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SUBJECTIVE AND PSYCHOPHYSIOLOGICAL RESPONSES TO AIRCRAFT NOISE

K. BÄTTIG, R. BUZZI, H. ZEIER and R. MÜLLER
Institute of Behavioral Sciences,
Federal Institute of Technology, Zürich, Switzerland

ABSTRACT

A questionnaire study involving 132 subjects confirmed the results of a previous official survey carried out in the same area. A total of 54 persons selected as a homogeneous subsample were chosen for later psychophysiological tests at their homes during the airport rush hours. This report includes the analysis of noise effects on the electrocardiogram and skin conductance in 32 of the 54 persons. The data indicate that significant interactions between the statistically obtained noise clusters and the psychophysiological clusters exist in many of these cases. The frequency of such significant interactions tends to increase both with chronic noise exposure and acute noise exposure during the test, as well as with subjective annoyance reactivity. It is also influenced by the kind of ongoing activity of the tested subject, whether he is asked to perform a task, to relax or to concentrate on estimating actual noise annoyance. Since such cluster shifts do not describe magnitude and direction of the observed effects, caution must be applied in interpreting these data in terms of health, and a further more detailed analysis will be needed.

Attitudes and responses to aircraft noise have been investigated in several large questionnaire studies during the last years. Comparison between these studies is rather difficult, since different noise measures as well as different indexes of subjective ratings of noisiness have been used. Two more recent studies, the DFG study[8] carried out in Germany and the SPF study[24] carried out in Switzerland attempted to compare the relations between physical noise measures and questionnaire results for their own as well as for other studies (Table 1). Several different indexes of subjective ratings for noisiness have been used so far.

"Annoyance" has been estimated in the SPF as well as in the present study by presenting the subjects a scale reaching from one for no annoyance to ten for extreme annoyance. Most other studies rated annoyance by adding the number of selected personal activities such as sleeping, relaxation, conversation etc., which are reported to be disturbed by noise. The number of question items for this index varied from study to study. In the present as well as in the previous SPF study these items were considered as an index of "disturbance" of personal activities rather than as index of annoyance.

TABLE 1

Correlation between noise and subjective complaint indexes in several questionnaire studies among airport area residents.

Reference	N	Index	Noise-units	r	r^2
McKennel, 1963[18]	1 909 1 731	"Annoyance" (=Disturbance)	NNI PNdB	0.46* 0.37/0.38**	0.21 0.14
Coblentz et al. 1967[6]	c. 2 000	Disturbance	R	0.53*	0.28
TRACOR, 1970[25]	2 912	"Annoyance" (=Disturbance)	CNR	0.37* 0.49/0.41**	0.14 0.24/0.17
MIL Research 1971[19]	4 699	"Annoyance"	NNI	0.43*	0.18
Leonhard and Borsky, 1973[17]	1 103	"Annoyance"	CNR	0.32/0.38**	0.10/0.14
DFG, 1974[8]	660	"Global resp."	FBI (NNI)	0.56/0.58**	0.31/0.34
SPF, 1974[24]	3 939	Annoyance Disturbance	NNI	0.56* 0.50*	0.31 0.25
ZURICH, only[24]	1 471	Annoyance Disturbance		0.53* 0.46*	0.28 0.21
Goodman and Clary, 1976[12]	239	Annoyance Disturbance	NEF	0.30 0.30	(=Tau-c)

*values reported in SPF
**values reported in DFG.

As Table 1 shows, the correlations between objective noise and subjective complaints are similar for the different studies, suggesting that intercultural differences are not important. Generally such correlations are modest and do not explain more than about 20–30% of the variation. The weight of intervening variables such as socioeconomic status, age, personality, and duration of residence has also been analysed in several of the studies mentioned in the table but it failed to explain more than modest additional parts of the total variance of noise complaints.

From laboratory studies noise is also known to produce widespread psychophysiological responses[16]. Davis and co-workers[7] defined a complex of circulatory changes, changes of respiration, galvanic skin responses and change of muscular tension as the "N-response". This list of changes is neither complete, as changes of other bodily states can also be observed, nor specific, as such responses can be expected to a variety of pleasant or unpleasant stimuli and conditions besides noise. Furthermore, although the magnitude of such responses depends on noise intensity, being mostly absent with noise intensities of less than 70 dB, these responses are subject to habituation, disappearing or diminishing upon repeated presentation.

However, so far such responses have never been studied outside the laboratory under field conditions. Such an approach might be worthwhile, since field observations might not necessarily lead to the same results as laboratory studies and since the detection of such responses might represent a more objective measure than subjective questionnaire responses. The study was planned as a two-phase experiment. The first phase consisted of a relatively small sample questionnaire study to be compared with the earlier SPF study[24] and the second phase involved recording psychophysiological noise responses in a selected homogeneous subsample. This procedure was adopted in order to compare possible psychophysiological responses with the results of the conventional questionnaire method.

METHOD

Subjects

The subjects were chosen from the most heavily exposed areas of 9 communities situated around the airport Zuerich-Kloten. The addresses were obtained from the "Schutzverband der Bevölkerung um den Flughafen Zuerich" (SBFZ), which is a nonprofit citizens organization for public defense against airport noise. This organization selected the addresses from the telephone directory, rather than from their membership lists. Ninety-nine persons (27%) responded positively to the letters inviting them to participate in this investigation and these subjects proposed an additional 33 persons, increasing thereby the sample to 132 subjects. All the subjects were given standardized interviews and a subsample of 54 volunteers was chosen for subsequent psychophysiological measurements in their homes.

Interviews

The subjects were invited in groups of 4 to 17 persons, instructed and given a questionnaire consisting of both multiple choice and simple yes or no questions.

The first set of 87 questions (221 items) concerned exclusively noise and included 35 questions which were taken from the questionnaire of the SPF study[24]. The items of the OECD list[20] were complemented by additional relevant questions. The second set of 24 questions consisted of form B of a standardized psychovegetative complaint list. The 92 questions of the AUPI personality test[2] were taken in part from the FPI test[10] in order to evaluate the dimensions extraversion, neuroticism and openness and in part from a German translated and tested set of Eysenck Personality-Inventory items evaluating psychoticism. After this personality test the subjects were presented a scalometric self--assessment sheet for these 4 personality dimensions. These questions were followed by 90 questions concerning the socioeconomic and demographic situation. Answers were obtained to 95% of all 387 questions. At the end of these small group interviews the subjects were asked to volunteer in a subsequent psychophysiological recording experiment in their own apartment. The subjects were assured that their reports would be treated confidentially.

Psychophysiological measurements

Of the subsample of 54 persons only 32 subjects could be included in the analysis of physiological data. Ten subjects were used for initial pilot tests, several subjects were unable on attend to the preset dates of recording and for several other subjects, technical failures invalidated the collected data. Each recording session lasted roughly 90 minutes. These sessions were carried out either during the midday or late afternoon rush hours of the airport. The system Messerschmit-Bölkow-Blohm series 3800 was used for amplifying ECG and EMG potentials and transthoracic impedance that were used for measuring respiration. Skin conductance level and responses were obtained with the system Conductron 330. For this purpose Beckman electrodes were fitted below the armpits (respiration), above the eyebrows (EMG), medially below the ankle (skin conductance), and to the chest (ECG). The common reference electrode was placed onto the middle of the forehead. An AKG-C 451E microphone was placed into the window-sill of the subject's home and connected with a Northronic Type 107 noise level meter delivering analogue signals for dBA, dBD and dBlin sound levels. An oscilloscope was used to provide a visual display of all the signals and these signals were recorded with a Stellavox SP-7 tape-recorder modified for PCM recording. One track of the magnetic tape was used for recording actual sound and comments by the experimenter, the other track for recording the four physiological potentials and noise level after PCM--modulation with the 8 channel Johne and Reilhofer system Type 8K10.

During the recording session the subjects first had to fill out the forms A (Eysenck-Personality-Inventory,[9]) and B (psychovegetative complaint list as already used in the previous group interview). This was followed by a 10-minute period during which the subject was asked to rate annoyance for each overflight on a scalometer and to rate average annoyance at the end of this period. This was followed by the d-2 concentration test by Brickenkamp[5]. The following phases were: 10 minutes complete relaxation, second presentation of the d-2 test, second period of scalometric noise assessment, third d-2 test presentation and a final period of 10 minutes relaxation.

Data analysis

The questionnaire data were cross-tabulated and statistical operations carried out on a large scale computer using the SPSS-program and the Clustan program. The tape-recorded data of the psychophysiological experiment were first plotted with a Beckman polygraph. Then, for each block of 20 seconds of these recordings the average noise level (dBD), the average value and standard deviation of the intervals between single heart beats, the number and average amplitude of skin conductance changes were determined. Two separate cluster analyses for the noise and these psychophysiological data were then carried through for each subject. The recordings of respiration and EMG were not included in this first orienting analysis of the physiological data. Subsequently, the significance of interactions between noise and psychophysiological clusters were tested using the nonparametric Friedman test.

RESULTS AND DISCUSSION

The cross-tabulations for the more than 300 items of the questionnaire part of this investigation have already been presented in detail in an unpublished research report[1]. The present paper concentrates on the most important findings.

Questionnaire study

The main emphasis of the questionnaire study on the 132 subjects was to compare the sample characteristics and noise responses with the result of the SPF-1974 study previously carried out in the airport areas of Zürich, Basle and Geneva, and with other recent large sample studies. This sample of 132 persons is termed in the following as the IVW sample. In the present as well as in most other studies the sample excluded non-adults, residents of hospitals and asylums, as well as short-time residents.

TABLE 2
The % distribution of the samples over the different NNI noise strata in the IVW and in the SPF-1974 study.

Sample	N	30–39	40–44	45–49	50–54	>55
IVW	132	17	22	20	26	14
SPF (Zürich)	1 109 (>30 NNI)	15	31	30	22	2

The distribution over different noise strata is similar to the one in the SPF study with a higher portion of residents in the highest exposure stratum (>55 NNI) than in the SPF study (Table 2). Although the present sample and that of the SPF study are comparable for such demographic aspects as age, duration of residence, family status etc., they differ with respect to the socioeconomic status as shown in Table 3. Socioeconomic level is considerably higher in the present sample than in that of the previous SPF study. Further demographic and

TABLE 3
Socioeconomic differences between the IVW and the SPF-1974 sample (area Zürich, >30 NNI only).

	IVW (%)	SPF (%)
College level education	53–57	23–24
Income >4 000 SFr/month	58–68	7
Private home ownership	75–81	26
>5 rooms/apartment	67	22
>10 flight experiences	30	17
Blue collar or unskilled	1	42

socioeconomic comparisons among the different noise strata revealed the inhomogeneity of the sample as shown in Table 4. Residents of the highest exposure stratum differ from those of the other exposure strata by being modestly older, living longer in the area, belonging to a lower socioeconomic level, being politically less active and by originating more frequently from rural areas than from urban areas. Similar differences of socioeconomic level for different exposure strata have been seen in most other similar studies and may be

TABLE 4

Noise exposure (NNI) and socioeconomic/demographic data in the IVW sample. Group averages and Tau-correlation coefficients.

Variable/NNI	30–39	40–44	45–49	50–54	> 55	Tau
Average age (years)	44	45	45	45	52	0.15*
> 10 years residence (%)	52	69	37	71	84	0.15*
Grown up in rural areas (%)	48	50	31	56	89	0.17*
Educational index	2.9	2.6	3.1	2.8	1.6	−0.22*
Income score	4.8	5.0	5.3	4.6	3.8	−0.21*
Political participation (%)	44	33	50	35	5	−0.17*

*p < 0.01

nearly inevitable due to the local sociogeographic background and history. Additional tests for homogeneity (random split, subsample of the 54 subjects chosen for psychophysiological recording) revealed no further disparities for either socioeconomic or demographic characteristics or for noise complaints. The answer to the questions concerning noise irritations, ratings and complaints were grouped into four different sets.

Scalometric subjective assessment of noise annoyance compares well with the results obtained in the previous SPF study (Table 5). If there is any difference it can be seen in the higher annoyance ratings for the low exposure strata (<40 NNI) in the present IVW sample than in the previous SPF study. Disturbance of personal activities (used in other studies as annoyance rating) included eleven items in the present as opposed to 10 items in the SPF study. Table 5 compares the average scores obtained in the present and in the SPF study with the values obtained in other studies after correction to the same scale (0–10). The similarity between these results is greater than was the case for scalometric annoyance. Additional items of the questionnaire, used as index of discomfort, concern pragmatical adaptations, such as closing the windows, staying less often at home, considering a change of residence etc. The items of inconvenience, however, concern rather attitudes such as decreased satisfaction with the residential

TABLE 5

Average scalometric assessment of annoyance and disturbance index of annoyance (corrected for Guttman-scale) in relation to NNI noise exposure in the IVW sample and in selected other studies.

	Sample/NNI	30–39	40–44	45–49	50–54	> 55
Scalometric annoyance	IVW – Zürich	5.6	5.5	6.2	7.8	6.9
	SPF – Zürich – 1974	4.6	4.8	6.1	7.3	
	SPF – Geneva – 1974	3.8	5.6	7.0	7.7	8.2
Disturbance index of annoyance	IVW – Zürich	3.5	4.8	5.1	6.5	7.2
	SPF – Zürich	3.3	4.3		5.3	
	SPF – Geneva	2.8	4.9		7.0	
	Heathrow I[18]	3.0/4.0	4.4/5.0		5.9	
	France[11]	2.5/3.8	3.8/6.2		5.0/7.6	
	Schiphol[3]	3.6/3.9	5.3		5.1/6.3	

conditions, considering noise as a personal health problem and cause of insufficient relaxation. The average values for the different noise strata in the IVW sample are shown in Table 6. The increase of the average values with increasing noise exposure appears to be accelerated for the highest exposure strata.

TABLE 6
Noise exposure (NNI), average discomfort (0 – 6 scale) and inconvenience (0 – 6 scale) in the IVW sample.

NNI	30 – 39	40 – 44	45 – 49	50 – 54	> 55
Discomfort	1.8	2.3	2.5	3.3	3.8
Inconvenience	1.0	1.3	1.7	2.4	2.9

A test for the linearity of all these four indexes with respect to noise intensity revealed the following skewness factors:

Scalometric annoyance	−0.48
Disturbance of personal activities	0.04
Discomfort	0.13
Inconvenience	0.61

Near linearity of the exposure dependent increase is therefore obtained for the disturbance index of personal activity and for the discomfort index due to adaptative behavior. The low linearity of the two other increases might be due to the fact that they are to a greater extent influenced by subjectivity than reports on disturbed activity and adaptative behavior.

The absence of an increase of scalometric annoyance from the 50 – 54 NNI noise stratum to the more than 55 noise stratum is also paralleled by increased symptoms of resignation. More than 50% of the residents of the highest exposure stratum consider protests as useless against only 15 – 20% among the residents of all other exposure strata. However, there are no indications for a socioeconomic segregation due to aircraft noise, as the residents of the highest exposure stratum stayed for longer periods in the area than those of the other exposure strata (Table 4). In order to search for possible effects of intervening factors influencing noise-complaint reactivity, two different procedures were used. In the first step all possible correlations between noise relevant questions and all other questions concerning demographic, socioeconomic and personality aspects were calculated. Only a few consistent significant correlations were found, as discussed in the detailed report on the questionnaire part of this investigation[1]. These suggested that complaints (indexes annoyance, discomfort, inconvenience, disturbed activities) increased with increasing reports of physical sound effects. They were, however, widely independent of personality, sociodemographic and socioeconomic scores, but increased also with increasing health complaints.

In a second step the subjects of each exposure stratum were subdivided into three equal groups according to their reactivity. Towards this goal the individual scores on the four indexes were considered separately for each noise stratum, and divided into three roughly equal groups. The persons with the highest complaint scores were termed as "hyperreactive", the subjects with near-average complaint scores as "normoreactive" and the persons with the lowest complaint scores as "hyporeactive". The correlations of these reactivity indexes with intervening variables of demographic, socioeconomic, personality scores, health ratings etc. revealed a similar picture as the cross-correlations analysed in the previous step of the analysis. These attributes of hyperreactivity, normoreactivity and hyporeactivity were then investigated in the following second part of the study, which deals with the physiological measurements made in the field study.

Psychophysiological tests

The data of the subsample of 54 persons chosen for the psychophysiological tests have not been analysed completely due to the reasons given in the method section. Therefore, the present preliminary report includes only 32 subjects. Direct visual examination of the polygraphic traces revealed no consistent picture, because the differences between individuals, as well as within individuals during the different phases of the test, were very pronounced. Among the four physiological measures the traces representing respiration and EMG appeared to be considerably more irregular than the traces for ECG and skin conductance. For this reason the following cluster analysis on all 20 second average values was restricted to ECG and skin conductance. A separate cluster analysis was carried out with the sound data.

Two individual examples of the results of these cluster analyses over all successive 20 second blocks of a complete recording are shown in Figure 1. Both for subject VP 11 and subject VP 18 this graph shows the clustering of the data for the first half of the testing session. Normal distribution of noise intensity was not found, presumably due to the different noise characteristics of the different types of aircraft. In most cases 3 to 5 different noise clusters were found. Three to 6 clusters were found for the psychophysiological data depending on the individual person. Subject VP 11 represents an example in which the distribution of the psychophysiological clusters over the noise clusters significantly exceeded the chance level, while this was not the case for the other subject VP 18.

Significance of physiological cluster changes was tested first separately for the three external variables shown in the bottom of Figure 1, namely aircraft noise, accidental non-aircraft noise and conversation between subject and experimenter. For periods of interpersonal communication the physiological clusters changed significantly without exception in all 32 subjects as compared to all remaining phases of the test without conversation. Accidental external noise, such as children entering the room, phone ringing, closing the door etc. caused significant changes of the physiological cluster distribution in only four subjects. This appeared to be due to the fact that in most cases such events were not frequent and also very inhomogeneous in their sound picture. Possible effects of aircraft noise were examined in a more detailed fashion.

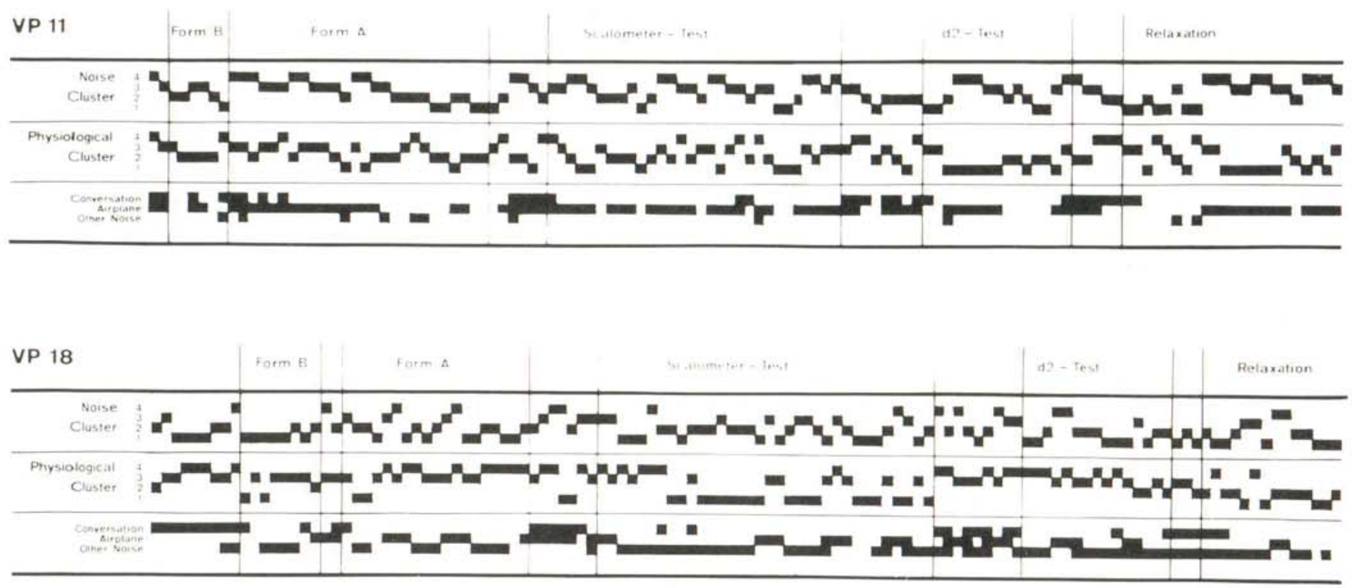

FIG. 1 – Two examples of the distribution of the physiological clusters (electrocardiogram and skin conductance) and the noise clusters over the successive 20-second blocks of the first part of the test. The interaction of noise and physiological clusters is significant in subject VP 11 but not VP 18.

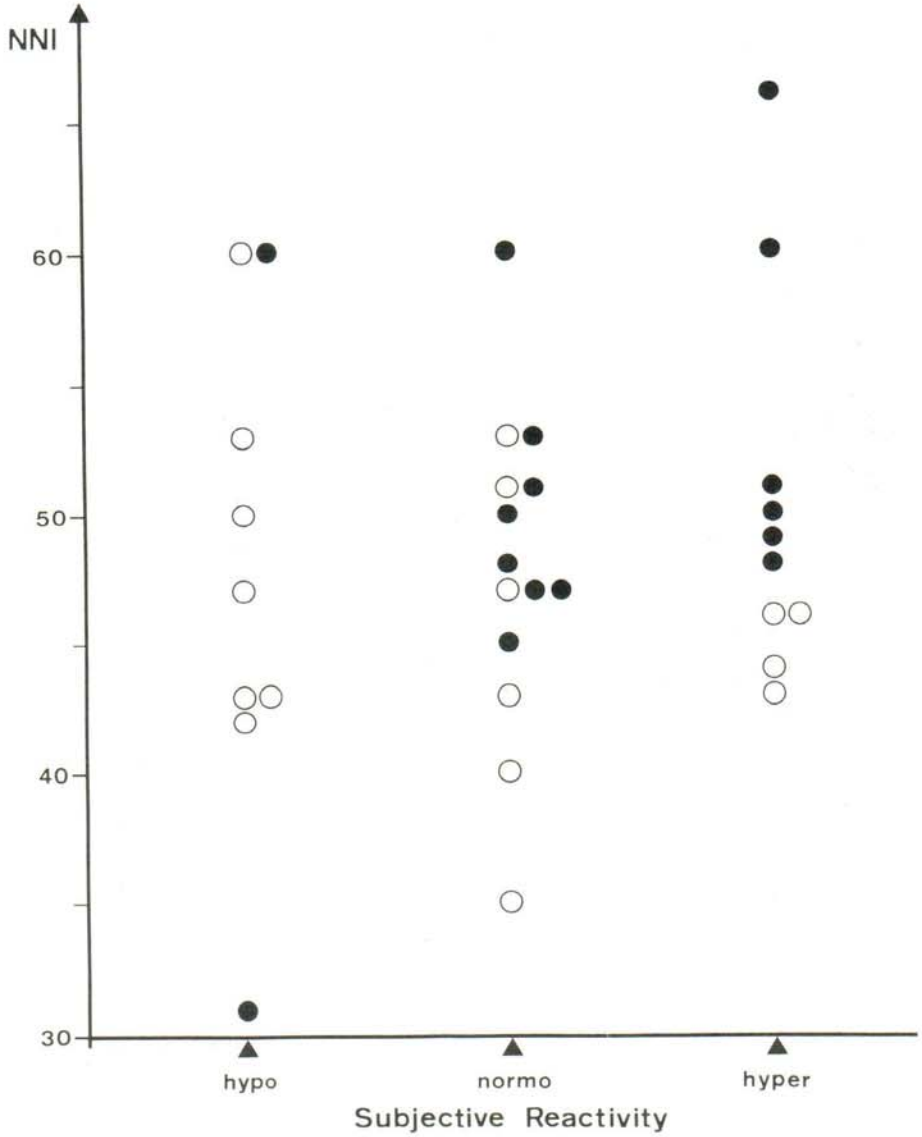

FIG. 2 – Subjective reactivity (according to the preceding questionnaire study), NNI exposure and significance (filled circles) or non-significance (open circles) of the noise effects on psychophysiological cluster distribution for all test phases combined.

Figure 2 shows the distribution of subjects with significant and non--significant aircraft noise effects on the psychophysiological clusters over the range of chronic exposure intensity expressed as NNI according to the statements of the airport noise control authorities. The statistical comparison involves in this case all phases with aircraft noise against all other test phases, regardless of the different ongoing activities of the subjects. The subjects are grouped in this figure into hyporeactive, normoreactive and hyperreactive persons according to their individual complaint reactivity as determined from the initial questionnaire phase of this study. It appears that with two exceptions all hyporeactive persons revealed no significant noise effects on the physiological clusters. A single hyporeactive subject with a significant noise effect at the very low exposure level of 31 NNI showed a considerable discrepancy between chronic noise exposure and actual noise exposure during the test (20 overflights during the test, 87 dBD average noise level). This was also the case for many other subjects. Among the normoreactive persons there is an overlap of significant and non-significant cases along the exposure scale, with significance starting around 45 NNI and non-significance reaching up to 54 NNI. With the hyperreactive persons a split is seen with all cases being significant above 47 NNI.

A similar picture was obtained if the same analysis was limited to the phases during which the subjects had to fill out forms and to perform the d-2 test.

Different pictures, however, were obtained if the analysis was restricted to the other phases of the test. Figure 3 shows the results obtained for the relaxation phase only. In this case there is no obvious correlation either with subjective reactivity or with exposure intensity. This suggests, that not only subjective but also psychophysiological noise responses are greatly dependent upon the ongoing activity of a person. Figure 4 shows the analogous analysis for the phases during which the persons had to rate the degree of subjective annoyance repeatedly on the scalometer. Although in this case the picture is also rather irregular, the portion of significant cases is greater above 47 NNI (13 against 8 cases) than below 47 NNI (2 against 8 cases). Furthermore, there is in this case no visible correlation with subjective reactivity. These differences among the different conditions within the test raise very interesting questions. The answer to them, however, must remain speculative at the moment.

The irregularity of the picture obtained for the relaxation phases might well be due to the inhomogeneity of the respective subjective conditions which escapes any external control. The complete absence of any influence of complaint reactivity during the phase of scalometric assessment of annoyance might be influenced by the fact that in this case physical noise intensity tended to be the determinant factor. If this were true, it would have to be concluded that in this phase the subjects applied concentration and responded rather to physical loudness than to annoyance. This lead to the difficult problem how to evaluate actual noise exposure during the test itself, as both the number and noise intensity of the overflights would have to be taken into account. In Figure 5 all cases are plotted against these two variables. This picture shows that the average peak values were mostly high, reaching up to more than 100 dBD and that the average number of overflights was also high amounting to average intervals of only 2–5 minutes between successive overflights. Considering separately the

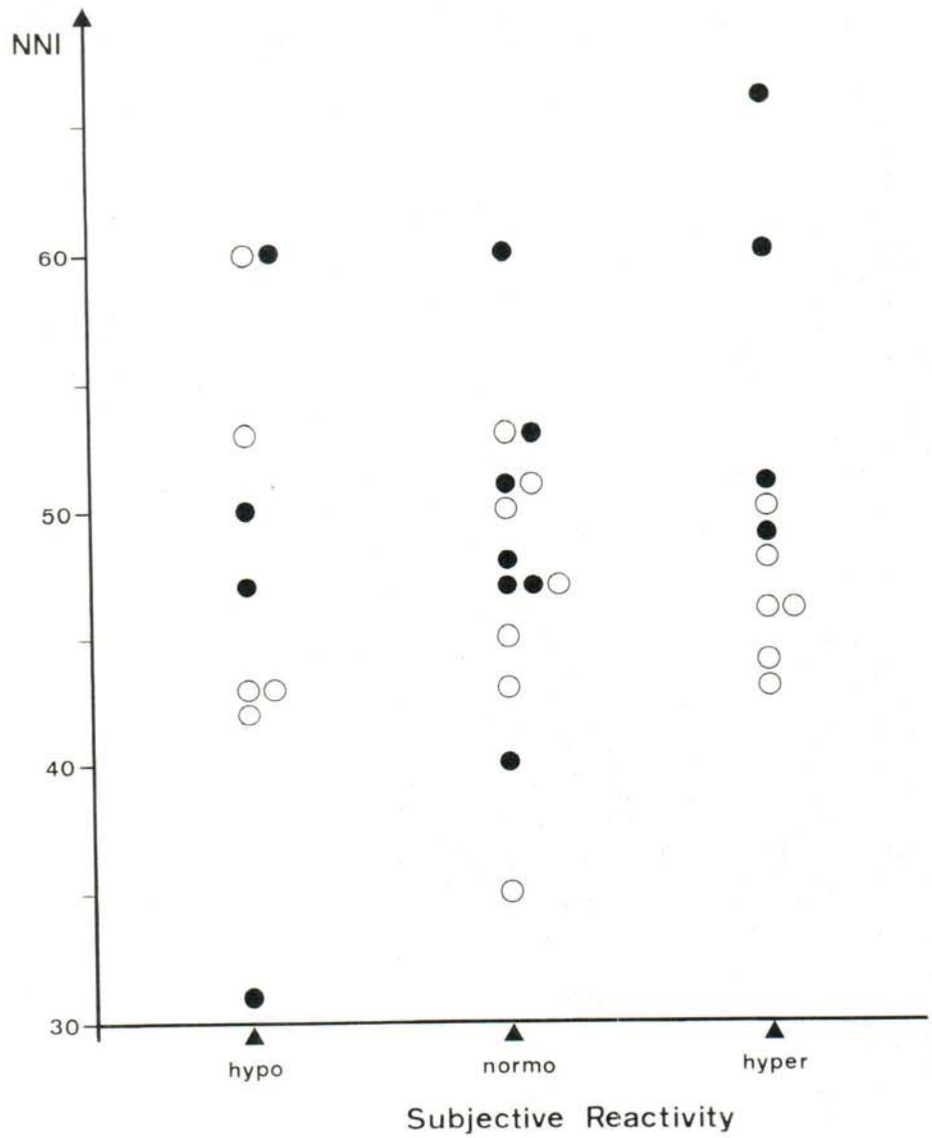

FIG. 3 – Subjective reactivity (according to the preceding questionnaire study), NNI exposure and significance (filled circles) or non-significance (open circles) of the noise effects on psychophysiological cluster distribution for the relaxation phases of the tests only.

influence of both the number and the average intensity of the single noise events it appears tempting to construct a composite index for both values in analogy to

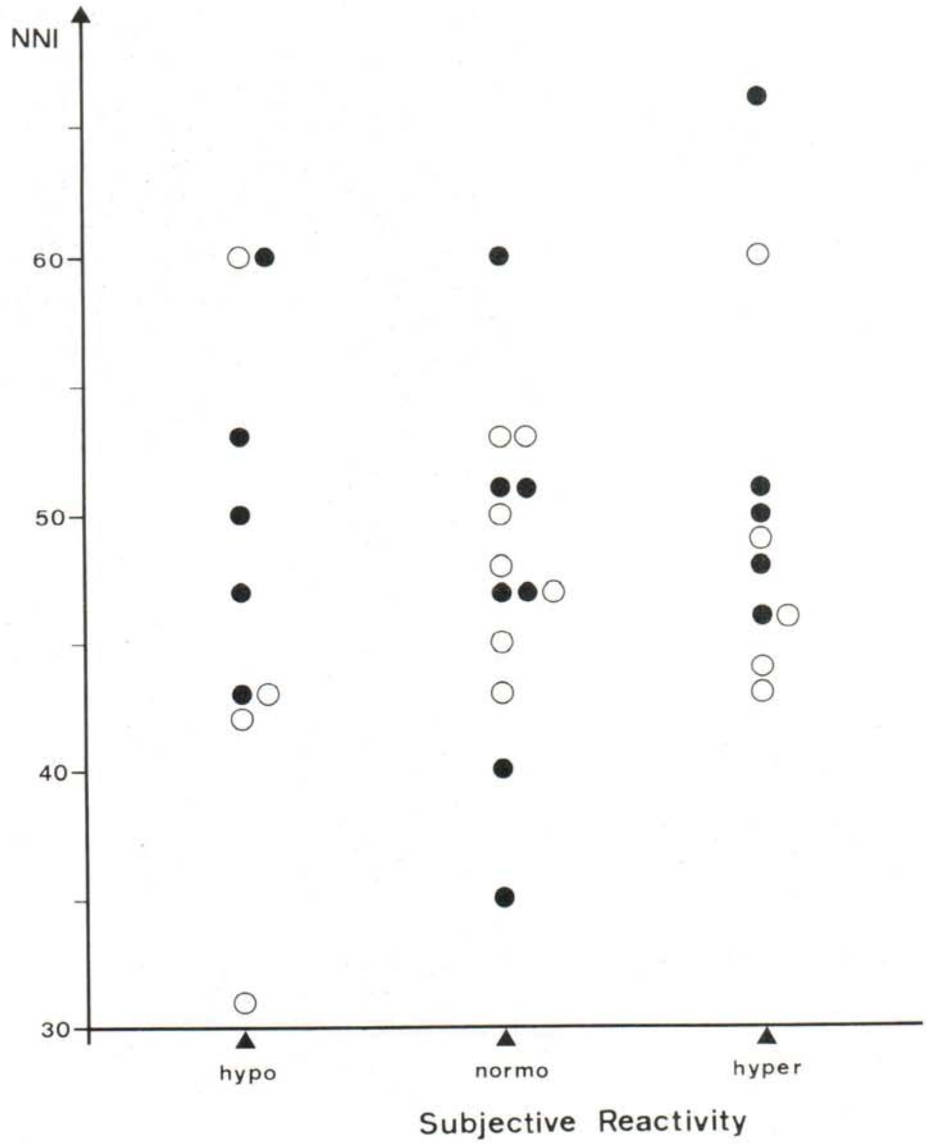

FIG. 4 – Subjective reactivity (according to the preceding questionnaire study), NNI exposure and significance (filled circles) or non-significance (open circles) of the noise effects on psychophysiological cluster distribution for only the phases of scalometric annoyance assessment.

NNI as a measure of chronic exposure. This, however, certainly has to wait for additional experimental data, especially for the lower NNI exposure range between 35 and 45 NNI.

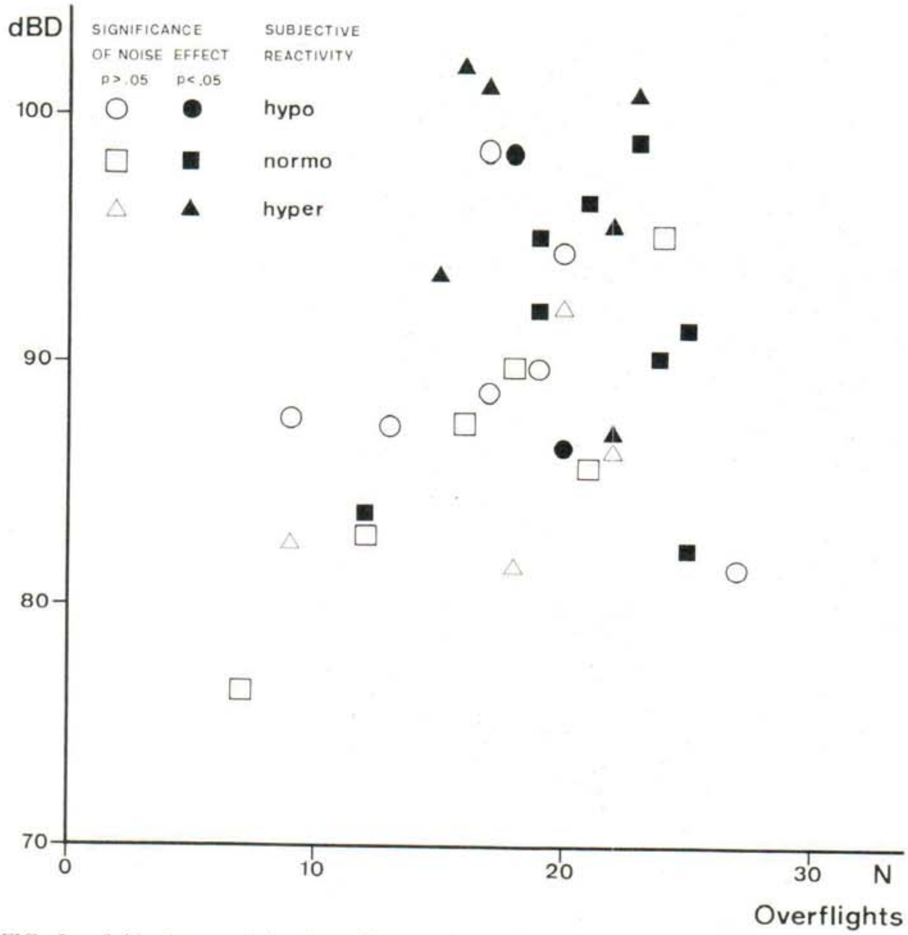

FIG. 5 – Subjective reactivity (according to the preceding questionnaire study), number and average dBD peaks of the overflights during the test, significance (filled circles) and non-significance (open circles) of the noise effects on psychophysiological cluster distribution for all phases of the tests combined.

CONCLUSIONS

The results obtained in the two phases of this experiment allow rather clear conclusions as well as questions for future research.

The small sample questionnaire study of the first phase emphasizes the scientifically widely supported conclusion[21] that intervening variables such as demographic, socioeconomic and personality aspects are of minor influence as far as personal reports of disturbed personal activities and behavioral adaptive responses to noise are concerned. As in the SPF-1974 study, summarized by Grandjean and co-workers[13] noise intensity is the factor which correlates most consistently with the frequency of complaining, although these correlations, even though they are significant, generally tend to be modest. Therefore, the present questionnaire study suggests that even with small samples of interviewed persons and even with restricted representativeness of a sample the results can be expected to be in line with the results of large sample studies[4,13,15,22,23] as reviewed and discussed in the earlier detailed reports on the questionnaire data[1].

Psychophysiological effects of noise have not been investigated so far under field conditions, but only in the laboratory, where they are generally subject to more or less complete habituation[16]. The present study indicates that under field conditions habituation may not develop fully. However, it has to be pointed out that the available scientific data on noise effects and habituation from laboratory studies are far from being complete[14].

Extreme caution is required when interpreting the present results in terms of possible effects of noise on health. The psychophysiological effects seen in the present study vary considerably from individual to individual in both direction and magnitude of the noise correlated cluster changes. A thorough study of these interactions has to be reserved for an additional stage of the analysis of the present data. The same holds for other effects of noise besides the electrocardiographic and skin conductance changes analysed in the present study. Furthermore additional cases from lower exposure areas are required in future research.

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