Performance, psychological, and physiological effects of office noise

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ABSTRACT

Speech is a common disturbance in offices. Irrelevant speech influences performance and subjective estimations. However, not many studies have examined simultaneously the consequences of irrelevant speech on humans regarding physiological, performance, and psychological aspects. All these aspects were examined in this study. The influence of irrelevant speech (65dB) compared to silence (35dB) was examined in a between-group laboratory experiment. Twenty-one subjects participated in the speech group and 19 subjects in the silence group. Sound conditions lasted for 50 minutes. Participants' performance, subjective experience, and various physiological stress measures (e.g., stress hormone level from plasma, and heart rate variability) were examined. Compared to the silence group, the speech group had lower performance and higher physiological stress level. Working during speech was rated to be more annoying and increasing workload, but less tiring than silence. Therefore, the influence of irrelevant speech should be minimized in offices, where work requiring concentration is needed.

INTRODUCTION

Noise and lack of privacy are the two most important disturbances in open-plan offices (Kim & de Dear, 2013). Irrelevant speech is one of the most disturbing type of noise in the office setting (Kaarlela-Tuomaala et al., 2009). It also influences cognitive work performance (Haapakangas et al., 2020). Working under office noise can make people to exert, i.e., to put more effort into their task to keep the performance level as high as without the noise. Both noise and exertion can cause stress. Stress can be seen in psychological and physiological consequences. Evans and Johnson (2000) found that working during office noise containing also speech caused higher adrenaline levels than working during silence. However, they found no difference in typing performance nor in cortisol and noradrenaline levels, but after office noise condition people tried to solve less puzzles and made less postural adjustments to their office furniture (Evans & Johnson, 2000). Another study examining the influence of office noise found effects on memory of words, feelings of tiredness and lack of motivation but no effects on other performance measures or cortisol or norepinephrine levels (Jahncke et al., 2011).

Speech has been identified more disturbing for performance than other noise types (Szalma & Hancock, 2011). However, not many studies have examined how working under speech influences performance, psychological experience, and physiological stress reaction.

The purpose of this study was to compare psychological experiences, cognitive performance, and physiological responses in two sound conditions: speech and silence. We expect that speech increases stress level, reduces performance, and increases negative subjective ratings compared to silence.

Detailed results are presented in wider perspective by Radun et al. (2020).

METHODS

Participants

Forty people participated the study (22 females, age mean 25 years, min. 19 years, max. 37 years). All participants had normal hearing. All participants gave an informed consent before participating the study. The ethics committee of Hospital District of Southwest Finland approved the study (ETMK Dnro 20/1801/2018).

Sound conditions

There were two sound conditions: silence and speech. Silence was wideband noise presented at sound pressure level 35 dB L_{Aeq}. The condition corresponds to typical ventilation sound in open-plan offices. Speech was a radio dialogue at 65 dB L_{Aeq}. Both silence and speech had a one-third-octave spectrum that was interpolated from the standardized human speech spectrum (ISO, 2012).

Participants division into sound conditions

Participants were divided into two experimental groups (two sound conditions) according to their gender and noise sensitivity score, which was asked when they registered themselves as volunteers. Approximately equal distributions were the goal. Noise sensitivity was measured with Weinstein's noise sensitivity scale (Weinstein, 1978). Total number of participants was 19 in silence and 21 in speech.

Measures

Psychological measures

After each task, the participants rated how much background sound irritated, bothered, or annoyed them (*annoyance*) and how demanding or loading performing the tasks was (*workload*). The scale for both questions was from 0 "Not at all" to 10 "Extremely". The perceived fatigue was measured using Swedish Occupational Fatigue Inventory (SOFI), which gave three scales: tiredness, lack of energy, and lack of motivation (Åhsberg & Gamberale, 1998).

Performance measures

N-back is a working memory task, where the participant responses whether the current stimulus is the same as n stimuli back as fast and as accurately as possible. Four difficulty levels were used n = 0, 1, 2, and 3. Each time, 30+n repetitions of each difficulty level were performed.

Serial recall tasks are also working memory tasks examining how well the participants can keep a list of numbers in their mind. Digits from 1-9 were presented one by one in a random order and participants were asked to write the correct order 10 seconds after the last digit was presented. 11 series were used. Two variations of the task were used: visual serial recall, where the numbers were presented visually on the display and auditory serial recall, where the participants heard the numbers from headphones.

Physiological measures

The physiological measures used were stress hormone concentration (cortisol and noradrenaline) determined from plasma, and heart rate variability (HRV) measured with a heart rate monitor around participants' chest. Plasma was taken from the peripheral venous access catheter that was placed in participants' arm in the beginning of the experiment. For HRV, the Low frequency/high frequency (LF/HF) relation was determined for periods of each cognitive task separately (visual serial recall, auditory serial recall, and N-back). LF refers to heart rate variability on frequencies 0.04-0.15 Hz and HF to frequencies 0.15-0.4 Hz. Larger LF/HF values mean greater sympathetic nervous system activity, which means more stress.

Procedure

Procedure is described in Figure 1. Silence (35 dB ventilation sound) was present in the room in every phase except in the experimental phase where the actual sound condition (silence or speech) was presented.

The experiment started at 11.45 each day and lasted on average for 3 h 19 min. Afternoon was chosen because diurnal variation in cortisol concentration is the largest in the morning. The experiment consisted of preparation, practice, baseline, experimental, and restoration phases. In the preparation phase, first the heart monitor and then the catheter were put on and hearing was tested. In the practice phase, all tasks were explained and rehearsed. The baseline phase and experimental phase involved the same cognitive tasks (visual serial recall, auditory serial recall, and N-back), and subjective estimations. The experimental sound was presented only in the experimental phase. In the restoration phase, participants filled questionnaires (personality and final questionnaire) with the silence in the background. The results from these two last questionnaires are not be reported in this article.

The blood samples were taken 6 times during the experiment. Psychological estimations related to sound were estimated several times during the experiment. *Annoyance* and *workload* were estimated after each task in baseline and experimental phases (8 times) and SOFI was filled each time after in the end of each sound condition (2 times).

Preparation phase 30 min	
Practice phase 25 min	
Baseline phase	Visual serial recall N-back
50 min	Auditory serial recall N-back
10 min	Break
Experimental phase	Visual serial recall N-back
50 min	Auditory serial recall N-back
Restoration phase 20 min	
Whole experiment: 3 h 20 min	

Figure 1. The procedure of the experiment. The red lines denote the blood samples. Questionnaires were filled after each task in the baseline and experimental phases. The gray area denotes the time the experimental sound was on (speech or silence).

Statistical analysis

To reduce the influence of individual differences, the difference between experimental phase and baseline phase was estimated for the psychological and most physiological measures (experimental phase – baseline phase). However, cortisol concentration showed the expected diurnal changes in cortisol levels, but also there seemed to be large differences in the baseline phase possibly due to excitement. Therefore, with cortisol we used the restoration phase measurement as the reference (experimental phase - restoration phase). In addition, the performance measures showed more variation in performance in the baseline phase than in the experimental phase possibly due to excitement of the experiment as well as learning the tasks. Therefore, we examined the performance measures with a direct between groups comparison without comparing them to baseline performance.

The groups were compared with each other using mixed measures analysis of variance, if the experimental phase had more than one observation on that variable. In those cases, time was the within-subject variable, sound condition was the between-subject variable and noise sensitivity was the covariate. If there was just one observation on that certain variable from the experimental phase, then univariate analysis of variance was used with sound condition as the between-subject variable and noise sensitivity as the covariate. From the performance measures of N-back task, only 3-back is reported here, since it was the only that filled the requirements of repeated measures analysis of variance. Greenhouse-Geisser correction was used, if the sphericity assumptions were not filled (interaction in auditory, and visual serial recall).

RESULTS

Speech was rated to be more annoying (F(1,37)=33.0, *p*<0.001) and workload was rated to be larger (*F*(1,36)=8.6, *p*=0.006) than silence (Figures 2 and 3). Unexpectedly, tiredness was larger during silence than speech (*F*(1,37)=10.0, *p*=0.003) (Figure 4). There was no difference between *sound conditions* regarding the lack of energy (*F*(1,37)=0.1, *p*=0.7) or lack of motivation (*F*(1,37)=1.3, *p*=0.2).

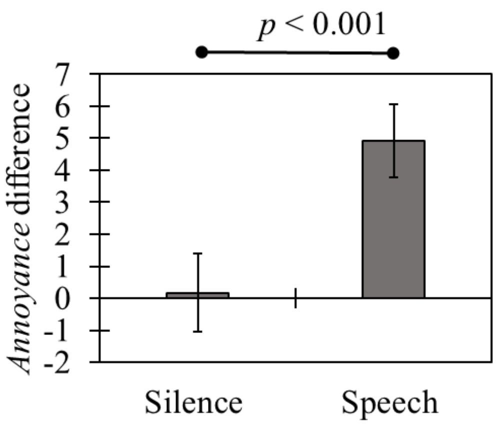

Figure 2. Annoyance difference compared to baseline phase in the studied sound conditions.

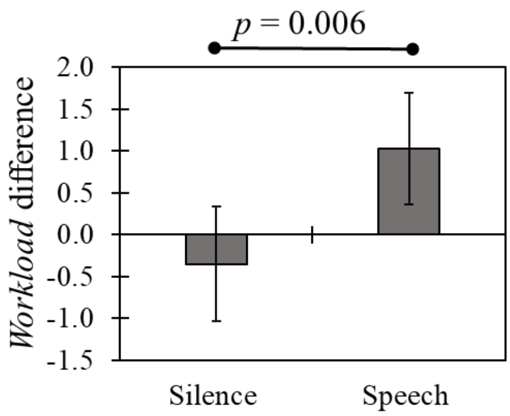

Figure 3. Workload difference compared to baseline phase in the studied sound conditions.

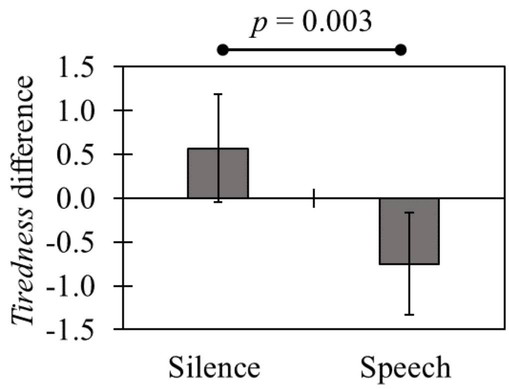

Figure 4. Tiredness difference compared to baseline phase in two studied sound conditions.

The performance accuracy was lower in 3-back task during speech than silence (*F*(1,37)=5.1, *p*=0.029) (Figure 5). In addition, in auditory serial recall task, the last numbers in the serial were more difficult to remember during speech than silence (*F*(4,152)=5.2, *p*=0.001) (Figure 6). In visual serial recall, there was no similar effect (*F*(5,170)=1.4, *p*=0.2).

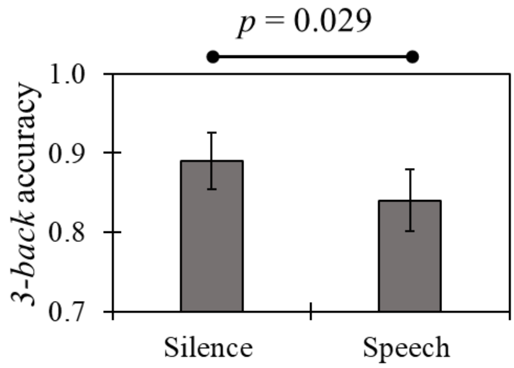

Figure 5. Average accuracy in 3-back task in different sound conditions.

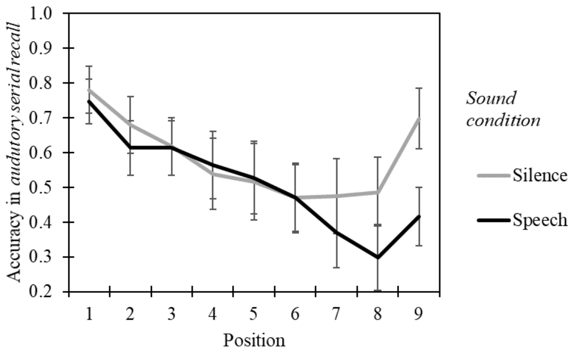

Figure 6. The accuracy in auditory serial recall task per digit's presentation position in a serial in different sound conditions.

The difference in cortisol levels between restoration and experimental phase was higher in speech than silence ($F(1,27)=4.3$, $p=0.048$). This indicates that physiological stress is higher during speech than silence.

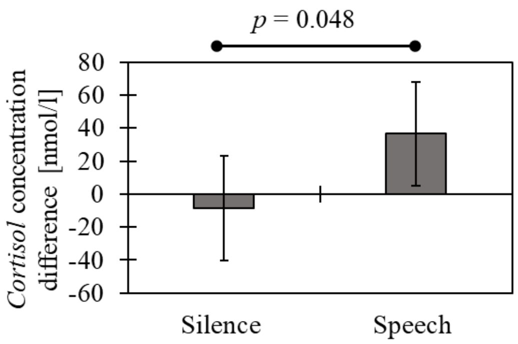

Figure 7. Cortisol concentration difference compared to restoration phase in different sound conditions.

Two physiological measures, noradrenaline and HRV, showed different interaction depending on the *sound condition* in relation to time. With time, noradrenaline level in the silence increased, while it stayed steady in the speech ($F(1,29)=7{,}8$, $p=0.009$) (Figure 8). This indicates that stress increased with time during silence and not during speech. N-back was the only task that was done twice during the experimental phase, which enables the examination of time in HRV. From first to second N-back tasks, HRV increased during speech, while the value stayed the same during silence ($F(1,35)=6{,}2$, $p=0.018$) (Figure 9). This indicates that stress increased with time during speech.

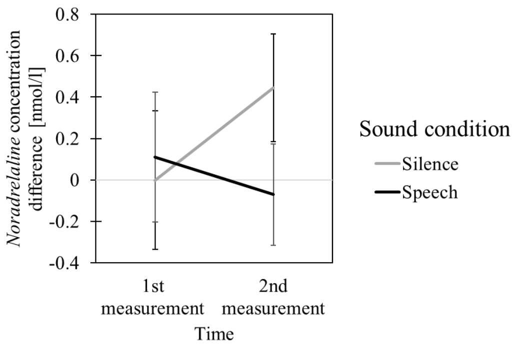

Figure 8. Noradrenaline concentration difference compared to baseline phase with time in different sound conditions.

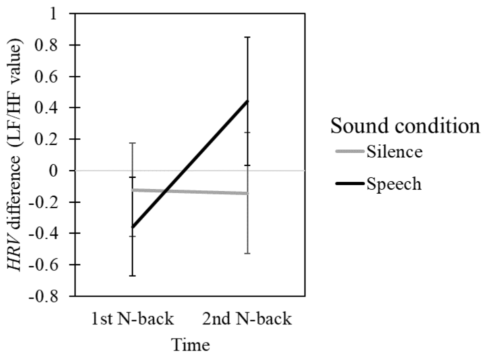

Figure 9. HRV LF/HF value difference compared to baseline phase for N-back tasks in different sound conditions.

DISCUSSION

An experimental study examining working during irrelevant speech and its influence on performance, psychological experience, and physiological stress measures was performed. This study shows that compared to silence irrelevant speech corresponding to the sound level of normal conversation was estimated to be more annoying and increasing workload, but also less tiring. Decreasing tiredness might be related to the energetic radio dialogue used as speech. During speech, remembering the last words in auditory serial recall task was harder and the accuracy of 3-back task was lower than during silence. The decrease in performance due to speech is in line with other research (Szalma & Hancock, 2011). Absence of the effect of *sound condition* on performance in visual serial recall was unexpected, since numerous studies have found an effect of speech on performance during visual serial recall task (Haapakangas et al., 2020).

Speech increased cortisol levels. Previous research has found no effect of office noise on cortisol levels (Evans & Johnson, 2000; Jahncke & Halin, 2012). However, in their studies, the background sound was office noise that contained only some speech, while in our study, speech involved an entire radio program (continuous dialogue). In addition, the level of speech was higher in our study than in previous studies (Evans & Johnson, 2000) and (Jahncke et al., 2011), 55 and 51 dBA, respectively. Contrary to expectations, there was a statistically significant interaction in noradrenaline levels and time indicating that during silence stress increased with time, but not during speech. However, we interpret the effect to be so small that it is not physiologically significant. The stressfulness of speech with time can be seen in HRV, which level rises with time during speech but not during silence.

Working during irrelevant speech causes more stress than working during silence. With time, these effects can be harmful for employees' health and motivation. For these reasons, Finland has set new building regulations concerning e.g. the room acoustic target values in open-plan offices (Hongisto & Keränen, 2018), which one aim is to reduce the negative effects of irrelevant speech.

CONCLUSIONS

Irrelevant speech corresponding to the sound level of normal conversation is considered annoying and increasing workload, it decreases performance at least in tasks requiring cognitive working memory processing, and produces physiological stress reaction. For these reasons, special attention should be given for reducing speech noise in offices.

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