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AN AIRCRAFT NOISE STUDY IN NORWAY

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## Introduction

An extensive study of aircraft noise is currently being conducted in Oslo, Norway. The traffic at Oslo Airport Fornebu that includes both national and international flights, totals approximately 350 movements per day: 250 of these are regular scheduled flights with intermediate and large size aircraft, the bulk being DC9 and Boeing 737.

The political decision to build a new airport to replace Fornebu has already been made, but until the late nineties the problems with aircraft noise in Oslo will continue, and to some degree they are also expected to increase.

During the summer months of 1989, Oslo Airport Gardemoen, which serves most of the charter traffic and intercontinental traffic, was being refurbished. From May till September the major part of the traffic was therefore transferred to Fornebu.

The total traffic during the summer of 1989 was expected to resemble the maximum level to which the regular traffic will increase before the new airport can be put into operation. The situation therefore represented a unique possibility to study the noise impact on the communities around Fornebu.

## Outline of noise study

A comprehensive social survey was designed, including questions on both aircraft and road traffic noise. A random sample of 1650 respondents in 15 study areas were contacted for an interview. These areas represent different noise levels and different locations relative to the flight paths.

The interviews were conducted in a 2 week period just prior to the transfer of charter traffic from Gardemoen to Fornebu.

In the same period the aircraft noise was monitored in all 15 areas. In addition the airport is equipped with a permanent flight track and noise monitoring system. The noise situation both in the study period and on an average basis can therefore be accurately described.

In Norway the official aircraft noise exposure index is called EFN. This index is quite similar to CNEL. However, we have also calculated LDN at Fornebu. For this particular aircraft mix and traffic pattern the difference between EFN and LDN was slightly less than 1 dBA, with EFN being the larger quantity. There is a partly effective night curfew at Fornebu with no scheduled operations between 11 pm and 7 am.

In August a group of 1800 new respondents were subjected to identical interviews in the same 15 areas, and the noise measurement program was repeated.

## Results

Only the results from the spring survey have been analyzed so far. In this report we will present the responses to a direct question on reaction to aircraft noise.

The respondent was asked: "Can you hear aircraft noise when being outside your home?", and if the answer was YES, we presented a follow-up question: "Would you consider this noise very annoying, moderately annoying, a little annoying or not annoying?" (The original questionnaire was naturally written in Norwegian, and these examples have been translated).

The results are given in Figure 1. The diagram shows the percentage (of the total number of people asked: Can you hear aircraft noise....) considering the noise very annoying as a function of the outdoor aircraft noise level in each location.

## Models for noise annoyance

A number of attempts have been made to give a mathematical description of the relationship between degree of annoyance and noise exposure. In 1978 Schultz (1) presented his well known synthesis, describing the percentage "highly annoyed" by a third order polynomial, see Figure 2.

Schultz's relationship was purely empirical, and as it is pointed out in a later publication (2), it was lacking a theoretical foundation.

We have previously presented a model based on the introduction of a threshold (3), assuming that only noise above a certain level could contribute to the annoyance. This concept has been validated by laboratory experiments (4), and we concluded that the energy-equivalent noise level calculated for noise above a given threshold is a good descriptor for noise annoyance.

Fidell et al. (2) have shown that differences between dose-response relationships that have appeared in different noise surveys can be accounted for by using a very simple model based on a fixed threshold and varying criterion value associated with different communities, see Figure 3.

A further elaboration on the threshold concept has led us to suggest the following hypothesis:

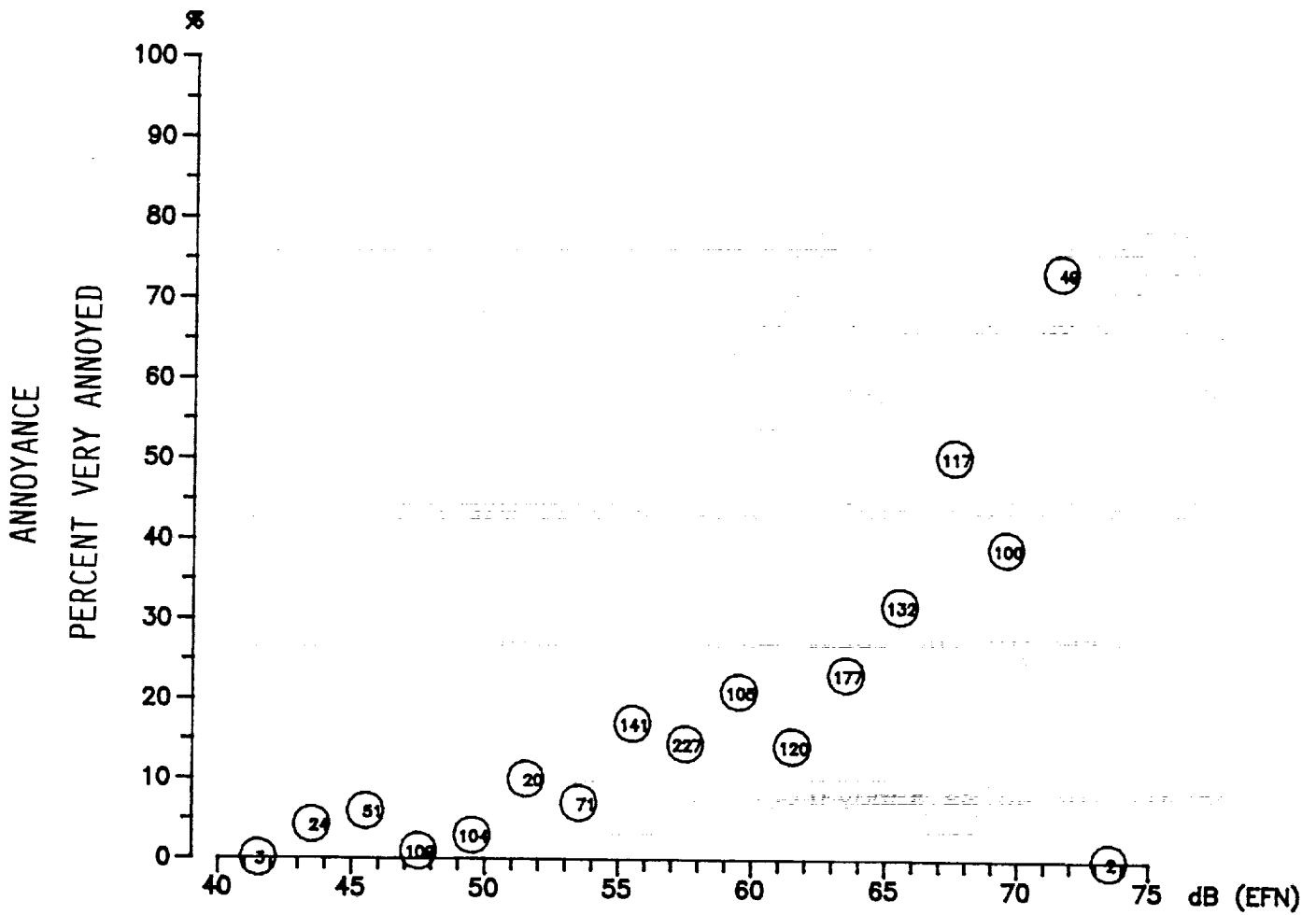


Figure 1. Results from the Fornebu survey  
 Percentage of people very annoyed as a function of  
 noise exposure. Circled numbers indicate number of  
 respondents for each noise level.

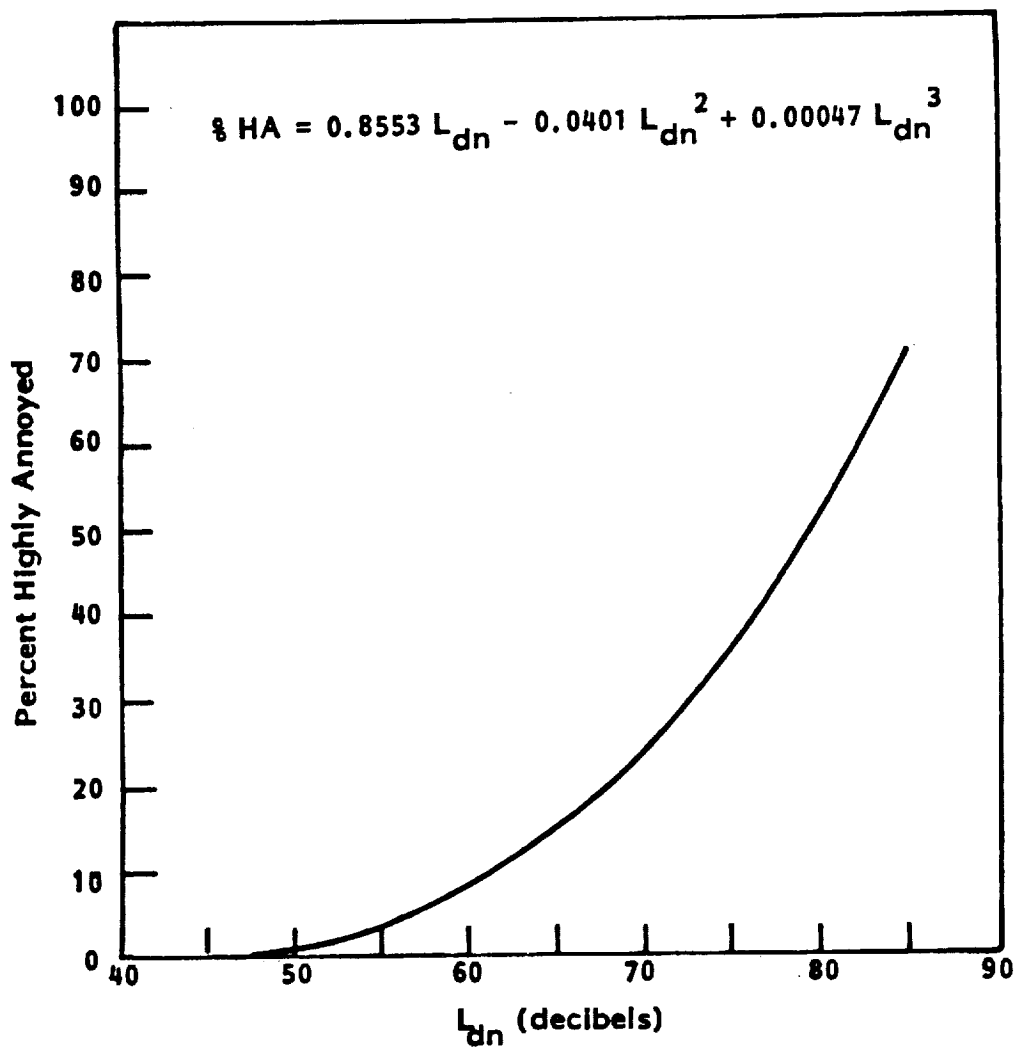


Figure 2. Dose-effect relationship for annoyance associated with general transportation noise according to Schultz; 1978

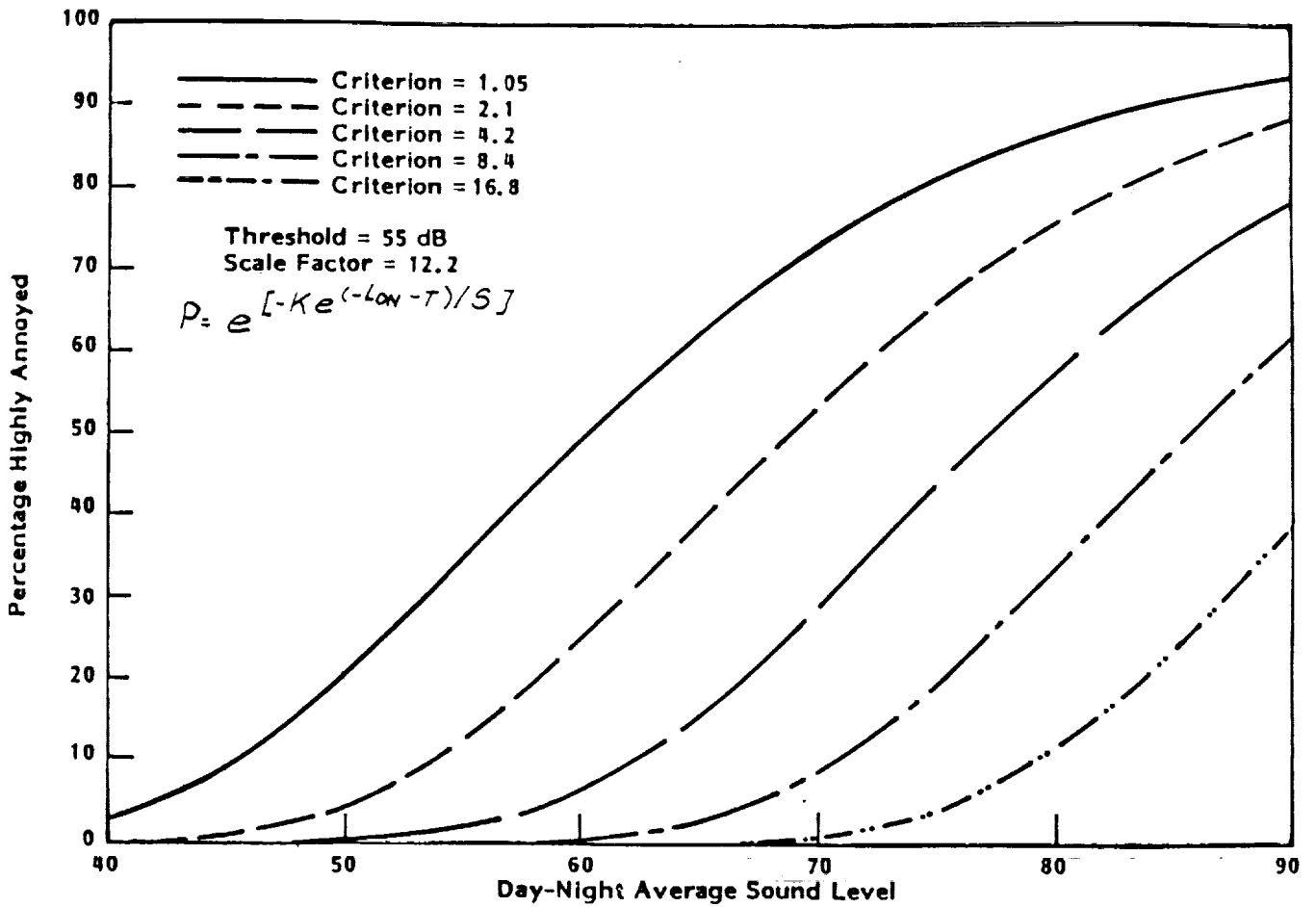


Figure 3. Effect of changing criterion for reporting high annoyance on dose-effect relationship; Fidell et al. 1987

There are two basically different processes that govern an individual's response to noise. At low levels up to a certain threshold, the noise is "tolerated" and represents only a certain "disturbance". If the response to a stimulus in this region follows traditional psychophysical theory, Weber's and Fechner's laws may be applied. Hence a function showing the relationship between degree of disturbance/annoyance and noise level in dB should be a straight line.

In any given situation there is a certain level, however, at which the noise changes from "just disturbing" to "really annoying". This situation may be explained by a threshold concept. We discussed the hypothesis with T.J.Schultz and he suggested the following possible explanation:

" I think we adopt 'contracts' among ourselves in order to live close together in communities. These 'contracts' are not usually acknowledged or even recognized, and certainly the number of 'clauses' is never known (much less their content). But they are there. They are not enforceable, obviously, until enough people realize that their 'agreement' is being infringed upon. And then it becomes a stickier matter with lawyers and courts who have never quite realized the nature of the 'implicit contracts' that determine the boundaries between undeniable 'disturbance' and 'annoyance', which appear when the contract has been felt to be breached."

In terms of reaction to noise the 'contract' implies that an individual has a certain limit of tolerance, and as long as the noise levels stay below this limit, the reaction follows a certain pattern as explained above. When the 'contract' is broken, however; that is, the noise increases above the limit silently agreed upon, the individual reacts immediately, and the reaction is of a different kind than in the 'disturbance mode'. The reaction to noise above this threshold follows a different psychophysical 'model', but again Weber's and Fechner's laws should be applicable. Hence a reaction versus noise plot in this level region will also be a straight line.

According to this hypothesis the relationship between degree of disturbance/annoyance and noise exposure can be depicted by two straight lines with a discontinuity at a certain threshold level.

The threshold level is an individual quantity and may vary depending on expectations, activity, location, time of day, etc. Different people within a community will have different thresholds. On a community basis we will therefore see a transition interval rather than a fixed noise threshold, but for simplicity reasons we may still use a single threshold level for our discussion.

Reported differences in community reaction to noise may thus be explained by differences in the threshold level for onset of the annoyance reaction. In a busy community with a high ambient noise level, we may expect a high tolerance threshold, where as the people living in a quiet rural area have a low threshold. This fact makes it impossible to compare dose-response relationships found in one community with those from another community without considering the possibility that the 'community reaction thresholds' are different.

The threshold is most likely associated with the instantaneous noise level rather than the equivalent level or a similar 'average' noise index. Differences in the reported annoyance in areas with equal LEQ may therefore also be explained by differences in the noise exposure pattern, even though the reaction thresholds are the same.

At a conference in 1988 we presented a paper indicating that location relative to the flight path was an important parameter for predicting the annoyance from aircraft noise (5). People living underneath the take-off flight path seemed to report a higher degree of annoyance than people living outside those areas.

For equal LEQ each noise event observed underneath the flight path has a shorter duration and higher maximum level than at other locations. This means that people living underneath the flight paths are more likely to feel that 'their contract has been breached', and they react more often according to the 'above threshold psychophysical model'.

## Discussion

In figure 4 we have fitted linear regression lines to the results from the Fornebu study. The dashed line ( $r=.865$ ) is fitted to the complete data set. We get a better fit, however, if we assume a change in the reaction pattern around 60-65 dBA. The two solid lines are based on data points 42-65 dBA ( $r=.911$ ) and 60-74 dBA ( $r=.878$ ). These results indicate a possible discontinuity in the 60-65 dBA region.

According to our previous findings we divided the different respondents into three groups depending on their residence. By using the information from the flight track recorder we could define three types of locations: areas underneath the approach flight paths, areas underneath the take-off flight paths, and areas never (or seldom) overflowed.



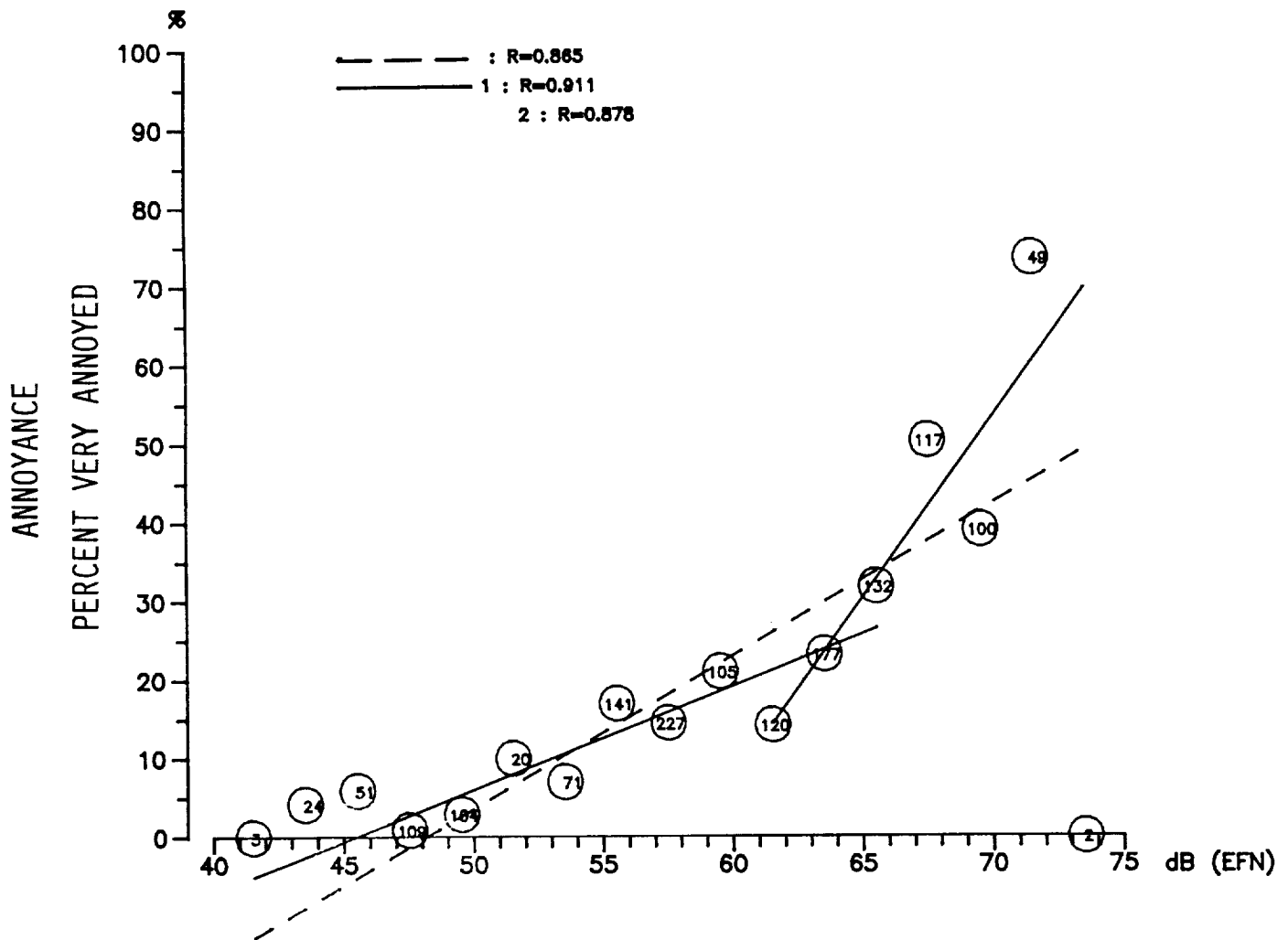


Figure 4. Results from the Fornebu survey  
 Percentage of people very annoyed as a function of noise exposure.  
 Dashed line: linear regression to all data points  
 Solid line: two regression lines, 42-65 dBA and 60-74 dBA

Figure 5 shows the response from people living in the approach path areas. A single regression line has a correlation coefficient  $r=.701$  where as a two-stage method yields  $r=.775$  for the 42-65 dBA region (477 respondents) and  $r=.484$  for the 60-74 dBA region (149 respondents).

Figure 6 shows similar results from the take-off areas. The total number of respondents is only 242 with most of them experiencing noise exposure above 60 dBA. A regression line is therefore fitted to the whole data set. The correlation coefficient is  $r=.789$ .

Figure 7 shows the results from areas outside the flight paths. A single regression line gives  $r=.908$ , whereas two lines for the same exposure regions as above have correlation coefficients  $r=.953$  (730 respondents) and  $r=.747$  (365 respondents).

### Conclusions

The total material is not large enough to draw firm conclusions. In the next phase of the study, however, we will have the results from an additional 1800 respondents. Hopefully these results will confirm our hypothesis.

We think the higher annoyance score observed in the take-off areas can be explained by the fact that people in these areas are exposed to higher instantaneous noise levels, and hence the probability of reacting according to the 'annoyance model' rather than the 'disturbance model' becomes greater.

One way of discriminating noise exposure that actually contributes to annoyance from noise exposure that is not of great enough magnitude to be recognized as such is to introduce a threshold level. We have shown in (3) that the equivalent level measured only for those periods that the noise level exceeds a certain threshold is a good descriptor for noise annoyance. Laboratory experiments have confirmed that the equivalent level with threshold, LTEQ, is superior to the regular LEQ in predicting subjectively reported noise annoyance (4).

Moreover, this index, LTEQ, is based on a psychophysical model. In his book, Community Noise Rating, (6) Schultz reviews different noise indices. In a comparison between LEQ and LTEQ he points out: "Not only is the correlation coefficient higher and the standard error of estimate lower for the plot against LTEQ (annoyance versus noise exposure), but the latter curve presents a much more plausible-looking fit to the data points than the LEQ curve."

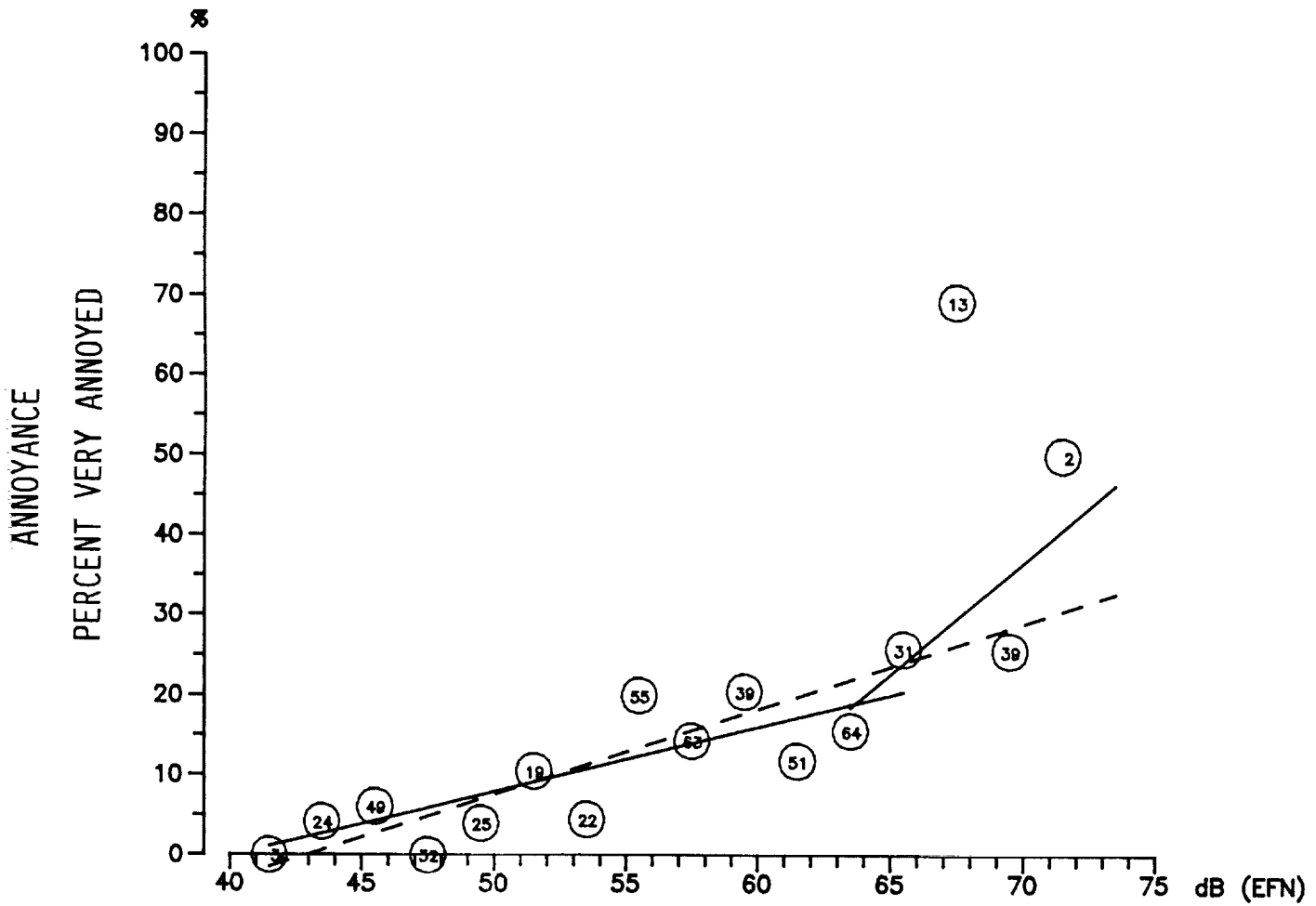


Figure 5. Results from the Fornebu survey  
 Percentage of people very annoyed as a function of noise exposure for respondents living under the approach flight paths.  
 Dashed line: linear regression to all data points  
 Solid line: two regression lines, 42-65 dBA and 60-74 dBA

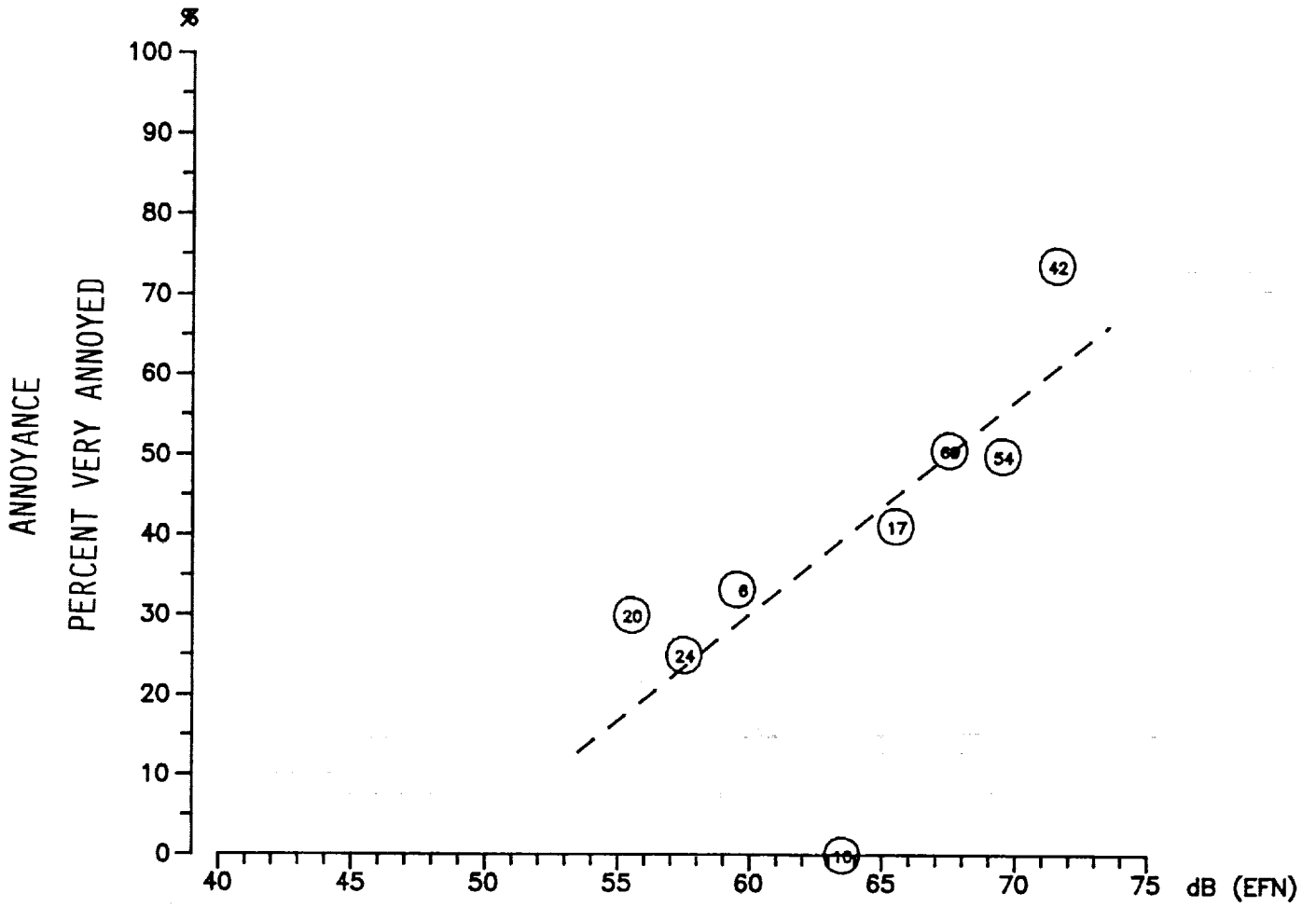


Figure 6. Results from the Fornebu survey  
 Percentage of people very annoyed as a function of noise exposure for respondents living under the take-off flight path.  
 Linear regression to all data points

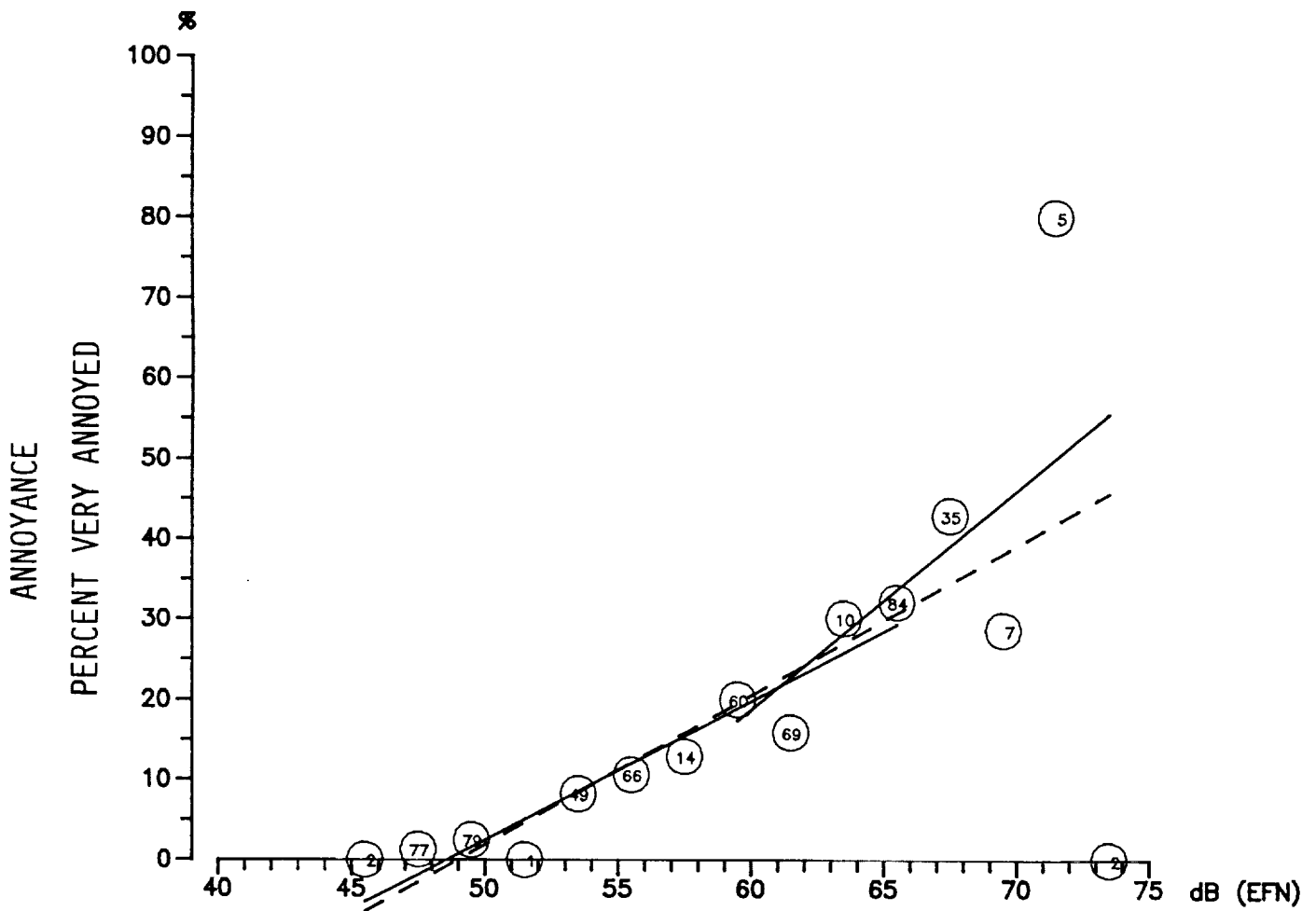


Figure 7. Results from the Fornebu survey  
 Percentage of people very annoyed as a function of noise exposure for respondents living outside the flight paths.  
 Dashed line: linear regression to all data points  
 Solid line: two regression lines, 42-65 dBA and 60-74 dBA

With the combined data from the two surveys around Fornebu Airport, we hope to confirm the hypothesis that the annoyance is a function of exposure to noise above a certain threshold, and that this threshold depends on community expectations rather than a fixed quantity. If this conclusion is valid, results from noise surveys around busy airports cannot be used to predict aircraft noise in other areas, for instance en route noise experienced in rural areas. The reaction to noise in these areas may be expected to be much higher, as the probability that the annoyance threshold is exceeded, is higher.

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#### Acknowledgment

To a good friend, Ted Schultz.