Predicting noise-induced sleep disturbance

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The findings of 21 studies of the effects of noise on sleep were reanalyzed in an effort to develop a quantitative dosage-response relationship. Large and systematic differences in sleep disturbance were observed between the findings of studies conducted in laboratory and in field settings. The influence of noise on sleep was also found to depend on additional factors such as the nature of noise and response metrics, noise source, background noise level, length of study, and sex of test participants. No reliable quantitative model for sleep disturbance could be developed from the studies reviewed.

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INTRODUCTION

The quantitative dosage-response relationship between noise exposure and the prevalence of annoyance synthesized by Schultz (1978) has proved to be a useful tool for assessing effects of transportation noise. The demonstrated utility of a quantitative dosage-response relationship for one important effect of noise on people has encouraged efforts to synthesize such a relationship for others, including sleep disturbance. The efforts of Lukas (1977), who reviewed the effects of noise on sleep in studies conducted through the 1960's, are perhaps the best known. Practical applications of the relationship derived by Lukas are limited by the relatively small amount of information then available for analysis, by the great variability of these data, and by the dissimilarity of noise exposure conditions in the laboratory and in communities. The current reanalysis of early data and more recent information was undertaken in the hope of establishing a more reliable basis for predicting sleep disturbance due to noise exposure in community settings. The studies reviewed in the current effort include reports of the effects on sleep of noise in 53 publications concerning noise-induced sleep disturbance under both laboratory and field conditions.

In the 26 studies reviewed by Lukas (1977), noise exposure was under experimental control and test participants slept in places other than their customary sleeping quarters. These studies intentionally exposed test participants to noises (primarily aircraft and vehicular traffic) at controlled times and presentation levels. Lukas considered four metrics of indoor noise as independent (predictor) variables. These four highly intercorrelated metrics were (1) maximum A-level, (2) "effective" (that is, duration adjusted) A-level, (3) effective perceived noise level (EPNL), and (4) single event noise exposure level (SENEL).[1] Lukas concluded from the relative strengths of the correlations between sleep disturbance and each of these metrics that duration-corrected noise metrics were preferable to metrics based on maximum noise level alone. Lukas thus adopted EPNL as the independent variable for the dosage-response relationship he derived.

Lukas focused on three measures of sleep disturbance, "awakening," "arousal," and "no sleep disruption" as dependent variables. "Awakening" was defined behaviorally, via a button push or a verbal confirmation of awakening. "Arousal" was defined as an indication of an awake stage derived from EEG records. "No sleep disruption" was defined as a failure to shift to at least one lighter stage of sleep within 1 min of stimulus termination, also as indicated by EEG records. The dosage-response relationships Lukas inferred for awakening and no sleep disruption (sleep stage change) are plotted in Figs. 1 and 2 along with other relationships described below.

Another well-known review of studies of noise effects on sleep, conducted by Griefahn in 1976, was published in translation in 1980. Griefahn, like Lukas, evaluated awakening and failure of sleep disruption as her dependent variables. The latter variable was termed "zero reactions" in Griefahn's analyses. Unlike Lukas, Griefahn used only maximum A level as an independent variable for predicting sleep disturbance. In addition to deriving dosage-response relationships for awakening and zero reactions, Griefahn also compared total sleep time and time spent in various sleep stages during nights with and without noise exposure. The sounds presented to test participants in studies analyzed by Griefahn included samples of aircraft, trains, white noise, tones, and road traffic, ranging in A-weighted level from 55 to 100 dB.

The relationships Griefahn derived from the data of 10 studies are also shown in Figs. 1 and 2. Although Griefahn reviewed many of the same studies reviewed by Lukas, Griefahn's synthesis suggested that awakening occurs at sound levels roughly 15 dB greater than those inferred by Lukas. Furthermore, the slope of the relationship inferred by Griefahn was greater for both awakening and sleep disruption.

Griefahn also noted evidence of habituation to noise exposure in the findings of laboratory studies. For example, a level of noise exposure that awakened half of the test subjects on the first night of a twelve-night test awakened only about a third of the test subjects by the seventh through twelfth nights. The frequency of reaction increased from 50% the first night until about the seventh night, when the percentage of zero reactions occurring had increased to 70%, at which level it remained until the twelfth night. Griefahn

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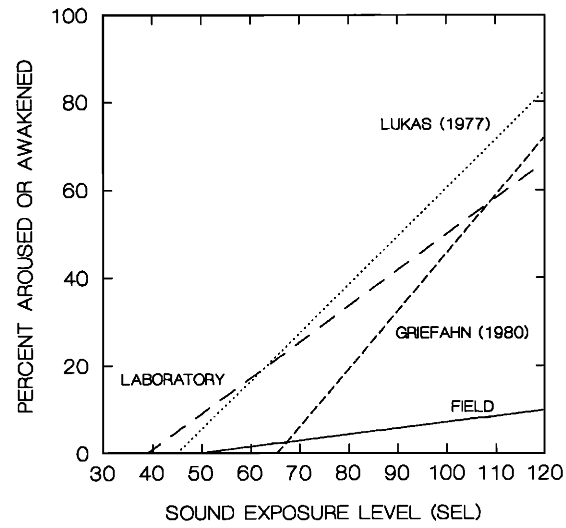

FIG. 1. Four dosage-response relationships for awakening as a function of noise intrusions measured in SEL: Lukas (1977), Griefahn (1980), current analysis of laboratory data, and current analysis of field data.

noticed a similar effect for awakenings from multiple signal presentations throughout the night at A-weighted levels of 58–87 dB. As the number of signal presentations increased from 0 to 35 per night, awakenings increase to about 3.5 per night by 30 signal presentations.

Habituation (in the current context, a learned ability to ignore the disturbance of noise intrusions) played a role in awakening, both over a series of nights and over events within a single night. Griefahn also commented on associations among sex, age, awakenings, and zero reactions. While no clear relationship was observed between the sex of test participants and sensitivity to noise-induced sleep disturbance, Griefahn noted that the sleep of older people (both numbers of awakenings and zero reactions) was more readily disturbed by noise than that of younger people.

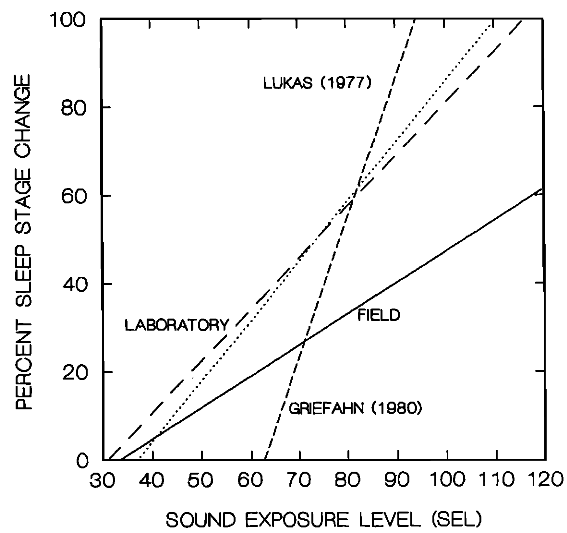

FIG. 2. Four dosage-response relationships for change to a lighter stage of sleep as a function of noise intrusions measured in SEL: Lukas (1977), Griefahn (1980), current analysis of laboratory data, and current analysis of field data.

The current reanalyses were undertaken because the dosage-response relationships developed by Lukas and Griefahn account for relatively little variance, and because new information about noise-induced sleep disturbance has been published since these relationships were developed.

I. METHOD

Data sets from 53 studies of the effects of noise on sleep were identified for the present review. The bulk of these were conducted under laboratory conditions with controlled signal presentations. Several, however, were conducted in field settings with naturally occurring noise intrusions occurring in the participant's customary sleeping quarters. Several contrived exposure studies were also reviewed in which an experimenter introduced noise intrusions into familiar sleeping quarters.

A. Studies reanalyzed

Of the 53 studies reviewed, data from 32 studies proved unusable for a variety of reasons including (1) non-quantitative information, (2) duplication of data in multiple reports, (3) lack of information about individual noise event levels, or (4) sleep or noise data which could not be converted into metrics consistent with those of the remaining studies. Table I summarizes the noise sources and data collection settings of the 21 studies used in the current analysis. Pearsons *et al.* (1990) describe the 53 studies in greater detail.

Bivariate regressions were planned to infer a dosage-response relationship from these studies. Additional multiple regression analyses were planned to explore effects on sleep disturbance of variables other than noise level.

B. Dependent variables

Of the numerous ways that sleep disturbance may be measured, only a few are useful for pragmatic environmental impact assessment purposes. For present purposes, measures of greatest interest are those most directly comparable with the predictor variable of a well-known dosage-response relationship for noise-induced sleep disturbance (FICON, 1992). The two dependent variables of the present analysis were (1) the percentage of test participants awakened or aroused, and (2) the percentage who exhibited sleep stage change (as measured electrophysiologically). Some studies reported results in terms of both measures, while others reported only one or the other measure of sleep disturbance. 136 data points from 21 studies were available for analyses of arousal and awakening. 83 data points from twelve studies were available for analyses of sleep stage change.

Information about percentages of test participants awakened or aroused by a noise of a specifiable level was not included in all of the reports reviewed, but could be estimated from published information in most cases. Twelve studies contained information on "no sleep disruption" (as defined above), although not necessarily in a form useful for dosage-response analyses. Some reports specified the percentage of subjects affected, but others specified only the percentage of time for one subject for which a failure of

TABLE I. Reanalyzed studies.

Study	Study type	Noise type	Number of nights
Collins and Iampietro (1973)	Laboratory	Simulated sonic boom	12
Horonjeff, Bennett, and Teffeteller (1979)	Quasi-lab	Transformer line, transmission, air conditioner, traffic	21
Johnson (1973)	Laboratory/ quasi-lab	Artificial ping	30
Kramer, Roth, Trindar, and Cohen (1971)	Laboratory	White noise	7
Ludlow and Morgan (1972)	Laboratory	Sonic boom	4
Lukas, Dobbs, and Kryter (1971)	Laboratory	Jet flyover, simulated sonic boom	20
Lukas and Dobbs (1972)	Laboratory	Jet flyover, simulated sonic boom	10
Lukas, Peeler, and Dobbs (1973)	Laboratory	DCB landing (treated and untreated), nacelles, pink noise burst	9
Lukas, Peeler, and Davis (1975)	Laboratory	Blown flap STOL (sideline and takeoff), turbo fan STOL, pink noise burst	8
Muzet, Scheiber, Oliver-Martin, Ehrhart, and Metz (1973)	Laboratory	Aircraft	1
Öhrström (1983)	Laboratory	Traffic	4
Öhrström, Rylander, and Bjorkman (1988)	Field	Traffic	
Osada (1975)	Laboratory	Rail	5
Pearsons, Bennett, and Fidell (1973)	Field	Aircraft	5
Research Group on the Effect of Noise (1971)	Laboratory	Jet Aircraft	
Rylander, Sörensen, and Berglund (1972)	Field	Traffic[a]	1
Stevenson and McKellar (1989)	Quasi-lab	Traffic	
Thiessen (1978)	Laboratory	Truck	24
Vallet, Gagneux, and Simonnet (1980)	Field	Aircraft	4
Vernet (1979)	Field	Rail, road	1
Zimmerman (1970)	Laboratory	800 Hz tone	1

[a]Majority of stimuli in study were sonic booms. However, one truck on one night was present during study of 189 people, the effects of which are included in this review.

change of sleep stage occurred within 1 min of the occurrence of a noise signal. Thus, sleep stage change (which includes all changes of sleep stage to a lighter stage, including awakening) is preferred in the present analyses in lieu of "no sleep disruption."

C. Independent variables

Noise metrics commonly used in sleep research to characterize individual events as heard indoors include (1) maximum A-level (AL_{max}), (2) perceived noise level (PNL), (3) sound exposure level (SEL), (4) effective perceived noise level (EPNL), and (5) C-level (CL). All of these measures either express sound pressure at a point in time (AL, CL, and PNL), or include duration by summing the noise over the entire event (SEL or EPNL). The effect of duration is apparent in the following approximation to SEL based on maximum AL and duration:

$$\mathrm{SEL}=\mathrm{Al}_{max}+10\log D/D_{ref}, \tag{1}$$

where D is the effective duration in seconds and D_{ref} is a reference duration of 1 s.

Noise metrics that characterize the noise of a group of events over an entire night or 24-h day include (1) equivalent noise level (L_{eq}), (2) composite noise level (CNL), (3) day-night average level (L_{dn}), (4) community noise equivalent level (CNEL), and (5) cumulative centile levels ($L_{\%}$). AL_{max}, used in the majority of recent studies, and SEL were selected for use as potential predictor variables for the present review.

Estimates of SEL were made for studies that reported only AL_{max} from the relation given in Eq. (1). Since most of the noise signals were either aircraft flyovers with a triangular time pattern, or steady sounds with a rectangular time pattern, the relation reduces to the following equations:

$$\mathrm{SEL}=\mathrm{AL}_{max}+10\log D_{10}/D_{ref}-3.7 \quad \text{(triangular time pattern)}, \tag{2}$$

$$\mathrm{SEL}=\mathrm{AL}_{max}+10\log D_{10}/D_{ref} \quad \text{(rectangular time pattern)}, \tag{3}$$

where D_{10} is the duration as measured while the noise is within 10 dB of its maximum level (10-dB-down duration) and D_{ref} is a reference duration of 1 s. Values used to estimate SEL from maximum AL_{max} for the studies reanalyzed are contained in Pearsons *et al.* (1990). The constant 3.7 is derived by integration of the squared sound pressure within a triangular time pattern of sound levels (in decibels) in accordance with the following formula:

$$\mathrm{SEL}=10\log\int_0^T(10^{\mathrm{AL}(t)/10}dt), \tag{4}$$

where $\mathrm{AL}(t)$ is the A level at each instant in time and T is the total duration in seconds.

Choices of additional predictor variables depended on availability. For example, age has been suggested to influence the relationship between noise and sleep disturbance (Griefahn, 1980). However, the reviewed studies reported age ranges so great that differences in age ranges (or median ages) among studies would have been slight. The only variables that could be coded with reasonable reliability were sex of test subjects, location of the study (laboratory or field), type of noise intrusion, a crude measure of background noise level, and number of nights subjects spent in a noisy environment.

D. Coding and transformations of variables

Several of the variables required recoding or transformation for purposes of bivariate and multiple regression analyses. Dummy coding (see Tabachnick and Fidell, 1989) was used to transform a number of variables such that one category was assigned a code of "1," while all other categories of that variable are assigned a code of "0." Background noise in AL_{max} was coded into three levels: lower than 30 dB, 31 to 49 dB, and greater than 50 dB. This three-level variable, BACKGROUND, was treated as a continuous variable. Likewise, type of study was classified into three categories: Laboratory, field, and contrived field study. Two dummy coded dichotomous variables were created for these classifications: Laboratory versus other study type (LAB), and true field vs other study type (FIELD). Additional dummy-coded variables included sex (MALE and FEMALE), and three variables indicating type of noise exposure: JET, BOOM, and TRAFFIC. Number of nights in a noisy environment (LENGTH) was a continuous variable.

Preliminary analyses were performed with a normal probability (probit) transformation of the two dependent variables (awakening/arousal and sleep stage change). Only those analyses with untransformed dependent variables are reported here, since results were not affected by the transformation.

E. Data analyses

Four separate bivariate regression analyses were performed for each combination of two dependent variables (arousal/awakening and sleep disturbance) and two independent variables (AL_{max} and SEL). Bivariate regressions were also calculated separately for laboratory and field studies. Four separate hierarchical multiple regression analyses were also performed for the same combination of the two dependent variables and two major independent variables. Because results for SEL and AL_{max} were very similar, only the multiple regression results for SEL are reported.

Order of entry of variables into the prediction equation was the same in each of the hierarchical regression analyses. The first variable entered was noise level. Variables based on subject characteristics, MALE and FEMALE, were entered next. Variables reflecting type of noise intrusion, JET, BOOM, and TRAFFIC were entered at the third step of the hierarchy. The fourth step included characteristics of the study: Location (LAB and FIELD), BACKGRD noise level, and LENGTH of time subjects spent in the study.

II. RESULTS

The data contained no serious violation of the usual assumptions of multiple regression analysis concerning multivariate normality, linearity, and multicollinearity, nor were there any unduly influential cases when using sleep stage change as a dependent variable. However, the three cases in which sonar-like pings were the noise source predicting arousal/awakening were grossly deviant from the remaining cases ($p<0.001$ using Mahalanobis distance as a criterion). These three outliers were therefore dropped from further consideration. When using arousal/awakening as a dependent variable, there is far greater variance in number of awakenings at high noise levels than at low noise levels. Underestimation of the influence of noise level on probability of awakening is the likely consequence.

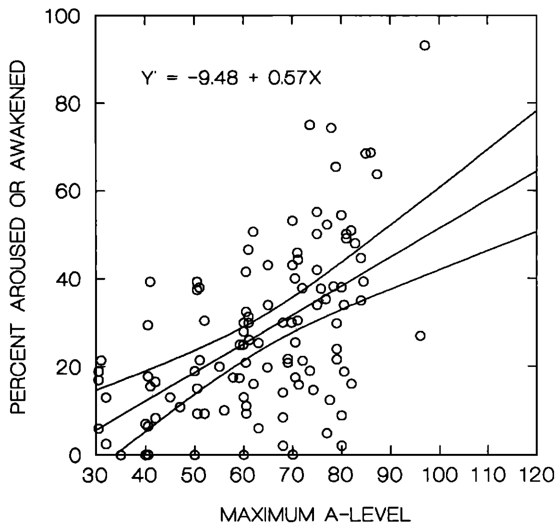

FIG. 3. Percent of participants aroused or awakened in laboratory studies as a function of noise intrusion measured in AL_{max}.

A. Bivariate relationships between noise and sleep

Figures 3 and 4 show bivariate regressions for predicting awakening from AL_{max} for laboratory (including contrived exposure) and field data points, respectively. Both laboratory

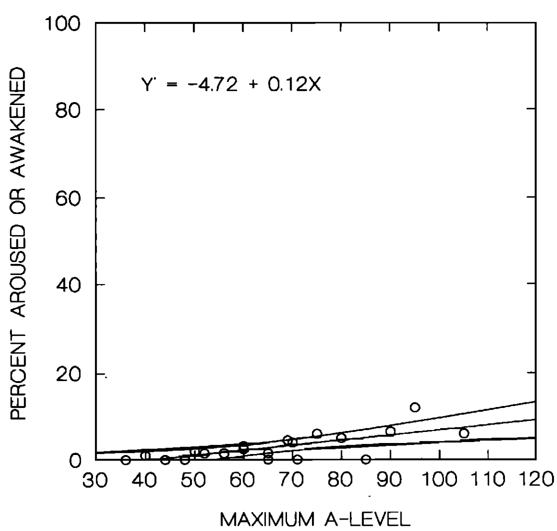

FIG. 4. Percent of participants aroused or awakened in field studies as a function of noise intrusion measured in AL_{max}.

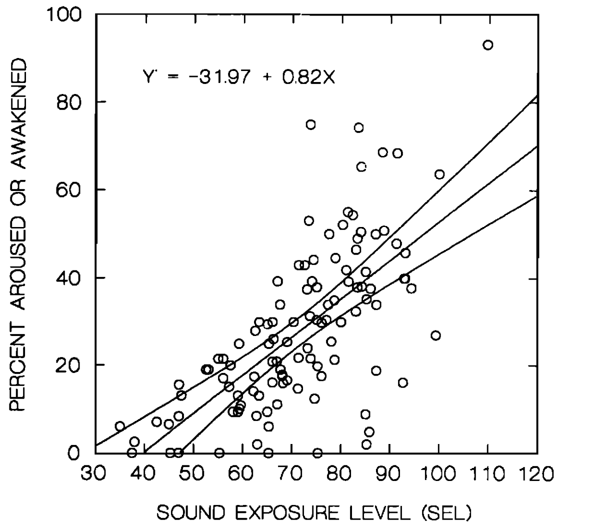

FIG. 5. Percent of participants aroused or awakened in laboratory studies as a function of noise intrusion measured in SEL.

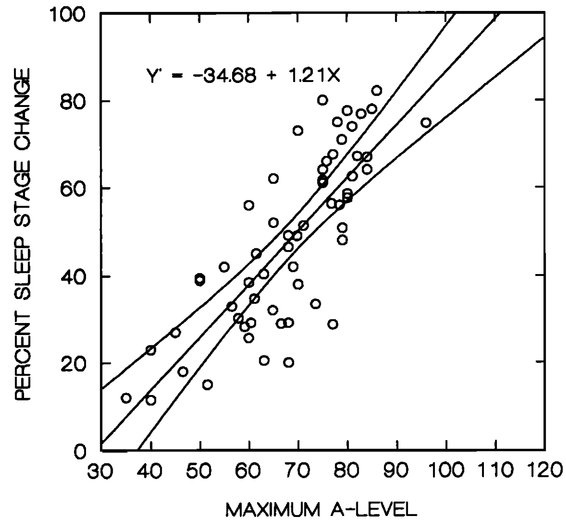

FIG. 7. Percent of participants changing to a lighter stage of sleep in laboratory studies as a function of noise intrusion measured in AL_{max}.

and field studies show a reliable relationship between AL_{max} and awakening: $r_{113}=0.47$, $p<0.01$, and $r_{19}=0.70$, $p<0.01$, respectively.

Bivariate regressions between awakening and noise level as measured by SEL also show reliable relationships for both laboratory and field studies: $r_{113}=0.62$ and $r_{19}=0.70$, $p<0.01$, respectively, as seen in Figs. 5 and 6.

Bivariate predictions of sleep stage change from noise intrusion measured in AL_{max} are likewise strong and statistically reliable: $p<0.01$, for laboratory data, $r_{57}=0.80$, as well as for field data, $r_{22}=0.83$ (Figs. 7 and 8, respectively).

Figures 9 and 10 show that bivariate regression using noise intrusion measured in SEL as a predictor remains strong: $p<0.01$, for both laboratory data, $r_{57}=0.79$ and field data, $r_{22}=0.78$.

B. Differences between laboratory and field studies

As is evident from Figs. 3–10, very different results were observed in laboratory (including contrived exposure)[2] and field studies for all four combinations of noise and sleep stage change. The slopes of the dosage-response relationships for laboratory data are much steeper than those for field data, although the field studies tend to produce more reliable regressions (narrower confidence intervals). Regression coefficients for laboratory ($B=0.57$) and field ($B=0.12$) were significantly different, $F_{2,132}=17.96$, $p<0.01$, for predictions of awakening from AL_{max}. Regression coefficients for laboratory ($B=0.82$) and field ($B=0.14$) were also reliably different when using the SEL measure of noise to predict awakening, $F_{2,132}=17.85$, $p<0.01$.

Reliable differences in regression coefficients were found between laboratory ($B=1.21$) and field ($B=0.77$) studies, $F_{2,79}=10.99$, $p<0.01$, when predicting sleep stage change by AL_{max}. Significantly different regression coefficients were again produced by laboratory ($B=1.17$) and field ($B=0.71$) studies, $F_{2,79}=18.64$, $p<0.01$ using SEL.

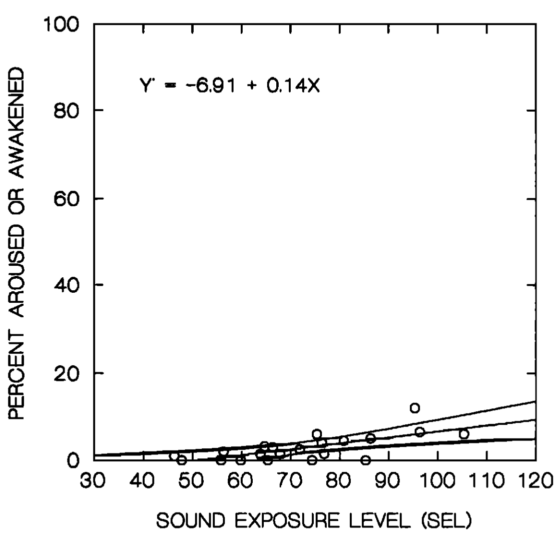

FIG. 6. Percent of participants aroused or awakened in field studies as a function of noise intrusion measured in SEL.

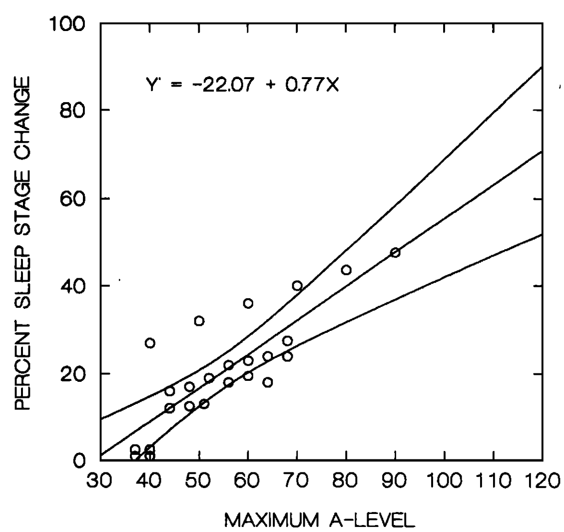

FIG. 8. Percent of participants changing to a lighter stage of sleep in field studies as a function of noise intrusion measured in AL_{max}.

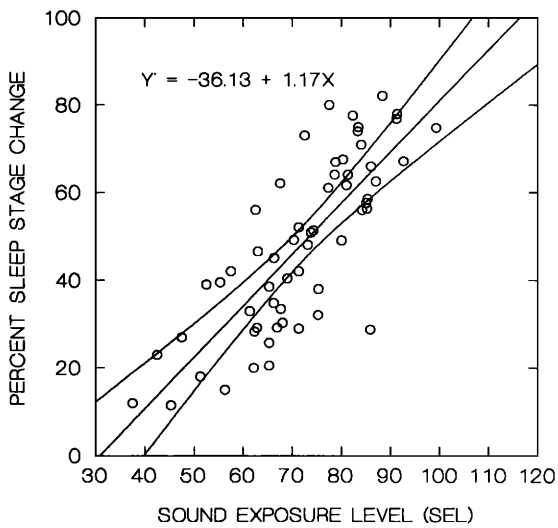

FIG. 9. Percent of participants changing to a lighter stage of sleep in laboratory studies as a function of noise intrusion measured in SEL.

C. Comparison with prior reviews

Figure 1 compares the current findings with those of Lukas (1977) and Griefahn (1980) for predicting arousal or awakening from SEL. Figure 2 compares results for predicting sleep stage change from the same means. The slopes of the relationship between noise metrics and effects vary from a very shallow slope in field studies, to increasingly steeper slopes for laboratory studies, to the relationship inferred by Lukas, and to that inferred by Griefahn. The relationship developed in the current review for laboratory studies resembles that of Lukas, but differs considerably from that inferred by Griefahn. The discrepancy between Griefahn's findings and those of Lukas and the present study may be attributable in part to the manner in which the transformation of Griefahn's results from AL_{max} to SEL was accomplished, and in part to the inclusion of different studies in the present analyses.

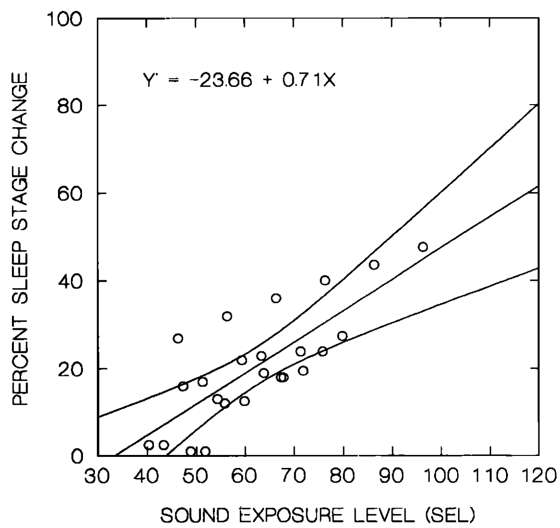

FIG. 10. Percent of participants changing to a lighter stage of sleep in field studies as a function of noise intrusion measured in SEL.

TABLE II. Hierarchical regression of several study variables including SEL on probability of arousal or wakening.

Variable	Regression coefficient	Standardized regression coefficient	sr^2 (inc)
Noise level			0.30^b
SEL	0.73	0.54^b	
Subject characteristics			0.02
Male	13.01	0.32^b	
Female	19.79	0.21	
Type of noise			0.03
Jet	−5.80	−0.13	
Sonic boom	−15.74	-0.25^b	
Traffic	−0.16	−0.00	
Study characteristics			0.26^b
Lab	−7.12	−0.18	
Field	−26.33	-0.49^b	
Background	12.47	0.31^b	
Length	0.53	0.22	
Intercept	=−49.19		
$R^2=0.61$			
Adjusted $R^2=0.58$			
$R=0.78^b$			

[a] $p<0.05$.
[b] $p<0.01$.

D. AL_{max} vs SEL

SEL was a stronger predictor of arousal/awakening than AL_{max} using a test for the difference between paired correlations with laboratory and field data combined, $z=3.22$, $p<0.01$. However, when predicting sleep stage change a stronger relationship was found using AL_{max}, $z=2.24$, $p<0.05$.

E. Other predictors of sleep disturbance

Table II summarizes the hierarchical regression of variables on the probability of awakening following exposure to noise intrusions of varying SEL values. A statistically significant relationship was observed, $F_{10,122}=19.03$, $p<0.01$, for all predictors together. In combination, all predictors considered accounted for 61% of the variability in awakening (58% when adjusted for inflation of R^2 due to small samples). Squared semipartial correlations (sr^2) indicate the importance of sets of variables as they are added to the prediction equation. Absolute values of standardized regression coefficients indicate unique contributions of variables to prediction (over and above contribution of all other variables).

All types of variables contributed significantly to prediction of arousal/awakening with noise level the strongest predictor. Significant prediction of awakening ($p<0.01$) was produced by gender (whether the subject sample was restricted to men) after adjusting for noise level. The noise-type offering the major contribution to prediction is whether sonic booms were used ($p<0.01$). Among study characteristics, study locus (laboratory or field) and background noise

TABLE III. Hierarchical regression of several study variables including SEL on probability of sleep stage change.

Variable	Regression coefficient	Standardized regression coefficient	sr^2 (inc)
Noise level			0.61^b
SEL	1.19	0.77^b	
Subject characteristics			0.02
Male	6.12	0.13	
Female	16.03	0.26^b	
Type of noise			0.07^b
Jet	−2.50	−0.06	
Sonic boom	−5.40	−0.07	
Traffic	11.73	0.24^b	
Study characteristics			0.14^b
Lab	8.14	0.18	
Field	−5.95	−0.13	
Background	1.06	0.02	
Length	0.55	0.20^a	
	=−55.33		
Intercept			
$R^2=0.83$			
Adjusted $R^2=0.80$			
$R=0.91^b$			

[a] $p<0.05$.
[b] $p<0.01$.

level both made strong, statistically significant ($p<0.01$) contributions to prediction.

Table III shows that sleep disturbance as defined in terms of EEG is more predictable than by awakening alone, $F_{10,72}=34.69$, $p<0.01$. With all variables considered together, 83% of the variance (80% adjusted) was accounted for in predicting sleep stage change. Noise level made the greatest contribution to prediction. Other variables related to sleep stage change included sex and type of noise ($p<0.01$). Length of the study also provided reliable prediction of sleep stage change ($p<0.05$).

III. DISCUSSION

Differences in dosage-response relationships inferred for laboratory and field studies were pronounced whether disturbance was measured by awakening or sleep stage change, and whether noise was measured as AL_{max} or SEL. The apparent effects of noise on sleep were stronger under laboratory conditions both when predicting arousal or awakening and when predicting more subtle measures of sleep disturbance.

For example, Figs. 5 and 6 show that when measuring awakening to noise measured in SEL, a 10 dB increase in noise was associated with an increase in probability of awakening of about 8% in the laboratory, but only about 1% in the field. Indeed, Figs. 4 and 6 show that even at noise levels or SEL values as high as 85 dBA no awakenings or arousals were observed in at least one study. This observation suggests a strong influence of habituation on susceptibility to noise-induced sleep disturbance.

Although noise disturbs sleep in laboratory studies to a greater degree than in the field, laboratory studies provide less reliable data. Sleep disturbance produced by experimentally controlled noise is more variable than disturbance produced by naturally occurring noise, especially with respect to awakening. The range of sleep interference in laboratory data is enormous, particularly at high levels. At 85 dB (SEL), the probability of awakening varies from less than 5% to as much as 75%. The wide confidence bars in Figs. 2–10 suggest caution in generalizing laboratory findings.

It is also clear that sleep disturbance is highly sensitive to the definition of disturbance. Dosage-response relationships are stronger for milder sleep disruptions than for awakening. SEL provides stronger prediction of awakening, while AL_{max} better predicts change to a lighter stage of sleep. The current results suggest more reliable predictions based on SEL. Note, however, that many of the SEL values were derived from studies which reported only AL_{max}.

The results clearly show that prediction of sleep disturbance can be enhanced by taking into account factors other than noise level, although interpretation must be tempered by the crude nature of most of the measures. As expected, the strongest determinant of sleep disturbance was noise level, whether measured in AL_{max} or SEL. No additional predictors were assessed with sufficient accuracy or reliability to reveal the magnitude of their influence on interference with sleep. Habituation, almost certainly a major moderator of the influence of noise on sleep, was measured only crudely as the length of the study.

Correlations among predictors in these data tended to be much higher than would be expected in the population to which generalization is desired, because some were spuriously produced by the way the studies were conducted. The effect of these spurious correlations is to limit the magnitude of the apparent contribution of any single predictor after adjusting for other predictors. Since each one of the independent variables significantly affected sleep in at least one of the multiple regressions, all should be considered in further analyses.

The foregoing discussion addresses the contribution of individual predictors to sleep disturbance, but not the issue of overall prediction. Although some of the multiple regressions yielded reliable predictions, this predictability may be low relative to that which could be obtained if better measurement of predictors were available. Greater individual variability in arousal and awakening at higher noise levels also attenuates multiple correlations.

IV. CONCLUSIONS

Analyses of published findings on noise-induced sleep disturbance revealed large discrepancies between those of laboratory studies and those of field studies.[3] These discrepancies were so great that there is little basis for inference of a simple dosage-response relationship between noise exposure and sleep disturbance in both laboratory and community settings. The influence of noise on sleep depends on a variety of factors: The noise metric chosen, the response metric chosen, consideration of numerous nonnoise factors affecting the relationship, and, especially, whether the study is conducted in the laboratory under contrived conditions or in natural settings with noise intrusions typical of those settings.

The differences observed between findings of laboratory and field studies call into question dosage-response relationships in common use for environmental assessment purposes. In particular, the current analyses strongly suggest that the laboratory results from which such relationships have been derived may not be applicable to prediction of sleep disturbance effects in community settings.

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[1]SENEL is a noise metric developed for use in connection with California airport regulations. SENEL differs from SEL only by exclusion of A-weighted sound levels which fall below a threshold. For purposes of the review by Lukas, SENEL and SEL are identical. Furthermore, both SEL and SENEL differ from an "effective" A level only by a constant (10 dB) related to the reference durations for the various metrics.

[2]Only three of contrived exposure studies (conducted in the field, but with experimenter-controlled noise intrusions) contributed data to the current analyses. Since this is too small a number for reliable comparisons, these results of these studies were combined with those conducted in the laboratory.

[3]Readers are advised that three large scale in-home studies of noise-induced sleep disturbance have been undertaken since the completion of the analyses reported in this article. The results of these studies have not been published in archival journals at the time of preparation of the current manuscript. Preliminary reports of the findings of these studies are, however, generally consistent with the results of the analyses reported here.

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