Patterns of physiological and subjective responses to vehicle pass-by noises, depending on age, gender, and personality traits

G. Notbohm, R. Schmook, S. Schwarze

Institute of Occupational Medicine and Social Medicine, Heinrich Heine University, 40204 Duesseldorf, Germany, notbohm@uni-duesseldorf.de

INTRODUCTION

In former laboratory studies, we compared the perceived sound quality of pairs of noise recordings (traffic noises as well as single pass-by noises) adjusted to the same L_{eq} of 83 dBA that resembled each other except for one aspect, e.g. the same car passing by either with petrol or diesel engine (Notbohm et al. 2002; Schwarze et al. 2003). In most pair-wise comparisons, stronger physiological responses were accompanied by more negative judgments on the respective sound. But there were a few exceptions in which the sound creating a stronger physiological arousal was judged more favorable (Gärtner et al. 2003).

This seemingly contradictive result might be understood better in terms of the psychological model of affective reaction to external stimuli illustrated in Figure 1: Any sensory stimulus triggers physiological and cognitive responses which can be assigned to the categories "activation" and "pleasantness" resulting in four different tendencies of judgment (Bradley & Lang 2000; Västfjäll et al. 2002). Most traffic noises can probably be perceived as activating *and* unpleasant, but it is evident that there are single pass-by noises (e.g. from sport or luxury cars) that at least by some people are judged to be activating as well as pleasant. With regard to our studies mentioned above carried out with young male students, we concluded from some remarks that the young subjects perceived these specific car noises as sounding more "sportive" or "powerful" leading to a rather pleasant activation.

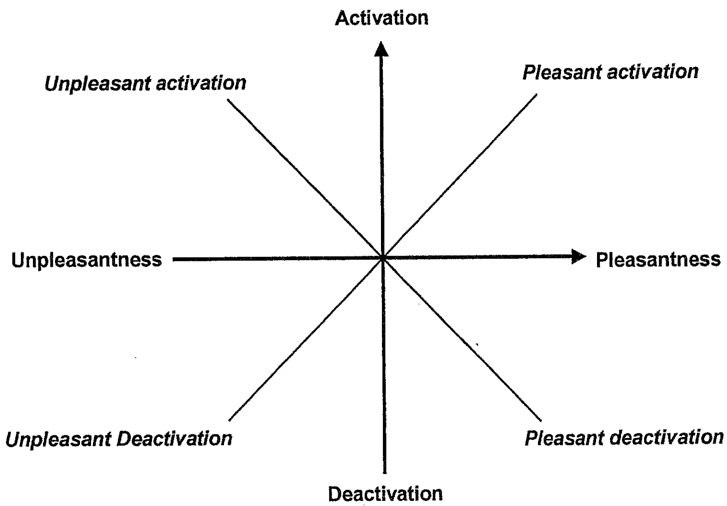

Figure 1: Two-dimensional model of affective reactions to external stimuli – activation and pleasantness

The present study is outlined to examine the effects of age and gender on the type of affective responses to vehicle pass-by noises more systematically using sounds from the previous experiments. However, far more factors are involved in shaping the individual response to sound. Already on the physiological level, there is much evidence

that responses are generally stronger with persons who display certain personality traits such as noise sensitivity (Stansfeld & Shine 1993), neuroticism (Belojevic & Jakovljevic 2001), negative affectivity (Smith & Rich 2000) or preferred coping strategies (Job 1999). Therefore, in the present study relevant personality traits are assessed additionally in order to examine their possible relationship to age or gender.

METHODS

Sample

The sample consisted of 66 subjects, who received a financial gratification for their participation. The subjects had to fulfill some preconditions: good state of health, especially no cardiovascular diseases, good hearing, no intake of medical drugs, alcohol, or caffeine on the day of the experiment, and no lack of sleep.

As the intention was to investigate the influence of age and sex, female and male subjects from two age groups were recruited: younger group 20–30 years, older group 40–55 years. Table 1 shows the distribution of subjects to the four subgroups.

Table 1: Subgroups of the sample (n = 66)

gender \ age	20–30 ys	40–55 ys
male	16	17
female	17	16

Physiological measures of effect

Four different physiological variables were measured during the experiment:

- finger-pulse amplitude (FPA) as a measure of the peripheral blood circulation
- skin conductance level (SCL) as a measure of the electric skin activity
- electro-myogram of the forearm (EMG) as a measure of the electric muscle activity
- heart rate (HR) as a measure of the heart beats per minute being also the base for calculating the heart rate variability.

All these parameters reflect changes of the physiological state of the body in a dimension of activation of the vegetative system elicited by external stimuli as well as by physical tension or emotional arousal. They have proven to be reliable measures of noise effects, but naturally respond also non-specifically to other stressors.

The physiological measurements were taken continuously during the experiment. For the statistical analysis, means for specific time intervals (2–5 s) for each subject were calculated and transformed into percentages in relation to the baseline value of 100% (mean of the last 30 s rest before start of the sound). In the following, we will just give results on FPA and SCL.

Subjective evaluation of the sounds

In addition to the physiological measurements, the subjective evaluation of the sound stimuli by the subjects was assessed by several questionnaires.

One questionnaire included three general judgments which had to be rated on interval scales. For each sound, the subject had to mark the degree to which s/he feels unpleasant or pleasant respectively deactivated or activated on scales ranging from – 4 to +4. These two variables are labeled "pleasantness" and "activation". Additionally we asked a summarizing question on how much the person liked the sound all in all with a bipolar scale ranging from 1 ("not at all") to 9 ("as much as possible").

Furthermore, the subjects were asked to rate the extent to which 23 adjectives applied to each noise on scales from 1 ("not at all") to 9 ("as much as possible"). Using factor analysis these adjectives were summarized to four factors labeled unpleasantness, noisiness, danger and sportiness. These factors were converted into scales by calculating the means ranging from 1 to 9 from all items loading highest on the respective factor.

Assessment of moderating variables

As mentioned above, personality traits which might influence the individual reaction to noise were assessed by means of relevant questionnaires, namely:

- Noise Sensitivity Scale (Weinstein 1978)
- Individual attitudes towards the acoustical environment (Notbohm 2010)
- NEO-Five Factor Inventory (Costa & McCrae 2006)
- Sensation Seeking Questionnaire (Zuckerman et al. 1978).

Experimental procedure

Each subject took part in one experimental session in the anechoic chamber. At the beginning there was a 15 min. period of silence for relaxation and habituation to the situation. Each sound lasted 2 min. and was followed by a silent period of relaxation of 4 min. The participants listened to ten sounds altogether, so the whole session lasted for 71 minutes totally. The first two sounds were given for familiarization as former studies had shown that the reactions to the first sounds were quite extreme sometimes. The following eight sounds were varied in order.

All noises were single car pass-by noises varying in three driving conditions: two variations of a car driving by 50 km/h in the 2nd gear with acceleration (original recording and modification of the engine sound), two variations of a car driving by 70 km/h in the 3rd gear with constant speed (original recording and modification of the tires) and four variations of a brake – idle – acceleration sequence. The sound level of all noises was adjusted to the same L_{eq} of about 83 dBA.

After presentation of the last noise, the electrodes were taken off. Then, after a short break the subjects had to fill in the questionnaires for the subjective evaluation while the noises were repeated in a shortened version.

PHYSIOLOGICAL AND SUBJECTIVE RESPONSES TO THE SOUNDS

Finger-pulse amplitude

The typical response of the finger-pulse amplitude to noise exposure is a decrease of peripheral vascular circulation displayed as a sharp drop as compared to the baseline followed by a slow return towards the baseline during further exposure. Figure 2a shows the mean curves of the four subgroups of the sample as an average over all eight experimental sounds. As the initial response is the most interesting, the first 30 s are presented on a larger scale. The young men (grey line) and the older men (blue line) clearly show the strongest responses with a maximum drop of the FPA below 50% respectively 65% of the baseline. Figure 2b summarizes the mean change of the finger-pulse amplitude during the first 30 s for all three subgroups. Statistically there is a significant main effect of age (p<0.01) and also of gender (p<0.001) as well as an interaction age x gender (p<0.001).

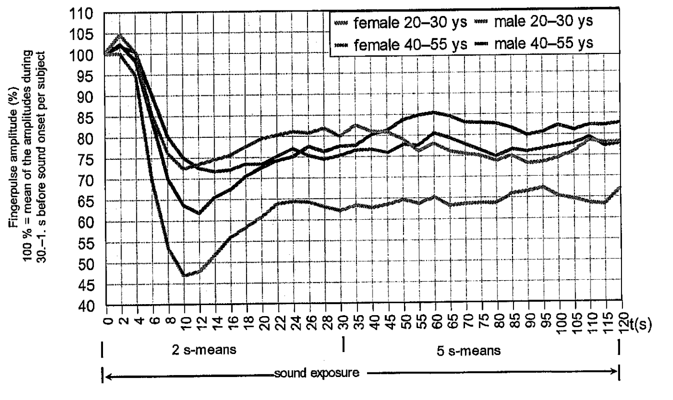

Figure 2a: Changes of the FPA for the four subgroups in relation to the baseline during noise exposure of 2 min. (means of all 8 experimental sounds)

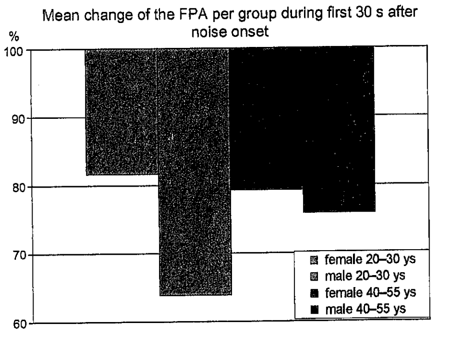

Figure 2b: Mean value of each subgroup for the change of the FPA in relation to the baseline during the first 30 s after noise onset

Skin conductance level

The skin conductance level is expected to rise in situations of physiological arousal. From Figure 3a it can be seen that all four subgroups show a very strong increase of the SCL in the first 10 s after noise onset, but the groups differ in the strength of response: The older women (red line) display the strongest response, followed by the younger women (orange line). The two male groups do not differ very much in their course of response. Figure 3b gives the numerical mean values of the rise of the SCL during the first 30 s. Statistically, there is a main effect of gender (p<0.001).

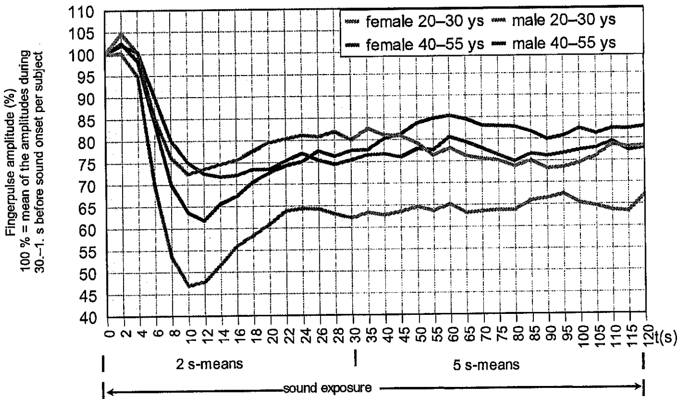

Figure 3a: Changes of the SCL for the four subgroups in relation to the baseline during noise exposure of 2 min. (means of all 8 experimental sounds)

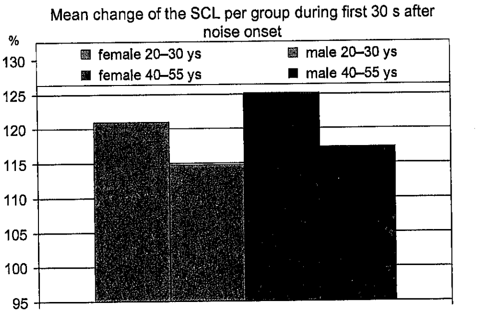

Figure 3b: Mean value of each subgroup for the change of the SCL in relation to the baseline during the first 30 s after noise onset

Subjective noise evaluation

As mentioned above, the subjects had to rate how much they like each noise ranging from 1 ("not at all") to 9 ("as much as possible"). Figure 4 shows the mean judgments for the different subgroups based on the totality of all experimental noises.

It is obvious that the noises are not liked very much – all the mean values in Figure 4 are in a range between 2 and 3. Nonetheless, women dislike the noises more then men (2.55 vs. 2.92), and the older dislike them more than the younger ones (2.64 vs. 2.83). For the four subgroups, there is a clear gap between the older women (2.31) and the other groups: young women (2.76), young men (2.89) and older men (2.94). As a result from variance analysis there is a significant main effect of gender ($p<0.001$) and an interaction of age and gender ($p<0.05$).

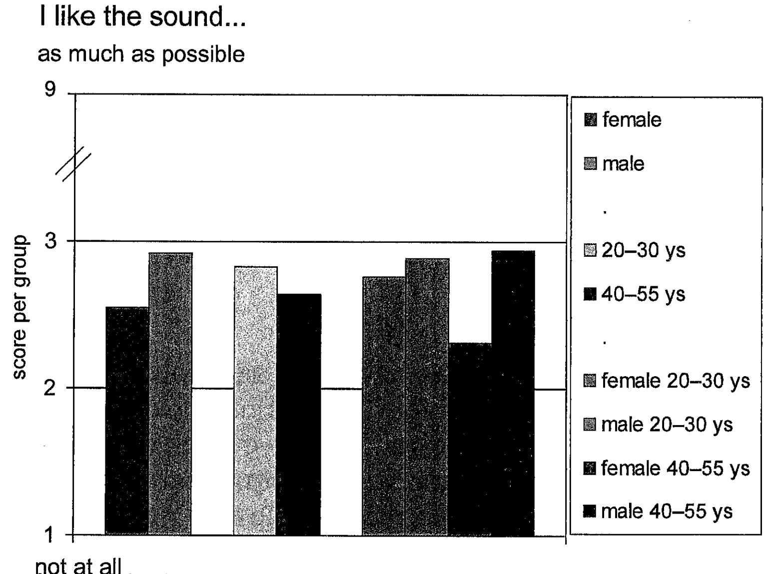

Figure 4: Mean values of the judgement "I like this sound..." from 1 ("not at all") to 9 ("as much as possible") on all experimental sounds for different subgroups: male vs. female (left), young vs. older (middle) and all four subgroups regarding age and gender

With regard to the other two general judgments, "pleasantness" and "activation", the results are similar: The older women feel clearly more unpleasant than the other groups, and the older women (and also the older men) experience more activation by the noises than the younger groups. For both variables, the main effect of "age" is significant ($p<0.05$).

Finally, the results of the scales extracted by factor analysis from the adjective list are shown in Figure 5. For the scale "annoyance", there is a main effect of gender ($p<0.05$) as well as of age ($p<0.001$) and an interaction between age and gender ($p<0.05$). The female subgroups rate the sounds higher than the male subgroups in terms of "annoyance", and the older subgroups give higher ratings than the younger ones, with the older females rating the sounds as the most annoying.

For the scale "noisiness", a main effect of gender is shown ($p<0.01$). An interaction between age and gender misses statistical significance ($p<0.06$). The female subgroups rate the sounds as noisier than the male subgroups with the older female subgroup rating the sounds as the noisiest. Regarding the scale "danger", there is a highly significant main effect of age ($p<0.001$). The older subgroups rate the sounds as more dangerous than the younger ones. For the scale "sportiness", a main effect of gender is found ($p<0.05$). The female subgroups rate the sounds as more sporty than the male ones. Altogether, the older women display the most critical attitude towards the experimental sounds with highest ratings for "annoyance", "noisiness", and "danger" whereas the other three subgroups do not differ that much in their noise evaluations.

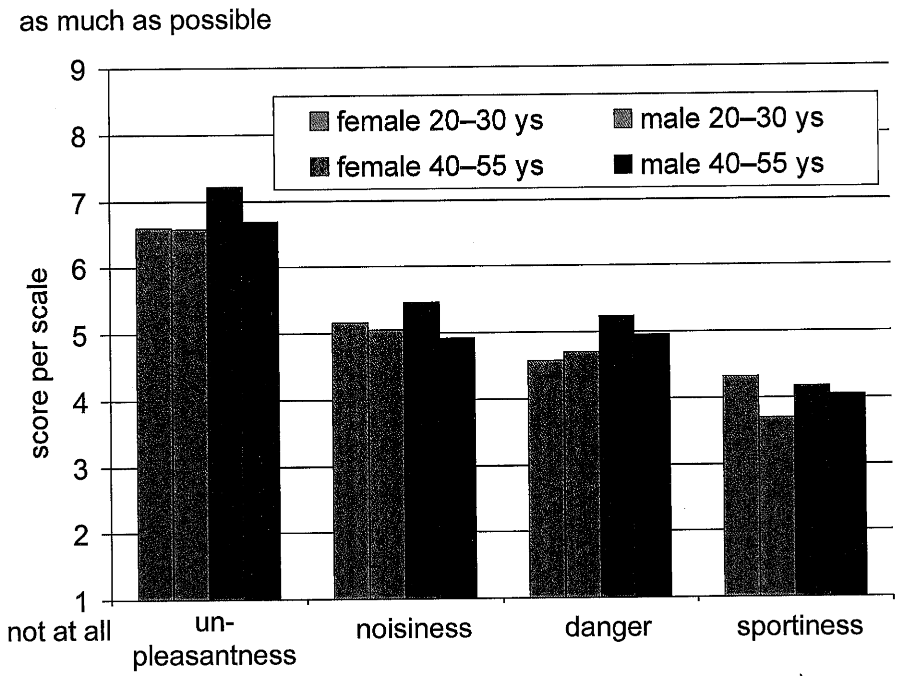

Figure 5: Mean scores of the four subgroups in the four scales derived from the adjective list for evaluation of pass-by noises

Influences of moderating variables on the individual noise effects

For some of the attitudes and personality traits assessed by the questionnaires, the distribution among the four subgroups of this study differs significantly, and some of them also correspond with the subjects' physiological responses to the pass-by noises.

Here we will only give some results concerning the skin conductance level as an example. In Figure 6, the sample is divided into two groups by median split, and then the mean SCL during sound exposure is compared between the two groups. The green bars represent the half of the sample in which the personality trait in question is represented strongly whereas the grey bars stand for the other half of the sample. The SCL response to the sounds was stronger for people with high noise sensitivity according to the Weinstein scale (Weinstein 1978). Two scales of the "Questionnaire on individual attitudes towards the acoustical environment" (Notbohm 2010) confirm this finding: higher sensitivity and stronger annoyance by noise as well as disliking activation by music is associated with higher SCL reaction. Three of the NEO Five Factor Personality Traits (Costa & McCrae 2006) also yield differences revealing some influences of moderating variables on the skin conductance level: People with higher values regarding neuroticism respond stronger and also people with low extraversion and openness.

Not included in Figure 6 are the results concerning the Sensation Seeking Questionnaire: the group with lower scores showed significantly higher SCL reactions than the other group in the total score as well as in some sub-scores. For the FPA reaction, there were fewer significant differences between the two groups of the median split: Stronger responses correspond with neuroticism, with high values of "agreeableness" and low values of "conscientiousness" from the NEO questionnaire and with "thrill and adventure seeking" from the Sensation Seeking Questionnaire.

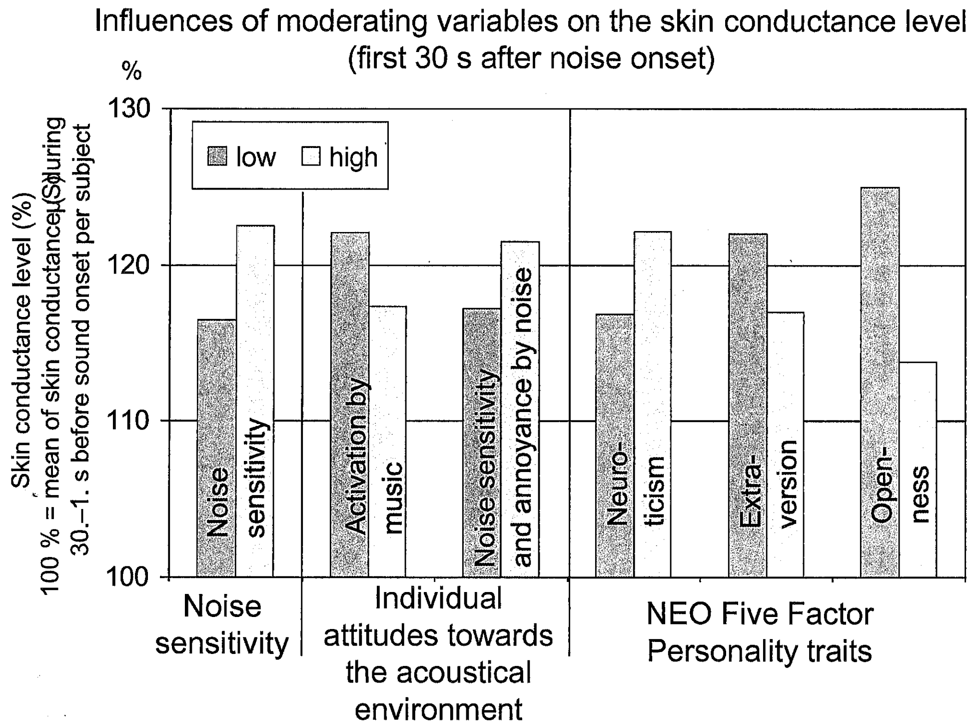

Figure 6: Mean levels of SCL-reaction to the noises for the two groups with lower (grey) or higher (green) values after median split for the given questionnaire scales

DISCUSSION

First of all, the physiological measurements reported above show distinct responses of all four subgroups to the pass-by noises applied. However, there are clear differences between the groups referring to the specific physiological reactions:

- The changes of the skin conductance level during noise exposure reflect exactly the differences between the subgroups with regard to dislike of the noise: The strongest response is found with the older women, followed by the younger women and the two male groups. This fits also well with the very negative judgments especially of the older women in the scales of the adjective list as shown in Figure 5.

- The reaction of the finger-pulse amplitude, however, yields a different pattern of response among the subgroups: Especially the young men show an impressively strong reaction to the stimuli, whereas the female groups respond quite weakly. There is only one corresponding result among the subjective responses, namely the more positive scores of the two male subgroups for the judgment "I like the noise".

The divergent results for the two physiological measures reported here have to be examined further. One explanation could be that the two physiological systems involved are influenced differently by the factors age and gender, i.e., that the tissue structure or hormonal changes might be largely responsible for the deviating responses of the groups with regard to the vascular responses.

Another intriguing explanation would postulate the existence of two different qualities or levels of reaction linked to the different physiological systems, and at this point the moderating variables get involved. The electro-dermal response corresponds very well to subjective data on the noisiness and the disapproval of the sounds, and the SCL reaction is stronger with noise sensitivity, annoyance by noise, introversion, and lack of openness. On the contrary, the FPA response seems to be connected with quite different traits such as agreeableness or sensation seeking. Of course, these are just some hints based on statistical relations, but they support the hypothesis that there are different patterns of response to environmental stimuli which express different subjective perceptions and stimulate divergent physiological pathways.

With regard to the demographic changes of our societies, the main result of this study seems to be the necessity to consider the differences in the perception of environmental noise not only in relation to age, but also to gender. This aspect of different patterns of response needs to be investigated more thoroughly to improve the understanding of human responses to real environmental noise and to optimize preventive measures.

ACKNOWLEDGEMENT

The study was supported by the European Research Group on Environment and Health in the Transport Sector (EUGT e.V.), Berlin.

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