12th ICBEN Congress on
Noise as a Public Health Problem

The role of noise sensitivity in acute physiological effects of noise

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ABSTRACT

A body of literature exists linking exposure to environmental noise to ischaemic heart disease and high blood pressure. Acute effects of noise are less clear in the literature. Noise sensitivity is a well-known predictor of noise annoyance. With this experiment, differences in acute responses to noise between high and low noise sensitive groups were addressed. Sensitivity groups were formed, based on scores on the Noise Sensitivity Questionnaire (median split). All participants completed three conditions while heart rate and torso impedance were measured: a baseline condition and two (cognitive) task conditions, one with aircraft noise (noise condition) and one without (silence). Heart rate variability analyses of preliminary data (n=19) showed that, of the two groups, noise sensitive individuals had marginally faster heart rates and higher levels of the sympathovagal balance (LF/HF). These results indicate that the heart and nervous system of high noise sensitive people, compared to those of low noise sensitive people, may be less able to adjust to the noise.

INTRODUCTION

A growing body of work shows that heart, blood vessels and the nervous system are affected by environmental noise. In this paper we will first give a brief literature overview of the effects of noise on several measures of the heart and nervous system, before introducing our experiment on the role of noise sensitivity in explaining physiological effects of noise.

Van Kempen et al. [1] showed a relationship between occupational and aircraft noise exposure and hypertension in a systematic review of heart disease data. The link between ischaemic heart disease and noise was not conclusive and a publication bias is not ruled out.

In a later meta-study, a 6% relative risk increase for ischaemic heart disease was found per 10 dB noise increase, starting from 50 dB [2].

The clearest effect of noise on health is hypertension. In the HYENA study (Hypertension and Exposure to Noise near Airports) a long-term dose-effect relationship was found between both night-time aircraft and road traffic noise and hypertension [3], and for some countries between noise and the prescription of anti-hypertensive medication [4]. Higher blood pressure as a result of noise was also found in children: children living in noisy environments and attending noisy kindergartens had higher systolic blood pressure levels than children in more quiet neigbourhoods [5]. Higher blood pressure in children as a result of aircraft noise was also found in the RANCH study (Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health) [6].

The relation between noise and heart rate (HR) is not univocal at this point. The heart rate showed no habituation in response to noise in a sleep experiment, in which participants were subjected to noise during 3 consecutive nights [7]. In contrast, no effect of noise was found on the mean beat-to-beat interval (RR), when people were exposed to background noise and to three levels of low frequency noise (70, 80 and 90 dB(C))[8]. In another study, only a marginal increase in HR was observed as a result of noise [9].

Similarly, non-consistent results were found for the effects of noise on arousal measures such as heart rate variability (HRV) and skin conductance. No effect of road traffic noise was found on parasympathetic activation, derived from the high frequency component (HF) of the HRV [10]. In the same experiment, a quicker recovery of skin conductance levels was found after nature sounds compared to road traffic noise [10]. In contrast, higher increases of the HRV low frequency band (LF) and of the sympathovagal balance (LF/HF) were found when comparing between high levels of low frequency noise (up to 90 dB(C)) compared to background noise [8]. Higher sympathetic vascular tone was found in response to noise in one sleep experiment [7], while arousal (measured with EEG) was not elevated in response to household noises [11]. Higher fluctuations of skin conductance were measured during aircraft noise compared to neighbourhood noise [12].

Subjective noise sensitivity is a good predictor for noise annoyance by environmental noise [13], [14]. Surprisingly, heart rates of low noise sensitive people were higher in response to road traffic noise than was the case for high noise sensitive people [15].

When considering the literature above, one of the main problems in explaining and interpreting the results is that the designs varied widely between the different studies, making it hard to judge whether diverging results are caused by these different settings and circumstances or if the results really do not replicate. Additionally, field and lab studies have their own sets of biases. With this laboratory study, we aimed to address the question whether noise sensitivity interacts with responses of the heart and nervous system to aircraft noise. If this is indeed the case, then diverging results in the past could potentially be explained by variations in noise sensitivity scores in the participant pool. In the current study, heart rate, torso impedance and skin conductance were measured during a baseline condition and during two experimental conditions, in which participants performed a 3-back task with and without aircraft noise. The 3-back task (which is a difficult cognitive task) was used to ensure that all participants were fully engaged in something other than the noise. The participants were divided in a high noise sensitive and a low noise sensitive group, using a median split on the outcome of the Noise Sensitivity Questionnaire (NoiSeQ) [16].

We expected to find both higher heart rates and more arousal for the high noise sensitive group compared to the low noise sensitive group, as well as interactions between groups and noise exposure effects. The experiment is still running, so results below are preliminary.

METHODS

Participants

Up to date, nineteen participants (Mean age = 20.9, 15 women) have voluntarily taken part in this experiment. Sensitivity groups were formed by applying a median split on the noise sensitivity scores, which resulted in a high and a low noise sensitive group. Participants received money or study credits for their attendance. This experiment was approved by the local ethics committee and was in accordance with the Helsinki declaration.

Materials

Seven electrodes were applied to measure the ECG and torso impedance using the Ambulatory Monitoring System (VU-AMS) of the Vrije Universiteit [17]. The three electrodes for the ECG were placed respectively just below the right collar bone 4 cm right of the sternum, on the left lateral margin of the chest between the ribs close to the level of the processus xiphodius and on the right side between the lower two ribs (ground electrode). Four electrodes were used to measure the ICG (Impedancecardiography), two of which were placed on the chest (at the bottom and top of the sternum) and the other two electrodes on the back (3 cm above and below the chest electrodes, resulting in a 6 cm longer distance on the back. Sampling frequencies were 1000 Hz for the ECG (Electrocardiography) and ICG (Impedancecardiography) and 10 Hz for the Skin Conductance Levels (SCL). The latest were recorded with two electrodes in a Velcro strap, placed around the medial phalanges of the index and middle finger.

The HRV data were preprocessed and a Fast Fourier Transformation (FFT) was applied with VU-DAMS software belonging to the VU-AMS system. The following frequency bands were taken into account: LF: 0.04 - 0.15 Hz and HF: 0.15 – 0.4 Hz.

The experiment contained 3 conditions of 8 minutes each: Baseline, Noise and Silence. In the baseline condition, participants sat still with their eyes closed. During the other conditions, a 3-back task was performed with aircraft flyovers in the background or in silence, respectively. The aircraft noise was played through Sennheiser HD600 headphones.

The 3-back task [18] was performed during the experiment. In this task, participants were asked to watch letters (both upper and lower case) in the center of the screen for 500 ms. One of two response buttons had to be pushed after every letter, corresponding to the occurrence of a target or non-target. The letter was a target when it was the same as the one 3 letters before and a non-target in all other cases. In total, 16 blocks of 20 letters were performed, which meant 8 blocks in each condition. The task was programmed in OpenSesame, version 0.25 [19].

Aircraft flyovers (75 ASEL, A320, [20]) were played during the noise condition. Every noise sample (lasting one minute) contained two flyovers.

A demographics questionnaire was used to obtain personal information about age, gender, education etc..

The Noise Sensitivity Questionnaire (NoiSeQ) was used to assess the individual noise sensitivity scores. This questionnaire has 35 items divided over 5 subscales: work, leisure time, sleep, habituation and communication [16]. The overall response range for the whole questionnaire is 0 – 105.

Procedure

Participants first received an explanation about the experiment and filled in the informed consent and the demographics questionnaire. After attaching the electrodes, they were led into a sound insulated room, where the baseline measurement took place first. After that, the participants practiced the 3-back task for 5 minutes, followed by the two experimental conditions, one with and one without aircraft noise. These order of these two conditions was counterbalanced between participants. The duration of the experiment, including application of the electrodes, was approximately one hour. On the day after the experiment, noise sensitivity was assessed online along with several other questionnaires, the data of which will be published elsewhere.

RESULTS

Every dependent variable was analyzed with a mixed design ANOVA, with condition as repeated factor and noise sensitivity as between factor.

A median split on the NoiSeQ scores resulted in a low noise sensitive group (LNS, n=10, M = 39.7, SD = 5.5) and a high noise sensitive group (HNS, n=9, M = 60.6 , SD = 5.9).

All results are depicted in Figure 1. Heart rates were marginally higher in the high than in the low noise sensitive group, $F(1,17)= 4.420; p = .051; r = .45.$ The interaction between condition and noise sensitivity was not significant: $F(1,47)= 2.419; p = .138; r = .35.$ No significant results were found for HF. The results for the main effect of noise sensitivity was $F(1,17)= 1.069; p = .316, r = .24,$ and the interaction: $F(1,17)= 1.166; p = .295; r = .25$. Also for LF, no significant result was found for the main effect of noise sensitivity or the interaction: respectively, $F(1,17)= 0.075; p = .787; r = .07$ and $F(1,17)= 0.167; p = .688; r = .10.$ The sympathovagal balance (LF/HF) showed a main effect for noise sensitivity: the high noise sensitive group showed higher levels on the sympathovagal balance than the low noise sensitive group, $F(1,17)= 5.444; p = .032; r = .49,$ suggesting that their stress levels were higher in the experiment. For LF/HF, no interaction was found: $F(1,17)= 0.067; p = .799; r = .06.$ The last measure that was looked at was skin conductance level. No main effect for noise sensitivity or interaction was found, respectively: $F(1,17)= 2.322; p = .146; r = .35$ and $F(1,17)= 0.516; p = .482; r = .17.$

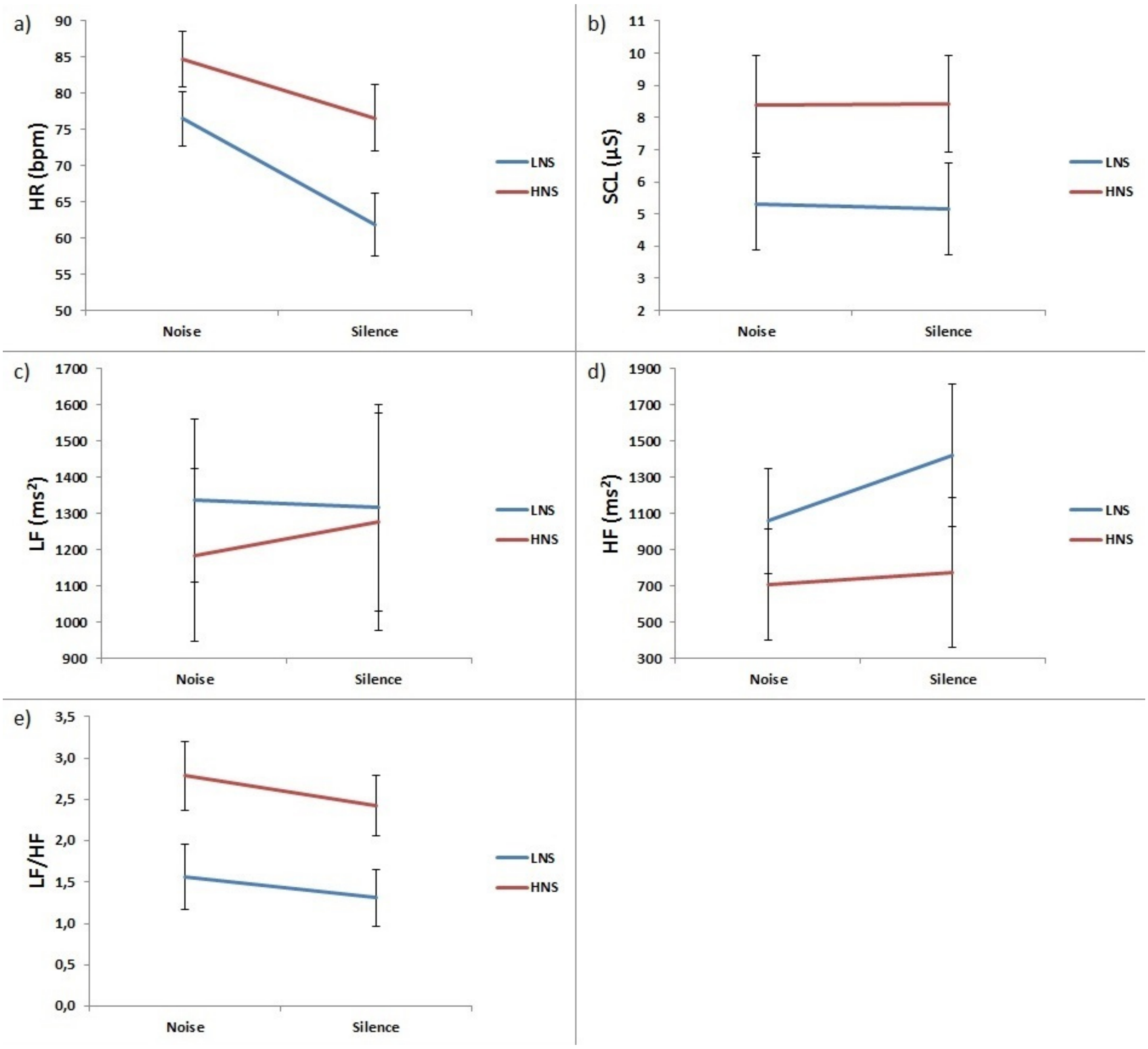

Figure 1: Each panel represents means and standard error of the mean bars (SEM) for the noise and silence conditions, for: a) Heart rate (HR), b) Skin Conductance Level (SCL), c) Low frequency (LF) component of the heart rate variability (HRV), d) High frequency (HF) component of the HRV, and e) Sympathovagal balance (LF/HF).

DISCUSSION

Marginally higher heart rates were found for the high noise sensitive group compared to the low noise sensitive group, which is in contrast with the earlier findings by [15]. Additionally, it was found that noise sensitivity coincided with higher levels of the sympathovagal balance (LF/HF), indicating that high sensitive people have higher activation levels of the sympathetic nervous system.

Surprisingly, at this point no interactions with noise, noise sensitivity and physiological measures were found, though it is still possible that the interaction for heart rate will become significant by the time we finish testing. We also expect the main effect of heart rate to be significant by that time. But, apart from this interaction for heart rate, it seems unlikely that any of the interactions on other dependent variables will reach significance, which leads us to conclude that noise sensitivity does influence the heart and nervous system, but it seems to do so independently of noise exposure. These findings show a resemblance to findings by van Kamp et al. [21] which show that noise sensitivity led to increased levels of noise annoyance, independent of the noise levels. It has been suggested that noise sensitivity is part of a general sensitivity to environmental stimuli. The current preliminary results are a further indication that this may be the case, but the direction of the causal relationship between noise sensitivity and physiology has yet to be determined. Perhaps noise sensitive people have a very active heart and nervous system, leading them to respond stronger to their environment.

We did expect to see an interaction between noise and noise sensitivity on LF as well. This indicator of both sympathetic and parasympathetic activity (but mainly sympathetic) are far from significance. Although an 8 minute interval was fairly short to accurately measure effects of low frequency power, it is doubtful that a longer experiment would have made a difference.

The participants were mostly students and people in their early twenties. The experiment should therefore be replicated with a different sample to see if the relationship between noise, noise sensitivity and physiological stress will subsist.

Finally, it is important to stress that the current results represent acute effects of a task situation with and without noise. It is important that these findings are replicated in the field and under more casual circumstances than in a laboratory while performing a demanding task. Also, more longitudinal research between sensitivity groups is necessary to confirm the idea that sensitive people may be under a constant physiological pressure.

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