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Subjective responses to aircraft noise in an outdoor recreational setting: a combined field and laboratory study

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Abstract

The knowledge about human perception of noise in outdoor recreational areas is limited. The aim of the present study was to study the relationship between different noise indicators and subjective responses to aircraft noise, aiming at developing applicable noise indicators in areas for recreational purposes. The perception of aircraft noise was investigated in a combined field and laboratory approach. The partially controlled outdoor field study was conducted in a recreational area close to Fornebu airport, the main airport in Oslo (until August 1998). A group of subjects were asked to score their perceived annoyance and acceptability of actual flyovers during a 50 min session as well as the total annoyance for the whole session. The subjects were later presented to the same aircraft noises, as recorded during the field session, in a laboratory experiment simulating outdoor exposure. Subjects exposed both in field and laboratory responded similarly under both conditions. In both test situations a high correlation was found between different noise indices, as well as between all noise indices and responses to single events. A significant relation was found between the number of aircraft noise events judged as "not acceptable" and the total annoyance response. The present observations showed a correspondence between subjective responses to aircraft noise, both immediate and total judgements, and personal attitudes towards the noise source, but not with self reported noise sensitivity.

1. Introduction

A substantial number of studies have focused on the effect of community noise on people in a home environment. Fewer investigators have addressed how exposure to noise is perceived in

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outdoor recreational areas (e.g., Refs. [1–7]). Only a few of these studies have aimed at quantifying dose–response relationships between aircraft noise exposure and subjective responses. Since annoyance towards noise is highly dependent upon the situation in which the noise is perceived, dose–response relationships derived from socio-acoustical studies in residential areas, are assumed not to be applicable to an outdoor recreational setting. Efforts to synthesize a dose–response relationship between noise from aircraft flyovers and annoyance in an outdoor recreational situation, may be complicated by the uncertainty with respect to each visitor's cumulative noise dose. One reason for this uncertainty is the visitors' inability to give a precise reconstruction of their hiking route at the time of the interview [4].

Experience of natural quiet is highly valued among outdoor recreationists in Norway [8]. With increasing noise in both urban and rural areas, it is a need for more knowledge about how people react to noise in outdoor areas for recreational purposes. The present study is part of a national project on reactions to aircraft noise in recreational areas. Because of the scarcity of scientific literature on this topic, a multidisciplinary approach was used, including observational studies (on-site surveys and telephone interviews) as well as a study with an experimental design. An overall aim of the project is to find a suitable noise indicator, for environmental control purposes, which is reflecting the response to noise in recreational areas.

This paper will present all results from the experimental study in field and laboratory: an outdoor quasi-experimental field study and an open-air simulating study in the laboratory. This methodology was chosen to obtain subjective responses to aircraft noise in a recreational situation, under more controlled conditions than what is possible with a survey methodology. Previous studies have also employed a simulated environment method for studying responses to transportation noise and obtained similar reactions to noise in field and laboratory studies [9–11]. The majority of these studies have simulated an indoor environment such as a home or a working place. Previous audio simulations in the laboratory have well reflected on-site ratings of annoyance for both natural and urban environments [12,13]. One of the laboratory studies with an outdoor recreational context suggests that noise from helicopter, have a negative impact on the visitors' experience and even affected the perceived aesthetic quality of landscapes [14]. The negative effects were most pronounced at high noise levels (80 dB(A)), but also helicopter noise exposure at low levels (40 dB(A)) led subjects to negatively perceive tranquillity, naturalness and scenic beauty, and caused increased annoyance responses.

The present study sought to explore the possibility of a simulated environment study to reflect exposure–response relationships obtained in an outdoor recreational area. Immediate responses to single aircraft noises were chosen as the dependant variable for developing exposure–response relationships, and these individual responses were further analyzed with respect to total annoyance and acceptability responses from the whole session of noise exposure. In addition, the annoyance responses were analyzed in relation to noise sensitivity and personal attitudes towards the noise source, since these factors are earlier found as important effect modifiers, both in population- [15,16] and laboratory studies [17–19]. Annoyance was chosen as the primary response measure in the present study. Annoyance has been defined as *a feeling of displeasure associated with any agent or condition believed to affect adversely an individual or a group* [20]. The study by Fidell et al. [4] strongly suggest that noise-induced annoyance is a more direct measure of the effects of aircraft overflights in outdoor wilderness areas than more global measures such as visit satisfaction or intent to visit.

2. Methodology/study design

2.1. Field study

The field study took place in an outdoor recreational area close to Fornebu airport in Oslo, Norway. Twenty-six subjects ranging in age from 24 to 35 years were recruited on a voluntary basis. The field study was conducted on two different days: day 1 ($n = 10$, 5 men and 5 women) and day 2 ($n = 16$, 7 men and 9 women), in order to obtain larger variation in noise exposure for single noise events, and thus to achieve a better basis for developing an exposure–response relationship. Before the listening session started, the subjects received precise instructions, both verbally from the experimenter and in writing. To simulate a recreational situation, the subjects were allowed to sit down or go for a short walk during the experimental session, but were not allowed to talk to each other. In the instructions to the subjects the use of the annoyance rating scale was thoroughly explained. Each subject was equipped with a pen and a protocol for him or her to write down their responses. During the 50-min listening session, the subjects rated and recorded their annoyance response to each actual aircraft departure, flyover and approach operation. The subjects also recorded the time point of each aircraft noise event, in order to be able to relate individual exposures to the annoyance responses. Subjective reactions were obtained using a continuous 10-point numerical (VAS) scale labelled with "not at all annoying" on the 0-end and "extremely annoying" on the 9-end. The subjects were also asked to make a judgement as to whether each aircraft noise was acceptable or not in an outdoor recreational situation. The acceptability ratings were assumed to strengthen the interpretation of the annoyance responses. Immediately after the session, the subjects received a questionnaire on total annoyance. Total annoyance is here defined as how the subjects perceived the noise from all the aircraft operations during the session. The subjects were asked to judge the total annoyance according to four categories: (1) "not at all annoyed", (2) "slightly annoyed", (3) "rather annoyed" and (4) "highly annoyed".

2.1.1. Noise recordings

Simultaneously with the outdoor listening session, aircraft noise events were recorded on DAT through a Gras Environmental microphone 41 AL with a Norsonic 336 front-end. A- and C-weighted noise descriptor values were calculated in Matlab, and Zwicker loudness values were calculated in a sound quality program (B&K 7698). In addition, binaural recordings were conducted with an artificial head and torso system (B&K 4100) for accurate reproduction over earphones in the subsequent laboratory study.

2.2. Laboratory study

The laboratory experiment was conducted as a simulated environment study, 14 months after the outdoor field study. The experiment took place in a soundproof room ($6.3\,\mathrm{m} \times 3.2\,\mathrm{m} \times 2.8\,\mathrm{m}$) equipped to simulate an outdoor recreational setting. A slide projector produced a picture from the recreational area in which the field study took place on a white screen on the wall. The other walls were covered with a black, light-absorbing textile to minimize reflection. The projector had been modified to make its ventilation external in order to avoid ventilation noise inside the room. The background sound level inside the test room was $L_{Aeq} < 20\,\mathrm{dB}$, and considerably lower than the field recording.

Table 1
Protocol for participants in the field and laboratory sessions

Group	No. of subjects	Field	Lab
1	10/9	day 1	Exposed to the *same noises* as in the field
2	16	day 2	Exposed to *different noise* as in the field
3	13	—	Exposed to the same noises as groups 1 and 2

All subjects from the field study except one, participated in the listening sessions in the laboratory. In addition, a control group was recruited for the laboratory study ($n = 13$, 7 females and 6 males 21–34 years of age). By including these subjects the authors increased the total sample and sought to induce control over the possible effect of participation in a previous, similar study. Upon arrival, the subjects were briefed on the overall purpose of the study and the test procedure to be followed. Initially, the subjects' hearing status was determined by pure tone audiometry (0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz).

In each experimental session two subjects participated simultaneously, seated in chairs facing the wall upon which the slide of the recreational area was projected. As in the field study, the subjects were not permitted to communicate with each other. The outdoor recording of the aircraft noise events from the field study (day 1) was presented to the subjects through earphones. All subjects were exposed to the same sound recording. The listening session lasted for about 50 min. The test procedure and the instructions were kept similar to the outdoor field study to the extent achievable. The subjects were urged to try to imagine themselves in a real outdoor recreational setting, when evaluating the noise events. After the listening session, the subjects were asked to fill in a questionnaire on total annoyance, total acceptability, noise sensitivity[1] [21], and attitudes towards the noise source [22]. The subjects were paid for their participation. The different exposure groups in field and laboratory are presented in Table 1.

2.3. Statistical analyses

Rank correlation and non-parametric tests were used for statistical analyses of the noise responses. In addition, ANOVA for repeated measurements was used to explore the difference between the two methodologies. The software package SPSS ver. 10.0 was used for the statistical analyses.

3. Results

Results from the field and laboratory study will be presented side by side, for comparison of the two methodologies. A total of 38 subjects, 17 males and 21 females participated in the two studies, ranging in age from 21 to 35.

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[1] A translated Swedish version of Weinstein's noise sensitivity scale including 20 statements concerning feelings towards noise with six answer alternatives.

3.1. Noise exposure

Since the first listening sessions took place in a natural outdoor setting, the experimenter did not control the number and levels of the noise exposures. Due to differing wind conditions, the area was mostly exposed to departures on day 1, whereas on day 2 landings constituted the most frequent aircraft operation. The background noises, on both days, were mainly birdsong, occasional voices of passing people, and distant sounds from cars and high-speed boats. Fig. 1 shows frequency spectrum for a typical departure and a typical approach operation recorded in the field area. The recording from day 1 was dominated by discrete and high-level aircraft noise events. A high frequency of approach operations on day 2 resulted in less discernible noise events and lower noise levels than on the first day of experiment. Therefore, only the recordings from day 1 in field were chosen for presentation in the laboratory study. Table 2 shows exposure data from the field and laboratory sessions, both for single noise events and for the whole session.

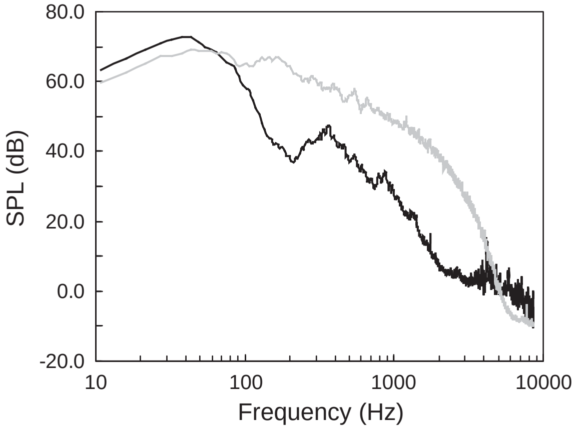

Fig. 1. Frequency spectrum for a typical approach and a typical departure operation: ——, approach; ——, departure.

Table 2
Exposure data

	Field (day 1) + Lab	Field (day 2)
Audible aircraft noise events		
No. of events	14	18
L_{AE} (dB)	58–104	54–82
L_{SAmax} (dB)	50–97	46–75
L_{Aeq} (dB)	41–82	41–61
Total session (50 min)		
L_{Aeq} (dB)	71	52
Background noise level L_{95} (dB)	40	43

Table 3
Median annoyance score (immediate responses)

	Field		Laboratory		
Annoyance responses	Group 1	Group 2	Group 1	Group 2	Group 3
Noise specific annoyance	6.0	4.3	5.4	6.9	5.8
Subject specific annoyance	5.9	4.5	5.5	6.3	5.4

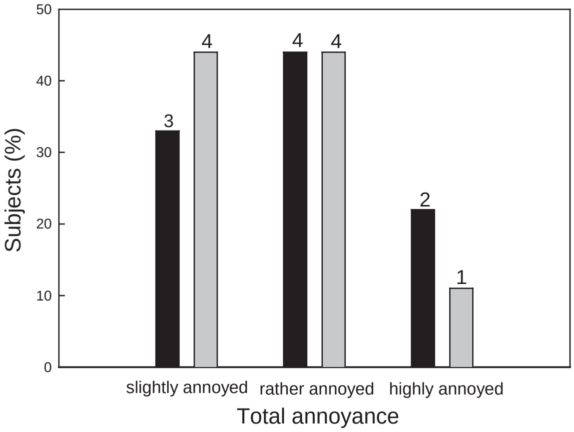

Fig. 2. Percentage and number (on top of the bars) of total annoyance ratings for group 1 in field and laboratory. ■, field; □, lab.

3.2. Subjective responses

3.2.1. Immediate annoyance responses

The average measures of immediate annoyance data are described either as *noise-specific* annoyance *or subject-specific* annoyance. The median value of all the subjects' annoyance responses to a given aircraft noise event (noise-specific) was analyzed in relation to the acoustical parameters in order to obtain exposure–annoyance relationships. The median value of each individual subject's annoyance responses (subject-specific) was compared to the subject's total annoyance level, as well as analyzed in relation to personal attitudes towards aviation and noise sensitivity. Table 3 shows some descriptive data on immediate annoyance responses.

3.2.2. Total annoyance

The distributions of total annoyance in field and laboratory for group 1 are shown in Fig. 2. Fig. 3 shows the total annoyance response distributions for the three groups in the laboratory, which is fairly similar for group 1 and 3. The total annoyance distribution for group 2 was skewed in direction of more subjects in the highly annoyed group and fewer in the group reported to be slightly annoyed. Nobody was "not annoyed".

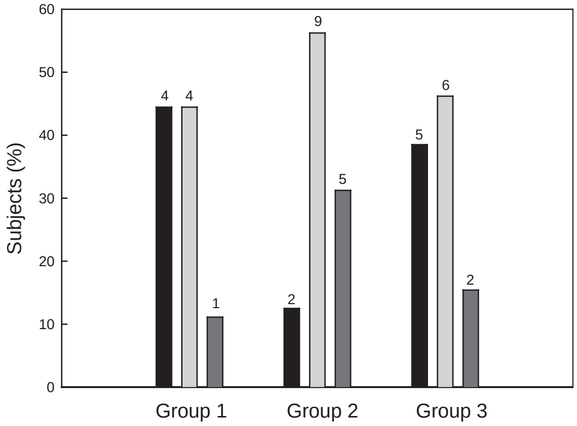

Fig. 3. Percentage and number (on top of the bars) of total annoyance ratings for the various groups in the laboratory: ■, slightly annoyed; □, rather annoyed; ▨, highly annoyed.

Table 4
Annoyance ratings and acceptability judgements for single noise events

	% "not acceptable" judgements				
	Field		Lab		
Location along the annoyance scale (0–9)	Group 1 (Day 1)	Group 2 (Day 2)	Group 1	Group 2	Group 3
0–2.9	0	0	3	8	2
3–4.9	38	28	42	15	28
5–6.9	72	79	82	83	64
7–9	100	100	100	100	100

3.2.3. Annoyance and acceptability responses

For both field and laboratory data there was a high correlation between immediate annoyance and acceptability responses (noise-specific noise annoyance vs. percentage of not acceptable judgements) ($r_s > 0.9$, $P < 0.001$). Noise events rated below 5 on the annoyance scale were in most instances judged as acceptable, and noise events above 5 were rated as not acceptable. Table 4 shows how acceptability judgements were related to the use of the annoyance rating scale. The field data revealed that no noise events rated between 0 and 2.9 were rated as "not acceptable", and 2–8% of these noise events were judged as not acceptable in the laboratory session. In both field and laboratory all aircraft noise events rated above 7 were judged as "not acceptable". There was also a highly significant correspondence between total annoyance and total acceptability ($\chi^2 = 21.1$, df $= 2$, $P < 0.01$).

3.2.4. Immediate versus total responses

The field data including both groups ($n = 26$) did not reveal any statistical significant relationship between immediate annoyance responses (both median and maximum) or percentage

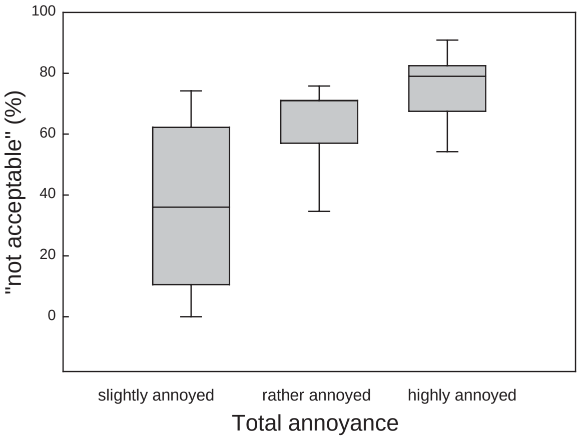

Fig. 4. Box-plot showing 25, 50, 75 percentiles for percentage of “not acceptable” sounds in each total annoyance group.

of “not acceptable” judgements and total annoyance. Also for the laboratory data ($n = 38$) no clear relationship between immediate and total annoyance responses was detected. Instead a significant difference in the percentage of noises judged as “not acceptable” was found between the various “total annoyance” groups ($\chi^2 = 11.6$, df $= 2$, $P<0.01$). The median values of percentage of noise events judged as “not acceptable” for the total annoyance groups “slightly”, “rather” and “highly” were 36%, 71% and 79%, respectively (Fig. 4).

3.3. *Noise sensitivity and personal attitudes towards aircraft noise*

Possible scores for the two scales were between 20 and 120 for noise sensitivity (Weinstein’s sensitivity scale) and 9 and 45 for personal attitudes towards the noise source. High score means a high degree of noise sensitivity and negative attitudes towards aircraft noise, respectively. Descriptive data for the two variables are shown in Table 5. The analyses of the relationships between subjective noise responses and the personal variables, noise sensitivity and attitudes towards aircraft noise, were conducted only on the laboratory data ($n = 38$). No significant correlation was found between noise sensitivity and subject specific median annoyance score ($r_s = 0.2$, $P = 0.26$) or the number of “not acceptable” judgements given by the subject ($r_s = 0.28$, $P = 0.09$). On the contrary, a significant correlation between the attitude scores and both subject specific median annoyance ($r_s = 0.43$, $P<0.01$) and the number of “not acceptable” ratings was detected ($r_s = 0.51$, $P<0.01$). A significant relation was also observed between total annoyance and attitude score ($\chi^2 = 7.0$, df $= 2$, $P = 0.03$), but not with sensitivity ($\chi^2 = 2.5$, df $= 2$, $P = 0.3$). Noise sensitivity differed significantly between the groups (1, 2 and 3 (control) in the laboratory). Multiple comparisons revealed that group 2 scored significantly higher than group 3 on both noise sensitivity ($Z = -7.8$, $P<0.01$) and on the personal attitude questionnaire ($Z = -2.1$, $P<0.05$). Both noise sensitivity and attitude scores were similar for group 1 and 3 (noise sensitivity: $Z = -0.84$, $P = 0.4$, attitude score: $Z = -0.57$, $P = 0.6$).

Table 5
Scores on Weinstein's noise sensitivity scale and on the attitude scale

Group		Noise sensitivity	Personal attitudes towards the noise source
1 ($n = 9$)	Range	56–91	20–41
	Mean	72.9	29.8
2 ($n = 16$)	Range	61–94	25–40
	Mean	79.4	33.7
3 ($n = 13$)	Range	51–97	26–35
	Mean	66.8	30.4
Total ($n = 38$)	Range	51–97	20–41
	Mean	73.5	31.6

3.4. Exposure–response relationships

3.4.1. Exposure–annoyance

The following noise indices were analyzed in relation to the noise-specific annoyance responses: L_{Aeq}, L_{Ceq} (over the time aircraft noise event was audible) L_{AE}, L_{CE}, L_{SAmax}, L_{SCmax}, L_{FAmax}, L_{FCmax} stationary loudness (ISO 532B) and max loudness. A high and significant correlation was found between the annoyance responses and all noise indices studied in the lab session ($r_s > 0.8$, $P < 0,01$). Because the noise events were acoustically homogenous, the noise indices were highly correlated ($r_s > 0.9$, $P < 0.01$). Also for the field session the correlation was high for most noise indices studied, but somewhat lower for day 2 than day 1, and especially for the C-weighted noise indices. The authers chose to use A-weighted sound exposure level (L_{AE}) in the further analyses of exposure–annoyance relationships, since this is a commonly used parameter when analyzing single noise events.

Exposure–annoyance relationships for both groups in field and for the three groups in laboratory are shown in Figs. 5 and 6, respectively. As Fig. 5 shows, a shift in the exposure–annoyance curve for group 2 compared to group 1 was observed in the field situation. The field data is therefore displayed separately for the two groups. In the laboratory session these same groups were now exposed to the same noise events, and as demonstrated in Fig. 6, the difference between the two curves was somewhat diminished. The exposure–annoyance relationships for the three groups in the laboratory were analyzed by using analysis of variance for repeated measurements, in which "group" was a "between-subject" factor and "noise event" a "within-subject" factor. The advantage of this analysis is that the whole data set can be included and not only a single summary measure like mean or median. The results of the analysis showed a significant "between-subject" factor ($F = 4.8$, df $= 2$, $P = 0.014$) and it was group 2 that was different from the two other groups. The mean difference in annoyance response was almost one unit on the annoyance scale between group 2 and both group 1 (Mean difference: 0.83, 95% CI; −1.67–0.01, $P = 0.05$) and 3 (Mean difference: 0.81, 95% CI; 0.05–1.56, $P = 0.03$). The mean difference between groups 1 and 3 was −0.03 (95% CI; −0.90–0.85, $P = 1.000$). When "noise sensitivity" and "personal attitudes towards the noise source" were put into the analyses as

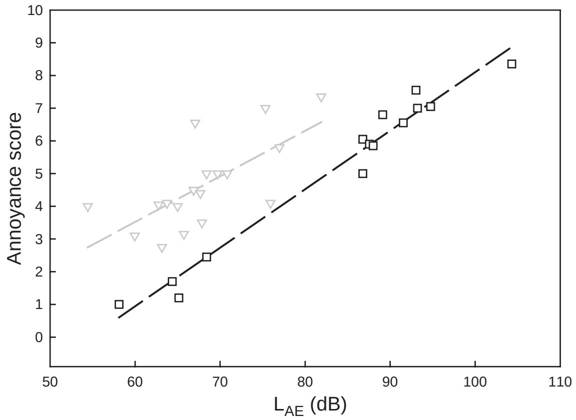

Fig. 5. Median annoyance responses as a function of sound exposure level for single noise events: scatter plot and linear least square regression lines for exposure–annoyance relationship for group 1 (□ – – –) and 2 (▽ – – –) in the field.

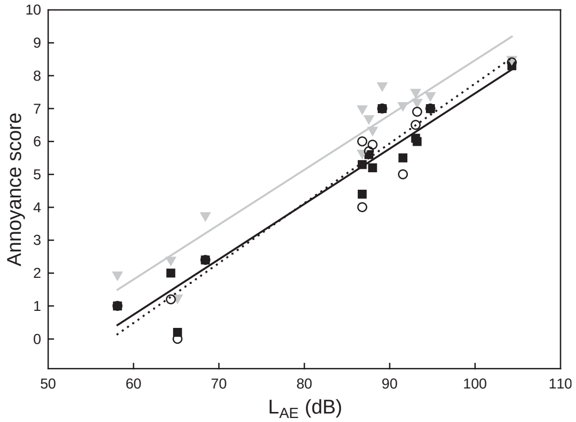

Fig. 6. Median annoyance responses as a function of sound exposure level for single noise events: scatter plot and linear least square regression lines for exposure–annoyance for the three groups in the laboratory, group 1 (■ ———), group 2 (▼——) and group 3 (○ ………).

covariates, the group effect disappeared ($F = 1.5$, df $= 2$, $P = 0.24$). Only the attitude response was significant in the analyses ($F = 3.2$, df $= 1$, $P = 0.02$) and using this as a single covariate the differences between the groups were no longer significant ($F = 2.2$, df $= 2$, $P = 0.13$). The factor of personal attitudes towards aircraft noise was a highly significant covariate ($P<0.01$).

3.4.1.1. Field versus laboratory. Comparisons of data from field and laboratory were performed for group 1 only, since this group was the only one exposed to the same noise events in the two sessions. Fig. 7 shows the exposure–annoyance relationship for field and laboratory data, as well as for the control group in laboratory. Analysis of variance for repeated measurements was used to quantify the difference between data obtained in field and laboratory. Both "method" (field or laboratory) and "noise event" ($n = 14$) were used as "within subject" factors in the analysis. This

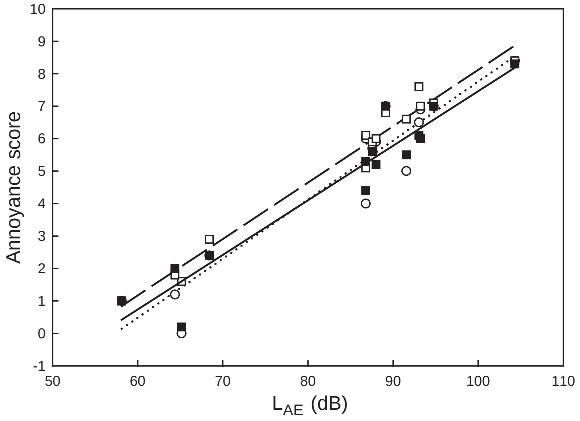

Fig. 7. Median annoyance responses as a function of sound exposure level for single noise events: scatter plot and linear least square regression lines for exposure–annoyance relationship for group 1 the field (☐ – – – –) and in the laboratory (■ ————) and the control group (3) in the laboratory (○ ………).

analysis showed the "method" factor not to be significant; the mean difference between annoyance data obtained in field and laboratory was 0.48 (95% CI:−0.12–1.1, $P = 0.10$). The factor of "noise event" was highly significant ($F = 71.4$, df $= 13$, $P < 0.001$) and no significant interaction effect (between the factor "method" and "noise event") was found ($F = 1.61$, df $= 13$, $P = 0.10$). A possible difference between the experimental and control group was also analyzed by using analysis of variance for repeated measurements, in which "group" was a "between-subject" factor and "noise event" a "within-subject" factor. Mean difference between experimental and control group was 0.03 (95% CI; −0.88–0.90, $P = 1.000$) and non-significant.

3.4.2. Exposure-response L_{AE} versus "non-acceptable" ratings

There was a high degree of correlation between sound exposure level (L_{AE}) and the percentage of non-acceptable ratings, both in field ($r_s = 0.87$, $P < 0.001$) and in the laboratory ($r_s = 0.96$, $P < 0.001$, control group: $r_s = 0.94$, $P < 0.001$). A test of the difference in acceptability ratings did not detect any significant difference between the same group in field and lab (Wilcoxon Signed Rank test, $Z = -1.29$, $P = 0.197$) or between the experiment and the control group in the laboratory (Mann–Whitney U: $Z = -1.06$, $P = 0.31$). No significant difference in acceptability ratings was observed between the field group and the control group in the laboratory (Mann–Whitney U: $Z = -1.57$, $P = 0.13$). Fig. 8 shows percentage of "non-acceptable" ratings as a function of noise level (L_{AE}), for both field and laboratory data. The best-fit regression lines shows that 50% "not acceptable" ratings were reached at the sound exposure level of approximately $L_{AE} = 80$ dB.

3.5. Hearing status

Hearing status was assessed in the laboratory by pure-tone audiometry in accordance with ISO 8253-1 [23]. Normal hearing, no hearing threshold exceeding 20 dB at either of the tested frequencies, was found in 24 subjects. Five subjects had binaural hearing loss up to 45 dB HL. The

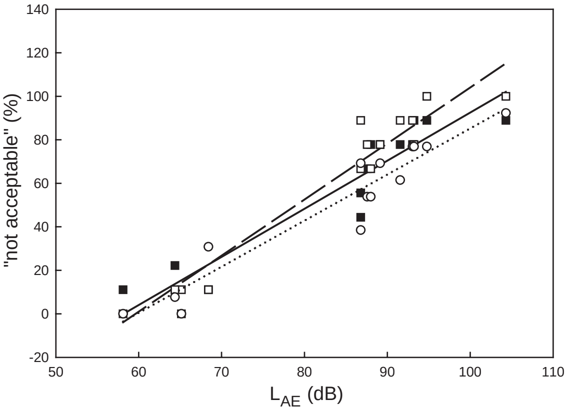

Fig. 8. Percentage of "not acceptable" responses for single noise events as a function of sound exposure level: scatter plot and least square regression lines for the group in the field (☐ – – – –) and in the laboratory (■ ———) and the control group (3) in the laboratory (○ ………).

rest of the subjects ($n = 9$) had slighter monaural hearing losses with hearing thresholds between 25 and 45 dB on one or more frequencies. The hearing status was checked when the subjects arrived at the laboratory 14 month after the field study. No significant difference in median annoyance was found between those with raised hearing level and those with normal hearing (Mann–Whitney U: $Z = -0.39$, $P = 0.71$). No subjects were therefore excluded from the analyses.

4. Discussion

The present study focused on noise perception in an outdoor recreational setting. Highly significant exposure–annoyance relationship was found between noise exposure of individual overflights and annoyance towards these events. A high correspondence between noise and annoyance for individual noise events is also found in previous studies in which home or a working environment has been the reference frame. There have been only a few studies attempting to quantify the relationship between noise exposure and noise annoyance in an outdoor recreational context. On-site interviews in parallel with noise measurements in recreational areas have been reported [3,4] . These studies have focused on the cumulative effect of noise rather than the response to individual flyovers. Hence, the quantitative relationships between noise exposure and annoyance from these studies are not directly comparable with the present study. Nevertheless, the study of Fidell et al. [4], showed that more than half of the variance in judgement of annoyance was associated with probable exposure to one or more aircraft flyovers with high noise level. In addition, aircraft that produced higher noise levels were reported to be more annoying than those producing lower levels of noise. This was confirmed in our study.

The choice of immediate response to single aircraft noises as the primary dependant variable in our study is justified by the nature of the context studied; hiking outdoors in a recreational area is of relatively short duration and the perceptions are based on immediate impressions from the surroundings. However, this might not reflect the importance of subjective responses integrated over a longer time period. Analyses of a possible coherence between immediate and total responses revealed a significant relation between the number of sounds judged as "not acceptable" and the total annoyance response. This implies that the number of events exceeding a certain threshold may be an important predictor of total annoyance in a recreational setting. However, Fidell et al. did not reveal any significant relationship between noise annoyance and the number of aircraft flyovers *noticed* among wilderness recreationists. Their analyses of possible correlation between *actual* flyovers and annoyance were complicated by the uncertainty of each visitor's actual noise exposure and the number of events included. However, in studies with more control over exposure data, the number of noise events, up to a certain number, has shown to be an important factor in subjective evaluation of noise exposure [24,25] . In the present study the number of overflights was not systematically varied, and therefore not a variable under investigation.

The exposure–response relationships obtained in the outdoor recreational area and in the laboratory were similar. An inexperienced control group was included in the laboratory study to control for a feasible effect on the laboratory results, of participation in the field study of similar type. A possible difference between the experiment and control group in the laboratory could also have been caused by a difference between the two groups with regard to personal factors such as noise sensitivity and attitudes towards aircraft noise. No such differences were found. The similar responses of groups 1 and 3 (control) in the laboratory indicate a non-significant effect of participating in a similar study, at least when the time interval is more than a year between the two studies.

In the field session, with different set of noise stimuli for day 1 and 2, group 1 gave lower annoyance scores than group 2, given the same L_{AE}. This was also found, but to a lesser degree, in the laboratory session, when the groups were exposed to the same aircraft noise events. This difference may partially be explained by a higher degree of negative attitudes towards the noise source in group 2, since adjusting for this factor in the analysis of variance, the difference in annoyance–exposure relationship between the two groups was no longer significant.

Alternative explanations for the higher annoyance level of group 2 (day 2) compared to group 1 in field might be that approach operations, which dominated on day 2, are more annoying than departures, given the same noise level. Differences in spectral and temporal characteristics, not fully accounted for in the dose metrics, may be an explaining factor. The difference can also have been caused by a response bias due to different set of noise stimuli—a stimuli context effect. Further, the background noise level (L_{95}) was 3 dB higher on day 2 than day 1, and the level of background noise has shown to affect subjective responses to noise in previous studies [26,27] . Finally, the difference in annoyance level between the two groups may reflect a difference in personal variables that affect the responses to noise, such as noise sensitivity and negative attitudes towards aircraft. Several factors might have contributed to the higher annoyance of group 2, but by statistically controlling for negative attitudes towards aircraft, the difference in exposure–annoyance relationship was no longer significant.

Results from other partially controlled studies have shown that indoor noise is perceived as considerably less tolerable than outdoor noise at the same noise level [28,29] , which suggests that people respond to the indoor noise level, and do not respond as if they were outdoors. A similar difference between the outdoor field and the indoor laboratory session in the present study was not found, which gives additional indication of the applicability of an outdoor simulation inside the laboratory. Also, a high correspondence between the annoyance response and the acceptability judgements reflects a similar interpretation of the annoyance scale in both field and laboratory. A similar relationship between annoyance and acceptability has also been reported in a previous study [30].

The data on the relationship between percentage of ''not acceptable'' ratings and noise exposure shows though, that noise events with higher sound exposure levels were judged somewhat more often as not acceptable in the field situation than in the laboratory. The differences in subjective noise responses were most pronounced between the experiment group in the field and the control group in the laboratory, and more pronounced for the acceptability ratings than for the annoyance responses, but revealed no statistical significant differences in this study.

Previous studies have found a strong relationship between self-reported noise sensitivity and annoyance towards noise, both in field surveys [16] and in laboratory studies [17]. The present data did not detect any correlation between noise sensitivity and annoyance or acceptability judgements, both with respect to immediate and total noise responses. A typical characteristic of noise sensitive subjects seems likely to be their increased attention to noise compared to subjects with lower sensitivity to noise. In the experimental situation, all subjects were asked particularly to pay attention to the noise events. A possible explanation then, for the lack of correlation between self-reported noise sensitivity and subjective noise responses, is that in such an experiment, all subjects were sensitized, and a possible effect of noise sensitivity on noise response is diminished. In another laboratory study on effects of noise on natural landscape assessment, noise sensitivity (Weinstein's noise sensitivity scale) did not correlate with annoyance response [14]. Presumably at higher noise levels people may become more commonly annoyed than at lower levels, when only the most noise sensitive get disturbed [31]. In this study the subjects were exposed to clearly audible aircraft noise events that in most instances exceeded a sound exposure level of 70 dB. In a field survey reported by Tarnopolsky et al. [32], no correlation was found between noise annoyance and sensitivity at 90 dB aircraft noise exposure.

5. Conclusion

Results from this study demonstrate a high correlation between noise exposure (L_{AE}), annoyance and acceptability responses for single noise events in a recreational setting. When the subjects were carefully instructed to respond as if they were in a recreational area, the outdoor-simulated laboratory study could reproduce the exposure–response data from the field study to a considerable degree. Significant relation was found between immediate acceptability responses to aircraft noise events and total annoyance. This suggests that number of noise events exceeding a certain noise level might be an important determinant of an integrated annoyance reaction towards noise in recreational areas, and should be further explored. The present observations also showed that the subjective responses to noise in a recreational setting, both immediate and total judgements, related significantly to personal attitudes towards the noise source, but not to noise sensitivity.

The present study will not conclude on annoyance and acceptability for aircraft noise in recreational areas on an absolute level. The applied methodology has the advantage of posing a high degree of control with the variables, but a possible disadvantage of being an unrealistic situation. A comparison of results from the present study and two ongoing surveys may assist in establishing criteria for acceptable noise levels in outdoor recreational areas.

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