The Effects of Sound Interference on Soldiers Cognitive Performance, Workload Assessment and Emotional Responses

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Abstract. Twenty-three male soldiers were exposed to continuous (7 kHz sine wave), non-continuous (irregular 7 kHz sine wave) and no-sound conditions during performance of cognitive tasks on a tablet computer. Tasks were sustained attention to response (SART) task and Baddeley's 3 min reasoning task. Task performance, workload assessment (NASA-TLX) and emotional responses (pleasantness and arousal) were assessed after each sound-task condition. We expected that disturbing and task irrelevant background sound would interference concentration and cognitive function and therefore have detrimental effect on performance, workload assessment and emotional responses. We found no effects on cognitive performance. However, in connection with subjective assessments, (1) workload was significantly higher during non-continuous sound conditions as compared to continuous and no-sound conditions and (2) no-sound conditions were experienced more pleasant and less arousing than the sound conditions. The results are of interest when considering working in noisy environments, as well as cognitive resilience to interference.

Keywords: Cognition · Distraction · Workload · Emotional responses

1 Introduction

At the end of 2016, U.S. Embassy workers in Havana, reported suffering from symptoms such as hearing loss, nausea and dizziness, which were thought to have come from the use of some sonic weapon or sound interference against the embassy. The investigations did not found evidence of sonic weapon and concluded that the symptoms might have been associated with the locusts chirping (typically at 7 kHz) or alternatively fumigation to stop the spread of the Zika virus prominent around that time [1, 2]. Whether the symptoms were caused by fumigation, grasshoppers, or a sonic weapon, it is of importance to study the potential effects of sound interference on human performance to be able to mitigate potential harmful consequences. In addition to intentional interference, humans working environments have become more and more noisy thus potentially distracting

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concentration and performance. In the present study, we were interested in examining whether disturbing sounds affects soldiers cognitive performance.

Environmental noise has been found to disturb sleep [3] as well as increase stress and cardiovascular risk [4]. People can in some degree get used to noise. This is especially true for noise that is predictable and consistent. There is also some evidence that background sounds may impair cognitive performance even though the evidence is not uniform. For example, Smith [5] found that performance on semantic processing test was impaired by intermittent, unpredictable noise, but that the noise had no effect on the syntactic reasoning test. The study suggests that unpredictable noise is more harmful for cognitive processing than consistent noise.

Sonic weapon use sound to injure, incapacitate, or kill an opponent. They are often based on loudness of the sound as extremely high-power sound waves can disrupt or destroy the eardrums of a target and cause severe pain or disorientation [6]. However, extreme sound levels are easy to detect and hard to produce and therefore their use in the battlefield or in hybrid-warfare is often impractical and uneconomical. In order to interfere with adversaries without revealing oneself, one could use lower sound levels that resemble natural or environmental sounds such as traffic noise or sounds coming from technological devices such as computers.

In the present study we wanted to examine whether disturbing and task irrelevant background sound would interference attention and concentration and therefore have detrimental effect not only on cognitive performance (in terms of sustained attention to response and grammatical reasoning), but also on subjective responses (in terms of workload and emotion). We used consistent and non-consistent 7 kHz sound that resembled a "coil whine" sound coming from a computer. Coil whine refers to a sound that is related to undesirable noise emitted by an electronic component vibrating as power runs through an electrical cable. We expected that sounds would impair performance, increase workload assessment and negative emotional responses.

2 Method

2.1 Subjects and Materials

Twenty-three male soldiers aged 23–32 (M = 24.6) participated in the study. Their task was to carry out sustained attention to response tasks (SART; see [7]) and Baddeley' 3-min reasoning tasks (see [8]) on a tablet computer. They were told that they should perform as well as possible and that during the test they may or may not hear background sound. Sound condition consisted of 7 kHz continuous or non-continuous sine wave sound or no-sound at all. The sine wave sound was produced with an online tool (https://www.szynalski.com/tone-generator/) and recorded to a computer. The non-continuous version of sound was generated with professional sound editing software simply by randomly cutting 1–5 s pieces of the continuous sound.

Concerning the tests, SART is a test that requires participant's constant attention and measures the speed and accuracy of his/her responses to a GO and NoGO stimuli. In the test subjects were asked to press response button as quickly as possible whenever other than number 3 was presented in the screen (i.e. one of the numbers 1, 2, 4, 5, 6, 7, 8, 9; GO stimulus) and refrain from pressing the button in the existence of number 3 (NoGO stimulus). One round of the test took about 5 min and contained 225 stimuli, of which the proportion of NoGO stimuli was 25. The mean response time (GO stimulus) and number of errors in GO and NoGO stimuli was used to evaluate the level of performance.

The Baddeley 3-min reasoning tests consisted of 64 statements about the order of letters A and B that were presented in the screen either in order AB or BA (e.g., “B follows A”, “B is not following A”, “B precedes A” etc.). The participant’s task was to answer correctly as many questions as possible in the fixed 3-min period. The number of corrects answers was used as a measure of performance.

Subjective responses were assessed with the NASA Task Load Index (NASA-TLX; [9]) and verbal statements corresponding to the 2-dimensional pleasantness and arousal model of emotion (see e.g., [10]). NASA-TLX consisted of multiple-choice questions about the mental, physical, and temporal demands of the task as well as the overall performance, effort and frustration level. Each dimension was rated on a scale of 1 (very low) to 20 (very high). The sum of the ratings was used as a workload measure.

Emotional responses were assessed with multiple-choice questions about the pleasantness (e.g., extremely unhappy and disappointed vs. extremely happy and satisfied) and arousal (e.g., extremely calm and sleepy vs. extremely energetic and aroused). Both dimensions were rated on a scale of 1 (very untrue for me) to 20 (very true for me).

2.2 Procedure and Data-Analysis

After a brief introduction of the experiment, the participants were seated in a lecture hall separately and with a 2 m distance of each other. After filling consent form, they were given the tablets and headphones and instructed about the course of the experiment. The experiment run automatically first through 3 task conditions in different and counterbalanced order for each participant for the SART task (i.e., SART with no-sound, with continuous sound and with non-continuous sound) and then through 3 task conditions in different and counterbalanced order for each participant for the Baddeley 3-min reasoning task (i.e., with no-sound, with continuous sound and with non-continuous sound). After each task, participants filled in the NASA-TLX and emotion questionnaire (also presented in the tablet). After finishing all tasks, participants were told to stay still and quietly until all participants had finished their tasks. The experiment took about 40 min in total.

The stimuli were presented in the center of the screen of Panasonic FZ-G1L2114T3 tablet using Inquisit stimuli presentation software (millisecond.com). Audio was adjusted to moderate level of 5 (about 60 dB - 70 dB SPL) in the tablet for all participants and presented through Logitech H390 USB headphones.

Given the quite low number of participants, the analyses was performed using Friedman's nonparametric analysis of variance in SPSS statistical software package with SART reaction time, SART error rate, Baddeley score, NASA-TLX score and emotional pleasantness and arousal ratings for each sound condition, each in turn, as test parameters.

3 Results

We found no statistically significant differences between the sound conditions for the cognitive performance test parameters (SART reaction times, SART error rates or Baddeley scores). In other words, soldiers were not distracted by the sound and were able to maintain steady performance level in all conditions.

However, the same was not true for the subjective assessments. The analysis revealed a significant main effect for the sound condition in predicting SART workload (NASA-TLX) score, F (2, 23) = 8, 44, p = .015. As illustrated in the Fig. 1. SART test elicited higher workload score during non-continuous sound (M = 61,04) as compared to continuous (M = 57,87) or no-sound (M = 57,43) conditions.

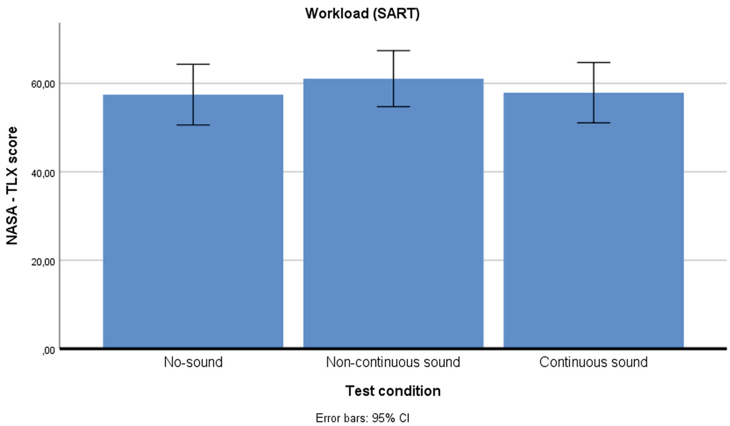

Fig. 1. Workload assessment score for SART test during no-sound, non-continuous sound and continuous sound test condition.

Analysis revealed also a significant main effect for sound condition in predicting pleasantness ratings for SART test, F (2, 23) = 10,02, p = .007. As illustrated in the Fig. 2, no-sound condition elicited higher pleasantness ratings (M = 11,7) than non-continuous (M = 10,09) and continuous sound conditions (M = 10,09).

Fig. 2. Pleasantness ratings for SART test during no-sound, non-continuous sound and continuous sound test condition.

In connection with emotional arousal, as illustrated in Fig. 3, sound conditions (non-continuous and continuous sound) elicited higher arousal ratings (M = 10,89) than no-sound condition (M = 9,83) for Baddeley reasoning test, F(1, 23) = 178,00, p = .029.

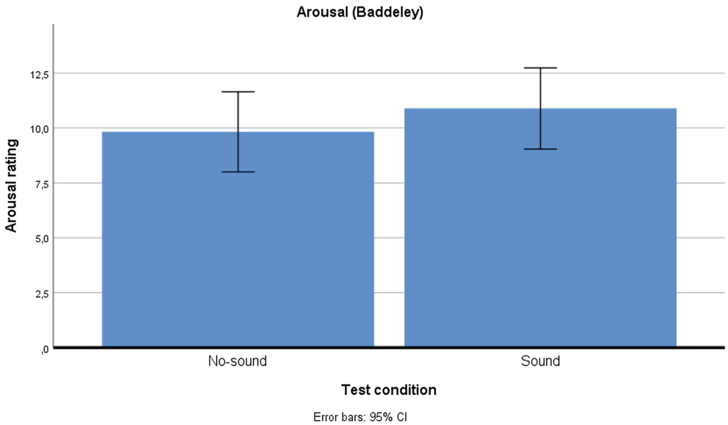

Fig. 3. Arousal ratings for Baddeley reasoning test during no-sound and sound test conditions.

4 Discussion

In the present study, we examined the effects of sound interference on soldier cognitive performance, workload assessment and emotional responses. We expected that disturbing and task irrelevant background sounds would reserve some attentional and information processing resources out of the resources allocated to primary task and therefore increase workload and impede task performance. We also expected that soldiers would prefer no-sound condition to sound conditions to be able to perform better in cognitive tasks.

Our expectations were only partially supported. As expected, sound conditions as compared to no-sound condition elicited higher workload assessment and less pleasantness in soldiers during cognitive tasks. However, soldiers were nevertheless able to perform equally well in cognitive tests during disturbing sound as during without the sound. There are several plausible explanations. First of all, soldier are well trained to operate and perform under stress conditions and given also that the tests were quite short, it is likely that their performance got only marginally affected. Given also that the sound stimuli was irrelevant and in different modality than the actual cognitive tasks, they may have been able to mobilize and focus their attentional resources well to the task and block out the distracting information. The effects might have been different if meaningful sounds, such as speech would have been used as a distractor. In further studies, it would be interesting to compare different sources and types of sounds as well as expose the soldier to longer periods of sound distraction.

In modern society and warfare, people are exposed to intentional and unintentional attempts to influencing not only to their opinions and emotions but also on work performance, such as attention and decision making. It is important to study the mechanisms of influencing and interfering to be able to counteract and mitigate the harmful effects.

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