | Saliva sample | Relax | Saliva sample | SOFI [a] | Cognitive tasks [b] | Filler tasks [c] | Cognitive tasks [d] | Saliva sample | SOFI | Filler tasks |
| Section 2 | Restoration treatment | After measures | | | | | | | | | |
| | Movie, River sound, Silence, or Noise | Saliva sample | SOFI | Cognitive tasks [d] | Saliva sample | Urine sample | | | | | |

Time →

[a] Swedish Occupational Fatigue Inventory. [b] The order of the cognitive tasks was as follows: Sustained Attention to Response Test (SART), Proactive interference (PI), Flanker, Reading span, Serial recall – letters, Updating, Operation span, Logical problems, Reading comprehension, Serial recall – numbers, Shifting. It took circa 110 min to complete the tasks. [c] The filler tasks were included to make all participants begin the next phase at the same time.[d] The order of the cognitive tasks at *Postwork* and *Postrest* was as follows: Sustained Attention to Response Test (SART), Proactive interference (PI). It took about 10 min to complete these tasks.

**Figure 1:** Overview of the procedure for one experimental session

## Procedure

Data collection took place at a simulated office at the University of Gävle, Tuesdays and Wednesdays between two and five p.m. Before the two experimental sessions, participants went through a practice session for one hour, several days in advance, to help reduce possible training effects on the cognitive tasks. The experimental session procedure is presented in Figure 1. The whole procedure took about three hours to complete and seven to eight participants were tested at each occasion.

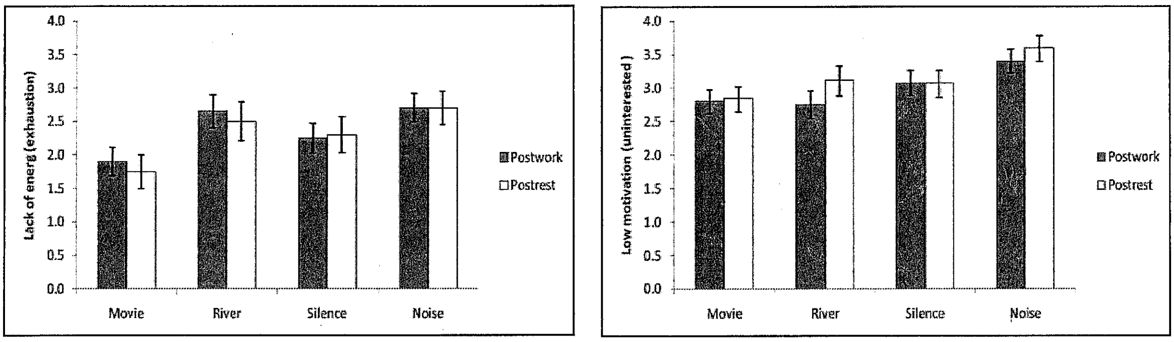
### Statistical analyses

A General linear model with repeated measures (mixed) design was used for the analysis of fatigue and restoration effects. When Mauchly's test indicated non-sphericity in the variance-covariance matrix for the within-subject analyses the Greenhouse-Geisser adjusted degrees of freedom and resulting *F*-tests are reported.

## RESULTS – EXPERIMENT A

### Effects of restoration on self ratings of fatigue

When comparing the self-rating scores (SOFI) from Postwork (before the restoration period) to Postrest (after restoration), the analysis revealed a significant between-subjects effect of restorative conditions on change in the ratings of lack of energy (exhaustion), $F(3, 29) = 3.10$, $p<0.05$, *partial* $\eta^2 = 0.24$; and of lack of motivation (uninterested) $F(3, 29) = 3.02$, $p<0.05$, *partial* $\eta^2 = 0.24$. Decomposition of this effect using simple effects analysis (LSD) demonstrated that the participants who saw the movie (including river sounds) rated themselves as *having more energy* (i.e., were less exhausted) in comparison with the participants listening to noise ($p<0.01$) and those listening to river sounds ($p<0.05$). The participants who listened to noise during the restoration period rated themselves as being *less motivated* (i.e., more uninterested) in comparison with the participants who listened to river sounds ($p<0.05$) or saw the movie ($p<0.01$), see Figure 2a and b. The post hoc analysis also demonstrated a marginal difference in *tiredness* (yawning) between the movie condition and the noise condition ($p=0.055$) and between the movie and river sound conditions ($p=0.052$). The results further indicated that the participants who heard river sounds or office noise during the restoration period rated their overall experience more negatively than the participants in the other two restoration conditions. These results support our main hypothesis by indicating that the sound conditions may promote different restorative experiences. No statistically significant effects from the restoration period were detected on the cognitive or physiological measures (all *Fs*<1).




Note: The scales ranged from 1 = not at all to 4 = a lot.

**Figure 2:** Self-ratings of **(a)** lack of energy (exhaustion) **(b)** low motivation (uninterested) before and after 7 minutes of rest in each restorative condition. Error bars are the standard errors of the mean.

METHODS – EXPERIMENT B

The research setting, procedure and design were the same in Experiment B as in Experiment A, except the inclusion of hearing status (hearing impaired, normal hearing) as between-subjects factors and that one more urine sample was added in the middle of the session. The measures used in Experiment B are further described in Jahncke et al. (2011a, b).

### Participants

The participants who took part in the study consisted of 20 hearing impaired (female 9; median age = 53) and 18 normal hearing persons (female 8; median age = 48). The participants with hearing impairment were recruited from the Swedish association of hard of hearing people (HRF) and we only included those in the age span 20-65 years old (some participants were however retired), and excluded those who reported having severe tinnitus and/or Menières disease.

### Noise and restoration conditions

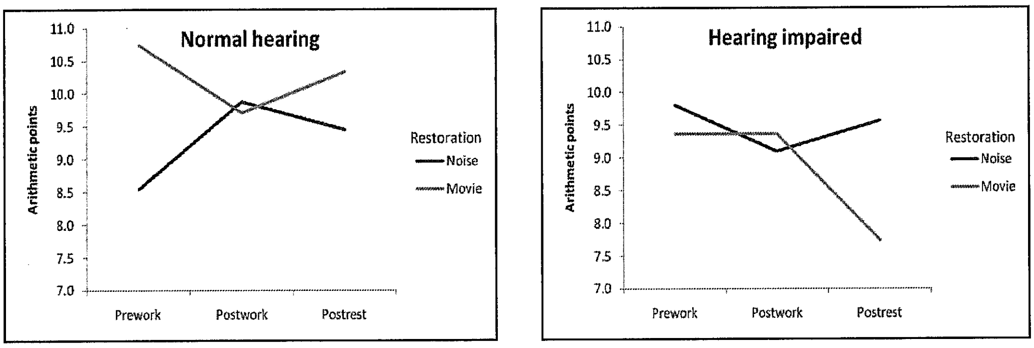
The same noise was reproduced as in Experiment A, however, now with a higher/lower equivalent A-weighted sound level (60 $L_{Aeq}$ vs. 30 $L_{Aeq}$) in the room.

The participants also went through a longer restoration period in Experiment B (14 minutes) compared to Experiment A (7 minutes). Only two restorative conditions were included this time in *the high noise condition*: half of the participants saw a movie with clips of nature environments in quiet and half of the participants just listened to office noise. In *the low noise condition* all participants sat in quiet during the restorative period (included as a control condition).

## RESULTS – EXPERIMENT B

### Effects of restoration on cognitive performance

As a first step we analyzed arithmetic performance over time during both the low noise exposure condition - with quiet as restorative condition, and the high noise exposure condition - with movie and noise as restorative condition. The analysis with session order and hearing (2x2) as between subjects factors, and noise and time (2x3) as within-subjects factors revealed a significant interaction between noise x time x hearing, $F(2, 58) = 3.12$, $p<0.05$, *partial* $\eta^2 = 0.10$. Both the normal hearing and hearing impaired participants had declined performance from Prework to Postwork in both noise conditions. Thereafter the hearing impaired participants′ performance increased to Prerest after a break in quiet and decreased after a break with movie or noise. For the normal hearing the opposite pattern emerged with decreased performance after restoration in quiet and increased performance after restoration with movie or noise (see Figure 3a and b).




Note: The scales ranged from 0 – 16 pts of correct answers.

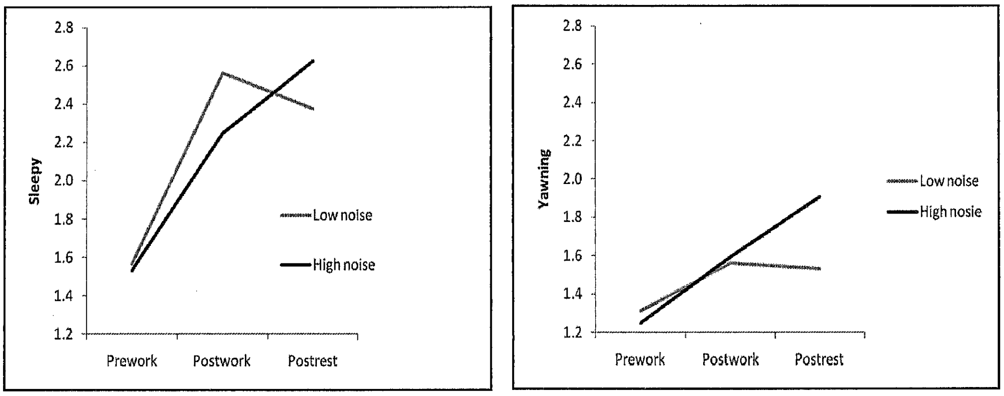
**Figure 3:** Arithmetic performance (points) for **(a)** the normal hearing and **(b)** the hearing impaired in high noise, with restoration during noise or with nature movie

As a second step we analyzed performance in the high noise condition only, to further explore the effects over time with restoration in noise or with a movie. The analysis with restorative condition, hearing and session order (2x2x2) as between-subjects factors and time (3) as within-subjects factor revealed a significant interaction between time x restoration x hearing on arithmetic performance (points), $F(2, 50) = 3.63$, $p<0.05$, *partial* $\eta^2 = 0.13$. Following our hypothesis, the normal hearing participants who had noise during their restoration period had declined performance from Postwork to Postrest and those who watched the nature movie had improved performance over the same time points. However, the hearing impaired showed the opposite pattern. A further analysis to check that the interaction derives from the change from Postwork to Postrest (and not from Prework to Postwork) showed that the interaction between time x restoration x hearing was still significant when only considering performance before and after the restoration period, $F(1, 25) = 7.50$, $p< 0.01$, *partial* $\eta^2 = 0.23$. An analysis conducted on the normal hearing only revealed a tendency of interaction between Time x Restoration, $F(2, 26) =$, $p = 0.076$, *partial* $\eta^2 = 0.18$, indicating that the effect of restoration tend to be prominent even if hearing is not considered. According to arithmetic performance our hypothesis of restoration seems to hold for normal hearing only.

The analysis of the other performance task (Sustained attention to response task; SART) revealed no effects of the restorative conditions (*F*s<1). The participants had few errors in this task which might indicate a ceiling effect.

## Effects of restoration on self ratings of fatigue

The analysis with hearing and session order (2x2) as between-subjects factors and noise and time (2x3) as within-subjects factor revealed an interaction between time x noise on the amount of yawning, $F(2, 48) = 3.92$, $p<0.05$, *partial* $\eta^2 = 0.14$; and a tendency to an interaction on sleepiness, $F(2.48) = 2.80$, $p=0.07$, *partial* $\eta^2 = 0.10$. The feelings of fatigue first increased from Prework to Postwork in both noise exposure conditions. Thereafter it was a decrease of fatigue to Postrest in the low noise condition (with restoration in quiet). The decrease of fatigue in quiet follows our hypothesis. However, in the high noise condition it was an increase of fatigue to Postrest, with the two restorative conditions of noise and nature movie considered as one restorative condition (see Figure 4a and b). A further analysis of only the restorative conditions in the high noise condition (i.e. movie vs. noise) did not reveal any significant effects (*F*s<1). Accordingly, no support was found for a nature movie to be more restorative than continued noise exposure in the subjective ratings. Though, after low noise exposure the silent condition promoted restoration in an efficient way.




Note: The scales ranged from 1 = not at all to 4 = a lot. Restorative conditions: Low noise = quiet, High noise = nature movie or noise

**Figure 4:** Self-ratings of **(a)** yawning and **(b)** sleepiness at Prework, Postwork and Postrest in high and low noise

The analyses of self ratings of motivation with hearing and session order (2x2) as between subjects factors noise and time (2x3) as within-subjects factors, revealed a significant interaction between time x noise x hearing on motivation (passiveness), $F(2, 48) = 3.04$, $p = 0.057$, *partial* $\eta^2 = 0.11$. Motivation decreased over time in both noise exposure conditions (i.e. high- and low noise), for the both hearing groups. Thereafter motivation decreased more for the normal hearing participants when they were in the low noise exposure condition (with restoration in quiet), compared to the high noise exposure condition (with restoration in noise or movie; i.e. in this analysis seen as one condition). The opposite pattern emerged, however, for the hearing impaired. Their motivation decreased more during restoration with noise and movie, compared to restoration in quiet. A further analysis of the restorative conditions in the high noise exposure condition only (i.e. movie vs. noise) did not reveal any significant effects (*F*s<1).

**Effects of restoration on acute stress**

No effect of restoration was found on the urinary catecholamines and salivary cortisol (All *F*s<1).

## CONCLUSION

So far, many environments have just been studied according to their visual value for restoration. The present study starts to address the gap in knowledge concerning the effects of the aural environment on the depletion and restoration of adaptive resources. The results from Experiment A showed that the participants who saw a nature movie (including river sounds) during the seven minutes break, rated themselves as having more energy after the restoration period, in comparison with both the participants who listened to noise and river sounds. Remaining in office noise during the restoration phase also affected motivation more negatively, than listening to river sounds or watching the nature movie. The stress hormones and cognitive performance were, however, not affected by the restorative conditions.

The results from Experiment B showed that a quiet break for 14 minutes was the most beneficial for the hearing impaired participants′ performance after noise exposure, while a break with other stimuli (nature movie) was most beneficial for the performance of the normal hearing persons. The normal hearing individuals also showed declined performance after a break with office noise. However, the quiet condition was the only condition which reduced self-rated fatigue for both hearing status groups.

This kind of multi-modal restoration also needs to be addressed in a larger context than at work. Looking at a combination of senses might indicate that a nature environment such as a noisy park might restrict restoration while a quiet park environment, where only nature sounds are heard, might promote restoration. When comparing different environments, it might also turn out that a calm café with soft music in a noisy urban environment might be more restorative than going to a crowded and noisy park, which would contrast with earlier results. The noise-level increments at workplaces and in urban areas demand compensatory strategies that include access to restorative environments. These are health issues that need to be further addressed.

## ACKNOWLEDGEMENTS

This project was funded by AFA Insurance and the University of Gävle and I would like to thank my supervisor Professor Staffan Hygge and the project assistant Niklas Halin for help in conducting these studies; and Ecophon and S-line office for the donation to the office setting.

## REFERENCES

Åhsberg E, Gamberale F, Kjellberg A (1995). Upplevd trötthetskvalitet vid olika arbetsuppgifter. Utveckling av ett mätinstrument [Perceived fatigue quality during different work tasks. Development of a measure]. Solna: Arbetslivsinstitutet.

Alvarsson JJ, Wien S, Nilsson ME (2010). Stress recovery during exposure to nature sound and environmental noise. Int J Environ Res Public Health 7*:* 1036-1046.

Berman MG, Jonides J, Kaplan S (2008). The cognitive benefits of interacting with nature. Psychol Sci 19: 1207-1212.

Berto R (2005). Exposure to restorative environments helps restore attentional capacity. Journal of Environmental Psychology, 25, 249–259.

Evans G W, Johnson D (2000). Stress and open-office noise. J Appl Psychol 85: 779-783.

Haka M, Haapakangas A, Keränen J et al. (2009). Performance effects and subjective disturbance of speech in acoustically different office types - a laboratory experiment. Indoor Air 19: 454-467.

Hartig T, Mang M, Evans GW (1991). Restorative effects of natural environment experiences. Environ Behav 23: 3-26.

Hartig T, Böök A, Garvill J et al. (1996). Environmental influences on psychological restoration. Scand J Psychol 37: 378-393.

Hartig T, Evans GW, Jamner LD et al. (2003). Tracking restoration in natural and urban field settings. J Environ Psychol 23: 109-123.

HRF – the Swedish Association of Hard of Hearing People (2008). HRF: s årsrapport 2008: Adjö yxskaft (eng: HRF's annual report 2008) (http://www.hrf.se). Stockholm, Sweden.

Jahncke H, Halin N, Hygge S (2011a). Performance, fatigue and stress in open-plan offices: the effects of noise and restoration on hearing impaired and normal hearing individuals. Manuscript, submitted.

Jahncke H, Hygge S, Halin N et al. (2011b). Open-plan office noise: cognitive performance and restoration. Manuscript, submitted.

Khalfa S, Bella SD, Roy M et al. (2003). Effects of relaxing music on salivary cortisol level after psychological stress. Ann N Y Acad Sci 999: 374-376.

Laumann K, Gärling T, Stormark KM (2001). Rating scale measures of restorative components of environments. J Environ Psychol 21: 31-44.

Laumann K, Gärling T, Stormark KM (2003). Selective attention and heart rate responses to natural and urban environments. J Environ Psychol 23: 125-134.

Navai M, Veitch JA (2003). Acoustic satisfaction in open-plan offices: review and recommendations (IRC-RR-151). National Research Council Canada: Institute for Research in Construction.

Oommen VGO, Knowles MK, Zhao IZ (2008). Should health service managers embrace open plan work environments? A review. Asia Pacific J Health Manag 3: 37-43.

Rashid M, Zimring C (2008). A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings: problems and prospects of sharing evidence. Environ Behav 40: 151-190.

Schlittmeier S, Hellbrück J, Thaden R et al. (2008). The impact of background speech varying in intelligibility: effects on cognitive performance and perceived disturbance. Ergonomics 51: 719-736.

Sörqvist P, Halin N, Hygge S (2009). Individual differences in susceptibility to the effects of speech on reading comprehension. Appl Cogn Psychol 24: 67–76.

Ulrich RS, Simons RF, Losito BD et al. (1991). Stress recovery during exposure to natural and urban environments. J Environ Psychol 11: 201-230.