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EFFECTS OF MILITARY TRAINING ROUTE NOISE ON HUMAN ANNOYANCE

C. Stanley Harris

ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY

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NOTICES

TECHNICAL REVIEW AND APPROVAL

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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Forty-nine subjects were tested in four experiments. Each subject experienced all conditions within his particular study. All experiments were designed to compare equal energy low onset rate flyovers with high onset rate flyovers. A measure of annoyance taken after each simulated aircraft flyover was the more sensitive measure of low versus high onset rate. The results indicate that onset rate contributes annoyance that adds to the annoyance produced by the acoustic level of the flyover. A serial search task performed during the last three experiments enhanced the annoyance reaction to high onset rate flyovers. The overall results provide support for an interim metric proposed earlier; that the Sound Exposure Level be corrected by 16.6 x log (onset rate/15 dB per second) for onset rates between 15 and 30 dB per second. The present results suggest that the penalty is needed but it may be necessary to extend the penalty beyond 30 dB per second. More research is needed to determine exactly how a final metric for high onset rate noise is to be applied.

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PREFACE

This study was performed for the Harry G. Armstrong Aerospace Medical Research Laboratory at Wright-Patterson Air Force Base, Ohio, under Project/Task 723134, Exploratory Noise and Sonic Boom Research by the Biodynamic and Bioengineering Division.

The author gratefully acknowledges Lt Col Mark Stephenson for his discussion and advise in selecting peak noise levels for the experiments. The author also thanks Mr Mike Ward of Systems Research Laboratories for help in scheduling subjects and Mr Keith Kettler and Mr Craig Zielazny of the University of Dayton Research Institute for handling most aspects of equipment setup and maintenance and subject testing.

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1. INTRODUCTION

Noise along Military Training Routes (MTRs) differs in a number of ways from conventional noise around airbases. These differences include the number of daily flights, their occurrence in time, their onset, duration and decay times, and their intensities and spectral characteristics. The most important of these factors seems to be the onset rate of the flyover. In preliminary observations, high onset rates seemed to create startle or "surprise" and contribute directly to the observers perceived annoyance (1, 2, 3). As a result of these observations, an interim noise metric was recommended for evaluating the potential annoyance of communities to MTR noise environments. The main feature of the interim metric is that for onset rates between 15 dB and 30 dB per second the Sound Exposure Level (SEL) is corrected by 16.6 x log(onset rate/15 dB per second). Higher onset rates are assigned the maximum rate of 5 dB; the same as added to the SEL at 30 dB/sec. This onset rate adjustment provides a noise penalty to account for increased intrusiveness because of the surprise factor of low altitude, high speed aircraft operations. The metric is based on the best available evidence, however, much extrapolation was necessary to make the data applicable to MTR operations. Therefore, more direct evidence is needed and the laboratory experiments described in this paper represent the beginning of the effort to obtain the required data. The main question examined in the present research was whether high onset flyover noise (impulsive) produces more annoyance than equal energy low onset noise (nonimpulsive). These studies will be followed by additional laboratory as well as field studies.

2. METHOD

2.1 Subjects

A total of 49 subjects were tested in four experiments. Twelve subjects were tested in each of the first three experiments and thirteen were tested in experiment 4. In experiment 1 the subjects were volunteers, both military and civilian, from the Biodynamics and Bioengineering Division. The age range of these subjects was 22 to 65 years. The remaining subjects used in the other three experiments were drawn from a contractor subject pool and consisted mostly of college students and housewives. They were recruited through university employment offices, however, anyone desiring a part-time position could apply. All of these subjects went through audiometric screening and were required to have normal hearing for participation in laboratory experiments. All were in their twenties or thirties.

2.2 Noise Source

The aircraft flyover simulations were presented in an anechoic chamber. A specially constructed experimental setup was used for presenting the noise stimuli (see Figure 1). In all experiments the subject sat between the two banks of speakers and the flyovers seemed to pass directly over his head in a front-to-back direction. The source of the noise was tapes recorded from various aircraft flyovers at various power settings, speeds, and altitudes. The altitudes for the aircraft for the measured recordings ranged from 100 to 1000 feet. Tapes recorded for use in the experiments contained a diverse mixture of aircraft, levels, and altitudes. A background noise level, recorded at the same time as the flyovers, of 45 dB was used in all experiments. The control and monitoring equipment was located in a room adjacent to the chamber. Standard instrumentation procedures were used for recording the experimental tapes, presenting the sound, and monitoring the Sound Pressure Levels (SPLs) generated during the presentation of the acoustic signal. Calibrations were conducted daily on the equipment and written operational checklists were used to ensure the proper and safe operation of the equipment. A block diagram listing the equipment for driving one set of speakers is given in Figure 2.

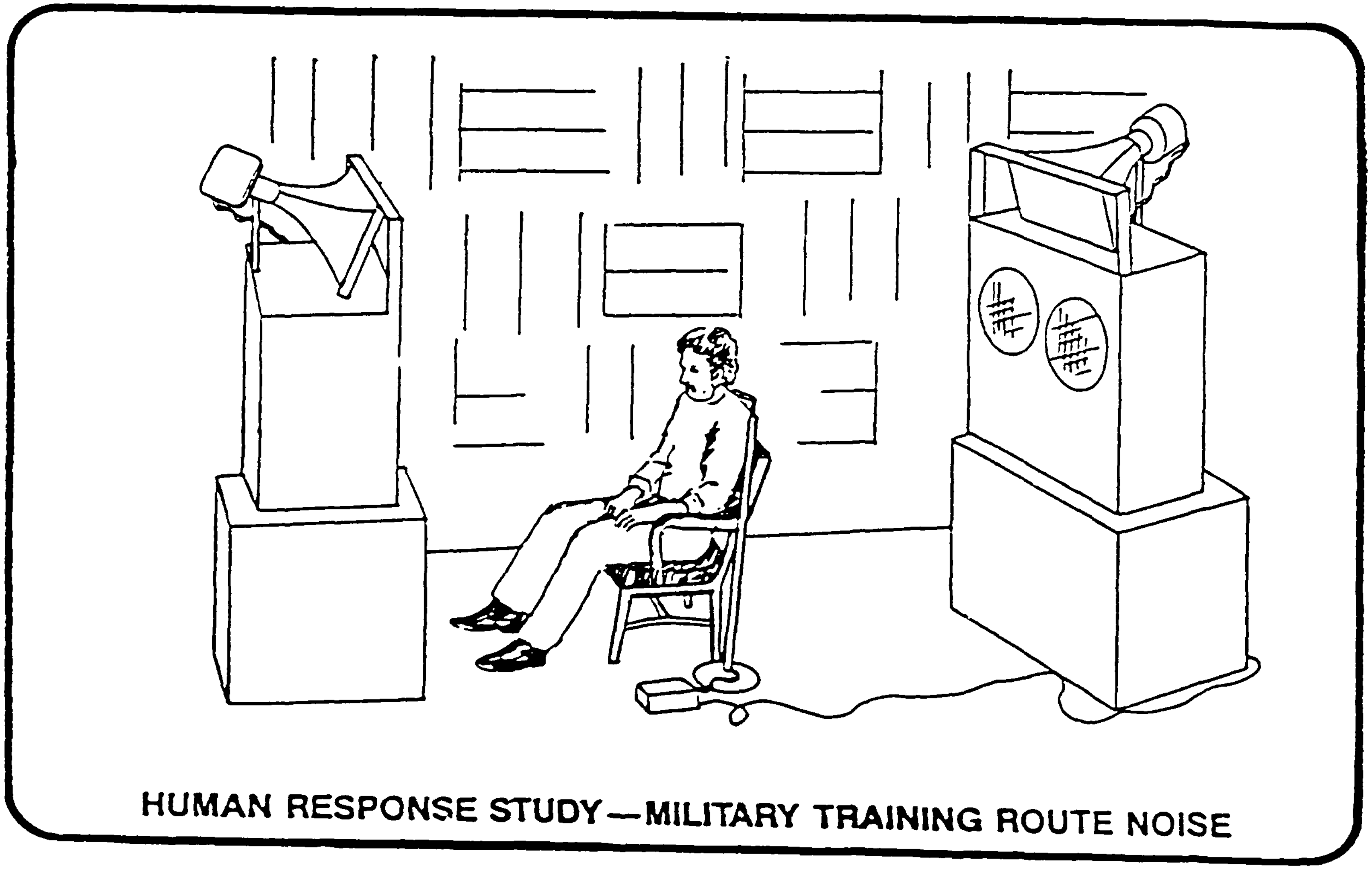


Figure 1. Experimental Setup for Subject Testing.

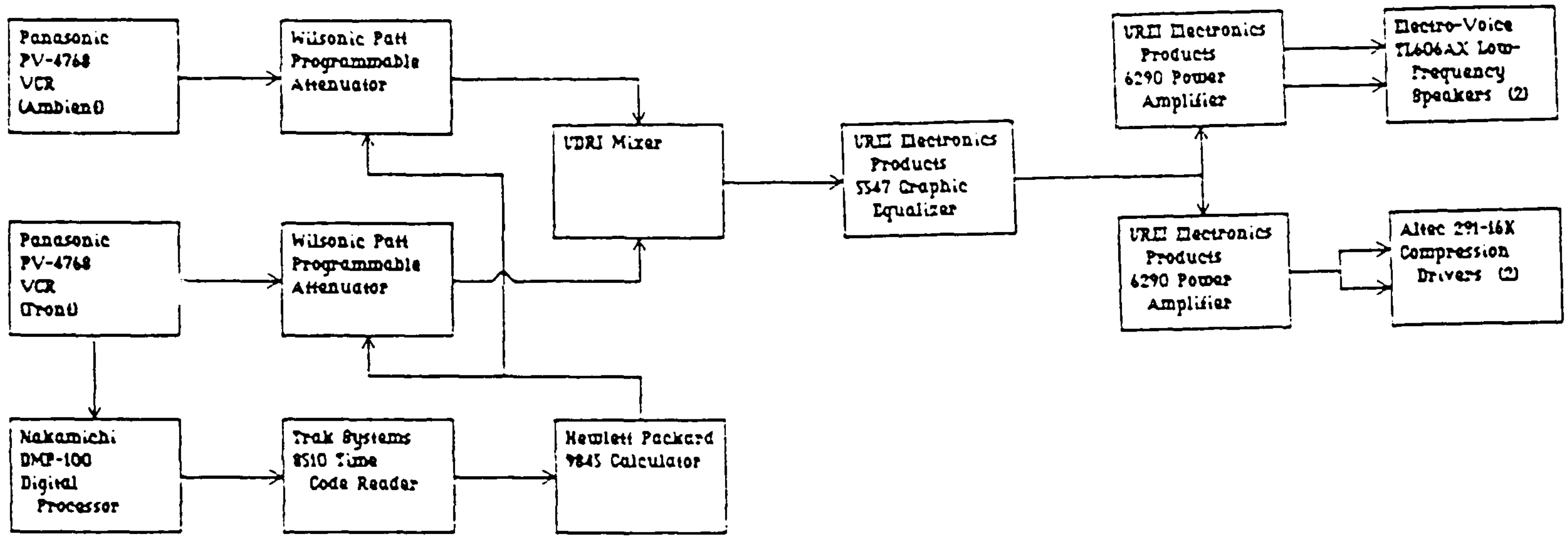


Figure 2. Equipment for Driving One Set of Speakers

2.3 Experimental Measures

A seven point rating scale with labeled intervals was used for obtaining annoyance ratings of the flyovers. These labels were minimally, slightly, fairly, moderately, decidedly, highly, and extremely annoying. Annoyance ratings were obtained for each flyover as well as an overall rating at the end of the experimental session. Also, ratings were obtained for each subject at the end of each session where the subjects were asked to rate "TODAYS FLYOVERS" against 15 scales of bipolar adjectives. This Semantic Differential approach attempted to measure the meaning of the experimental situations. Ratings for the familiar Semantic Differential factors of Evaluative, Potency, and Activity were obtained. Five scale items were used to assess each factor. A six point scale was used for each scale. The bipolar scales of BAD - GOOD, AWKWARD - GRACEFUL, UNPLEASANT - PLEASANT, ANNOYING - PLEASING and ROUGH - SMOOTH were used to assess the Evaluative factor. SMALL - LARGE, LIGHT - HEAVY, NARROW - WIDE, THIN - THICK, and WEAK - STRONG were used to assess the Potency factor. SLOW - FAST, RELAXED - TENSE, DULL - SHARP, PASSIVE - ACTIVE, AND CALM - EXCITEABLE were used to assess an Activity factor. Scores for each subject were obtained from an average of the 5 items for each factor. In the first experiment, all subjects made their ratings using pencil-and-paper. In the last three experiments, for the immediate rating of flyovers, subjects gave their ratings verbally and these were recorded by E. A large computer generated annoyance scale was taped at eye level approximately three feet in front of them. This was necessary since the subjects in the last three experiments were required to perform a continuous paper-and-pencil task (the Serial Search Task) while exposed to the flyovers. All two-digit numbers from 10 through 99 were used twice in constructing a page for the Serial Search Task (SST) in the same manner used by Kappauf and Payne (4). The two digit numbers were presented in pairs in different columns, and 15 pair were in each column. Each two digit number occurred once as the first member of a pair and once as the second member of a pair. The locations of the two digit numbers were changed from sheet to sheet in a random fashion and 12 different sheets were constructed for the experiment. Each subject received a different random order of the sheets. Subjects started each sheet by finding the number 10 in the upper left hand corner of the sheet as the first member of the pair. He wrote down the number which was the corresponding second member of the pair on his answer form and proceeded to look for this new number as the first member of a pair, and so on. E compared the numbers written by the subject with an answer sheet to check for accuracy and the number completed during the 15 minute time period.

2.4 Experimental Design and Procedure

In the first three experiments, the experimental conditions corresponded to the presentation of different noise tapes. The tapes for the four experiments are described in Appendix A. All tapes contained six flyovers. However, only four flyovers were directly related to the experimental conditions. The remaining two flyovers were relatively low level and were included to enhance the surprise effect by reducing the predictability of the occurrence of the higher level and higher onset rate flyovers. Within each tape the flyovers were randomly assigned according to the minutes in the 15 minute noise condition. The 24 hour Leqs in dB and Average Onset Rates in dB/sec for experiment 1 were as follows: Condition A Leq=61 Mean Onset Rate=7.3, Condition B Leq=61 Mean Onset Rate=38.3, Condition C Leq=69 Mean Onset rate=7.8, Condition D Leq=69 Mean Onset Rate=56.9, Condition E Leq=76 Mean Onset Rate=8, Condition F Leq=76 Mean Onset Rate=59.1. These levels corresponded to outside noise levels since no attenuation factors were included for structures.

There were only four experimental conditions in experiment 2 and these corresponded to the use of the first four tapes of experiment 1. The major differences between experiment 1 and 2 were in the use of contractor panel subjects in experiment 2 and the use of volunteers in experiment 1, the subjects were required to perform the SST in experiment 2, and in experiment 2 the sound level of the tapes was increased so that conditions A and B had 24 hour Leqs of 65 dB and conditions C and D had Leqs of 72 dB. The onset rates, of course, were the same as for the corresponding conditions in experiment 1. The primary interest in both these experiments was in comparing equal Leq conditions having high and low onset rates.

In experiment 3 all conditions had equal Leqs of 67 dB but differed in mean Onset Rates. The mean onset rates for conditions A, B, C, and D were 2.23, 11, 16.83, and 23.62 dB/sec, respectively.(see Appendix A).

In the first three experiments conditions were presented in counterbalanced order such that each condition was equally represented across days of testing, i.e., one block of a latin square was used. In experiment 1, two subjects were assigned to each of the six orders of presentation, and in experiments 2 and 3, three subjects were assigned to each of the four orders of presentation. A simple treatment by subjects design was used with Groups confounded with Order of presentation.

In experiment 4, subjects were presented the flyovers in a different random order for each subject. Four tapes were used but tapes did not correspond with conditions as in the other experiments. Subjects were tested at four levels of SEL values (100, 110, 115, and 122 dB) with three different onset rates presented in each level. Four tapes were presented; one on each of four days.

Upon their first appearance at the laboratory subjects were given instructions about the nature of the experiment, about procedures for using the rating scale, the Semantic Differential, and in the last three experiments detailed instructions for performing the SST. Subjects in experiment 1 were tested on seven different days, and subjects in the last three experiments were tested on five different days. Each subject was required to complete his testing within a two week period. The first day of testing for all subjects was a practice session in which the subjects were required to perform the ratings and/or task in the same manner as in the experiment proper. They were exposed to flyovers from a tape that contained the full range of stimulus values as used later in their particular experiment.

3. RESULTS

Table 1 shows the results in terms of statistical significance for the major factors in the Analyses of Variance calculated on the experimental measures taken in the first three experiments. From this table it can be seen that more significant effects were obtained in Experiment 1 for Groups (Order) and Sessions than were obtained in the other two experiments. Only one significant effect was obtained in experiments 2 and 3, other than the effect due to Noise and that was the significant effect for Sessions for the Evaluative factor in Experiment 3. Table 2 shows the mean differences between conditions that had equal Leqs but different onset rates. The annoyance measure taken immediately after each flyover was the only measure to show a statistically significant difference between impulsive - nonimpulsive conditions across the three experiments. This difference was shown at the highest Leq level in experiment 1 and at both the Leq levels of experiment 2. In experiment 3, where all Leq levels were 67 dB, Condition A was rated less annoying than conditions B, C, and D. There were no statistically significant differences among the latter three conditions. A significant difference was found between conditions A and D for the annoyance measure taken after each experimental condition in experiment 3.

For the Semantic Differential factors a significant difference was found for Potency for experiment 1 (C and D), for Activity for experiment 2 (C and D) and for the Evaluative factor for experiment 3 (A and D) as can be seen in Table 2.

Figure 3 shows the mean annoyance to the flyovers presented during Experiment 1. From this Figure, it can be seen that the greatest difference between conditions with equal Leqs was obtained for the highest level of 76 dB which was between conditions E and F. This difference of .65 in mean annoyance rating was significant beyond .05 as can be seen in Table 3. The Groups (Order) significant effect can be seen in Figure 4. Groups 1 and 2 made significantly lower annoyance ratings than did Groups 4 and 5. The annoyance rating taken after each noise exposure condition showed essentially the same pattern as the curve for the individual flyover ratings, however, there were no significant differences between conditions with the same Leq values. There were many significant differences between Leq levels (see Figure 5 and Table 4). The Groups

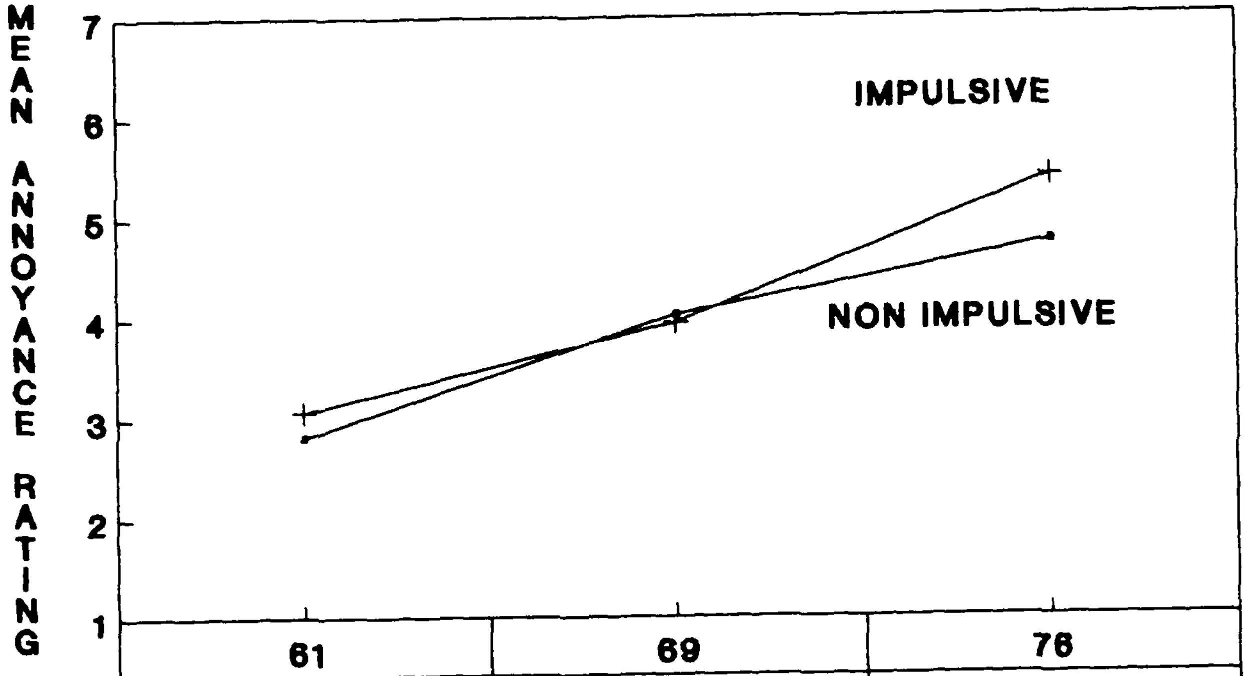
TABLE 1
ANOVA RESULTS FOR EXPS. 1, 2, 3

Measure	Groups(Order)	Noise	Sessions	N x S
Experiment 1				
Annoy during	$p < .05$	$p < .01$	NS	NS
Annoy After	$p < .05$	$p < .01$	NS	NS
Evaluative	NS	$p < .01$	$p < .05$	NS
Potency	NS	$p < .01$	$p < .01$	NS
Activity	NS	$p < .01$	$p < .05$	NS
Experiment 2				
Annoy During	NS	$p < .01$	NS	NS
Annoy After	NS	$p < .01$	NS	NS
Evaluative	NS	$p < .01$	NS	NS
Potency	NS	$p < .01$	NS	NS
Activity	NS	$p < .01$	NS	NS
No. Correct	NS	NS	NS	NS
Experiment 3				
Annoy During	NS	$p < .05$	NS	NS
Annoy After	NS	NS	NS	NS
Evaluative	NS	$p < .05$	$p < .05$	NS
Potency	NS	NS	NS	NS
Activity	NS	NS	NS	NS
No. Correct	NS	NS	NS	NS

TABLE 2
DIFF. HIGH VS. LOW ONSET RATE EXPS. 1,2,3

Experiment 1 Measure	Difference Between Conditions A & B	C & D	E & F
Annoy during	.25	-.08	.65*
Annoy After	.42	-.09	.50
Evaluative	-.18	.44	-.30
Potency	-.35	-.53*	-.30
Activity	.10	.31	.56
Experiment 2			
Annoy During	.96**	.82**	
Annoy After	.58	.17	
Evaluative	-.20	-.35	
Potency	.02	-.30	
Activity	.62	.66*	
No. Correct	3.42	3.58	
Experiment 3	**A & B**	**A & C**	**A & D**
Annoy During	.60*	.64*	.84*
Annoy After	.33	.33	.58*
Evaluative	-.23	.03	-.45*
Potency	-.27	.08	-.17
Activity	.70	.48	.70
No. Correct	1.00	-4.33	-2.83

* $p < .05$ ** $p < .01$



	61	69	76
NON I	2.81	4.02	4.75
I	3.06	3.94	5.4

24 HOUR LEQ IN DECIBELS

Figure 3. Mean Annoyance Rating for Four Flyovers per Condition versus Leq for Experiment 1.

TABLE 3
ANOVA AND MEAN DIFF. FOR ANNOY DURING EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	170.86			
AB(b) - Groups	5	136.86	27.37	4.83	p<.05
Error(b)	6	34.01	5.67		
Within Ss	60	87.57			
A (Noise)	5	57.65	11.53	20.46	p<.01
B (Sessions)	5	4.59	.92	1.63	
AB(w)	25	11.25	.45	.80	
Error(w)	25	14.09	.56		

Exp. 1: Annoy Rate Four Flyovers

Conditions	A	B	C	D	E	F
A 2.81		0.25^	1.21"	1.13"	1.94"	2.59"
B 3.06			0.96"	0.88"	1.69"	2.34"
C 4.02				-0.08^	0.73'	1.38"
D 3.94					0.81'	1.46"
E 4.75						0.65'
F 5.40						

^= Not Significant '= p<.05 "= p<.01

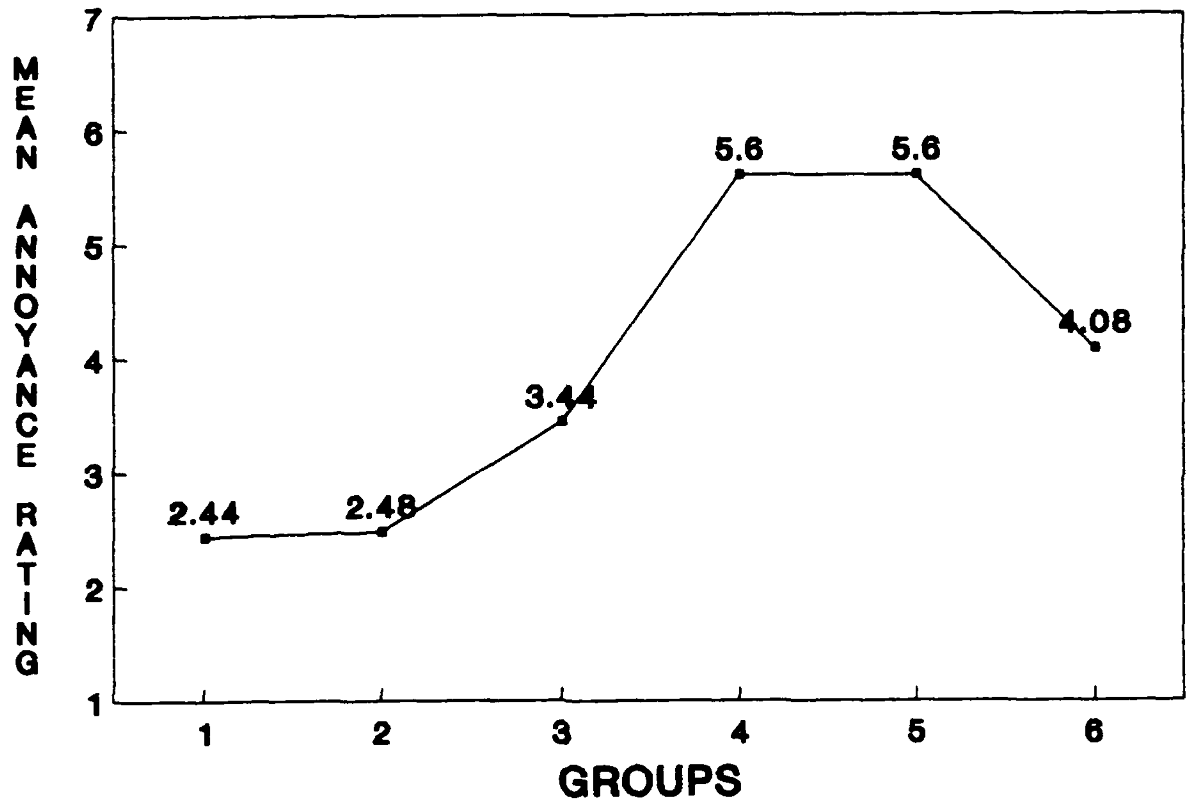


Figure 4. Mean Annoyance for Four Flyovers for Groups.

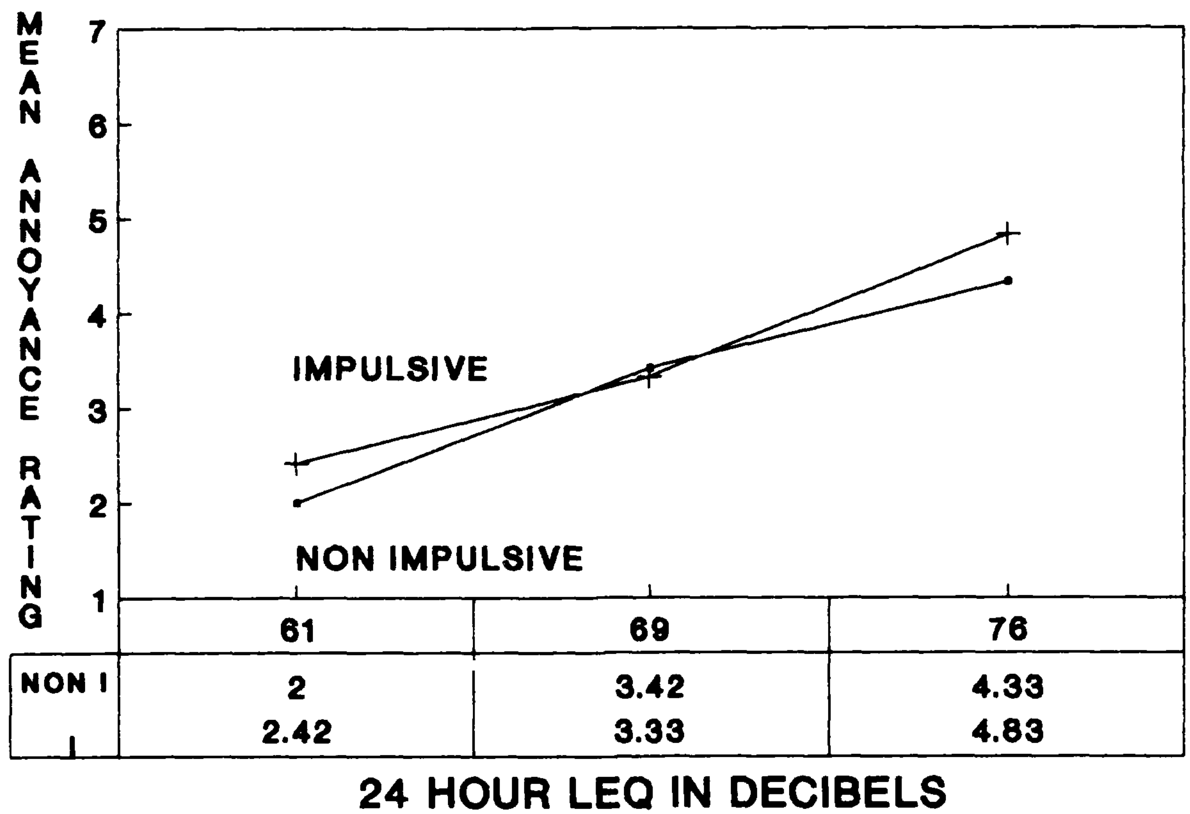


Figure 5. Mean Annoyance After Exposure versus Leq for Experiment 1.

TABLE 4
ANOVA AND MEAN DIFF. FOR ANNOY AFTER EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	130.78			
AB(b) - Groups	5	103.44	20.69	4.54	p<.05
Error(b)	6	27.33	4.56		
Within Ss	60	106.33			
A (Noise)	5	70.28	14.06	17.00	p<.01
B (Sessions)	5	6.44	1.29	1.56	
AB(w)	25	8.94	.36	.43	
Error(w)	25	20.67	.83		

Exp. 1: Annoy Rate After Exposure

Conditions		A	B	C	D	E	F
A	2.00		0.42^	1.42"	1.33"	2.33"	2.83"
B	2.42			1.00'	0.91'	1.91"	2.41"
C	3.42				-0.09^	0.91'	1.41"
D	3.33					1.00'	1.50"
E	4.33						0.50^
F	4.83						

^= Not Significant '= p<.05 "= p<.01

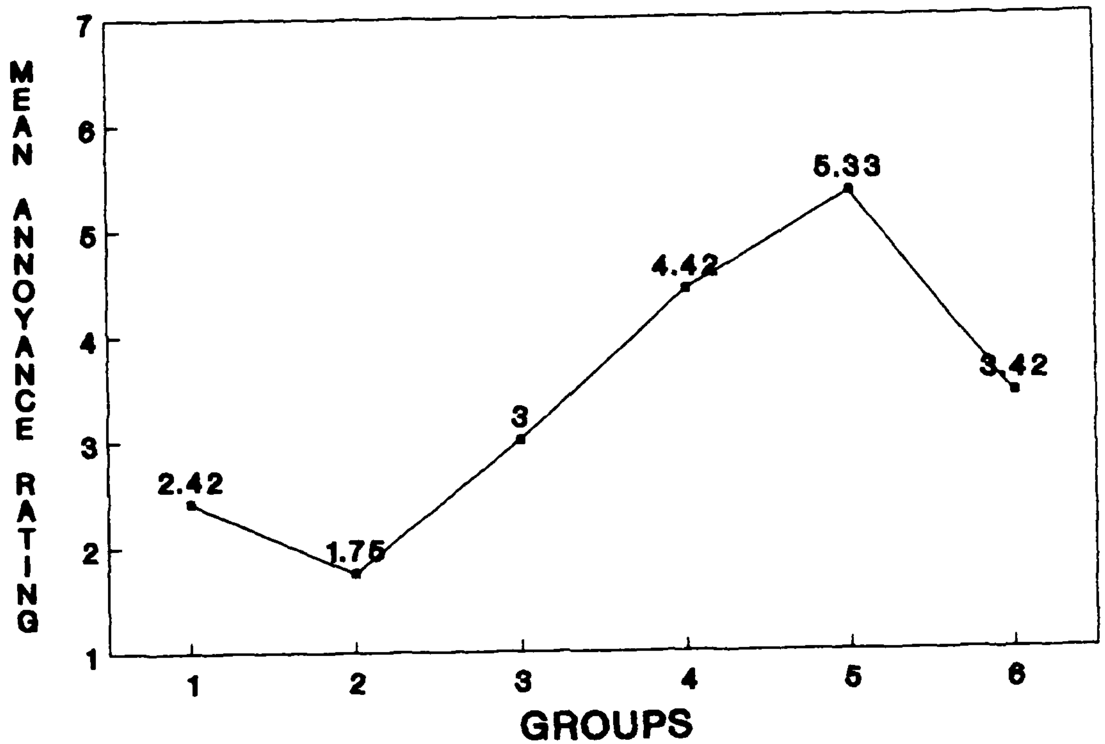
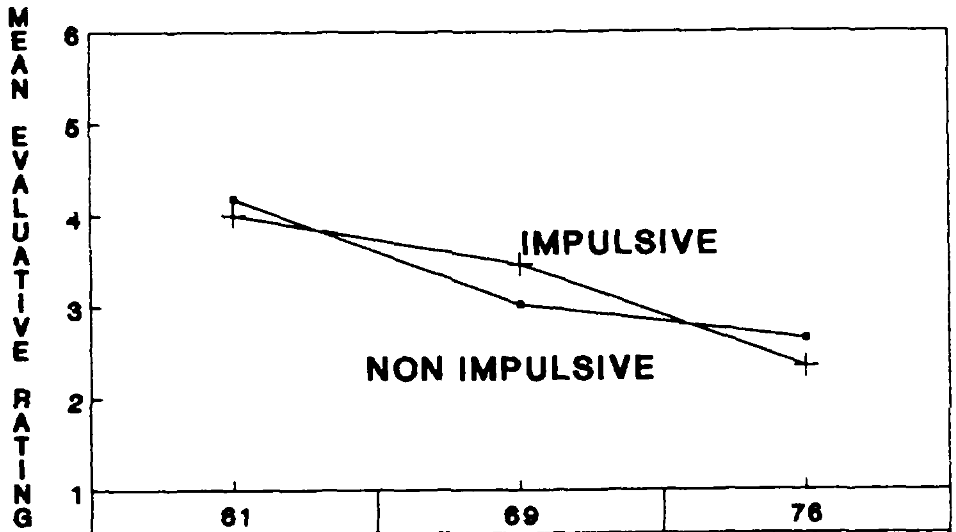


Figure 6. Mean Annoyance After Exposure versus Groups for Experiment 1.

effect for the annoyance after exposure measure is given in Figure 6 where it can be seen that Group 2 made significantly lower annoyance ratings than Groups 4 and 5, and Group 1 made significantly lower ratings than Group 5. Similarly, there were no significant differences between mean ratings for the Evaluative measure within Leq levels (impulsive - nonimpulsive), although there were a number of differences between Leq levels (see Figure 7 and Table 5). The Sessions effect for the Evaluative factor showed a tendency for the mean rating to decrease as a function of the number of sessions, however, the only statistically significant difference was between session 2 and session 6 (see Figure 8). For the Potency rating, a significant difference was found, between conditions C and D. The differences between A and B and E and F did not reach statistical significance, nevertheless, they were in the same direction as for C and D. Within Leq levels, low onset levels (nonimpulsive) tended to the rated as more potent than high onset levels (impulsive) (see Figure 9 and Table 6). Session 2 was rated significantly lower than session 6 with an overall trend of increasing potency rating with number of sessions (see Figure 10). For the Activity rating for Experiment 1 no significant effects were obtained between nonimpulsive versus impulsive conditions for the equal Leq conditions, although at the highest Leq level the difference approached significance ($p<.10$) with the impulsive condition rated as the more active (see Figure 11 and Table 7). The Sessions effect for Activity showed that session 2 was rated significantly less active than sessions 5 and 6 with an overall trend of increased activity with number of sessions (see Figure 12).

The only statistically significant effects in the Analyses of Variance conducted for experiment 2 were for the main factor of noise. This was obtained for all measures except for the number correct measure on the SST where no significant effects were obtained, although subjects had a higher number completed in the impulsive conditions (see Figure 13). Figure 14 shows the mean annoyance to the flyovers presented during experiment 2. It can be seen that both impulsive conditions were rated higher than their equivalent energy nonimpulsive condition. The difference between both the impulsive - nonimpulsive conditions was statistically significant at the .01 level (see Table 8). No significant differences between the impulsive - nonimpulsive conditions were found for the annoyance rating after the flyover exposure and for the Evaluative and the Potency measures (see Figure 15,16 and 17 and Tables 9,10, and 11). For the Activity measure, condition D was rated significantly more active than



	61	69	76
NON I	4.18	3.03	2.65
I	4	3.47	2.35

24 HOUR LEQ IN DECIBELS

Figure 7. Mean Evaluative Rating versus Leq for Experiment 1.

TABLE 5
ANOVA AND MEAN DIFF. FOR EVALUATIVE RATING

SOURCE	DF	SS	MS	F	P
Between Ss	11	41.85			
AB(b) - Groups	5	27.80	5.56	2.37	NS
Error(b)	6	14.05	2.34		
Within Ss	60	58.13			
A (Noise)	5	32.30	6.46	21.00	p<.01
B (Sessions)	5	3.89	.78	2.53	p<.05
AB(w)	25	14.24	.57	1.85	
Error(w)	25	7.69	.31		

Exp. 1: Evaluative Ratings

Conditions		A	B	C	D	E	F
A	4.18		-0.18^	-1.15"	-0.71"	-1.53"	-1.83"
B	4.00			-0.97"	-0.53^	-1.35"	-1.65"
C	3.03				0.44^	-0.38^	-0.68'
D	3.47					-0.82"	-1.12"
E	2.65						-0.30^
F	2.35						

^= Not Significant '= p<.05 "= p<.01

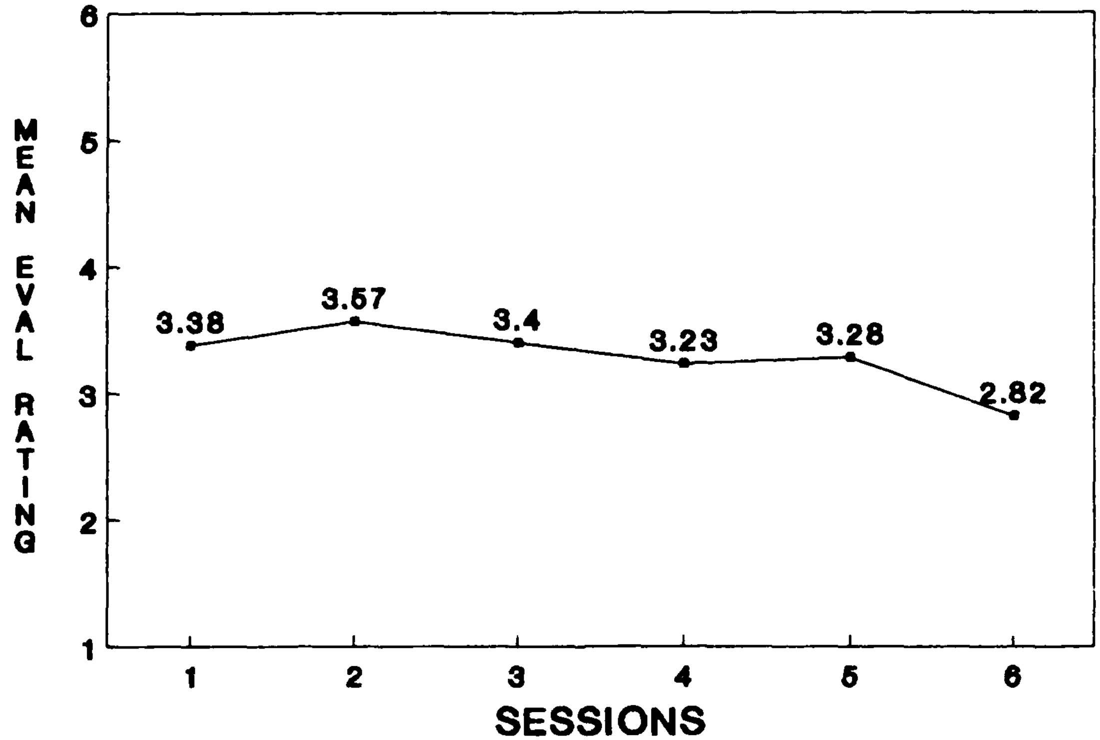
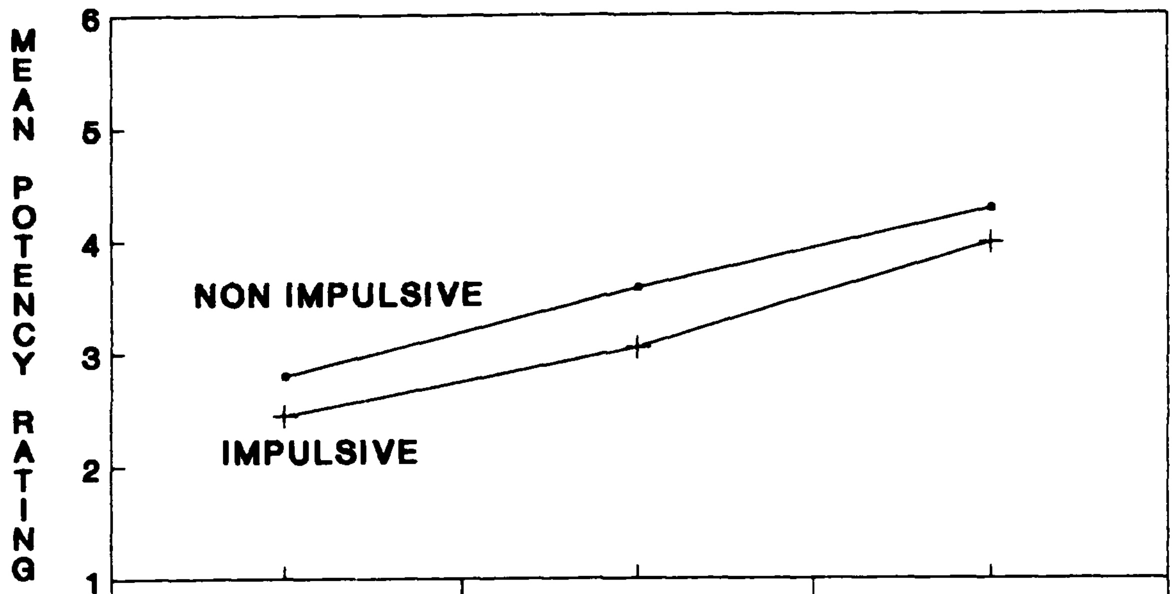


Figure 8. Mean Evaluative Rating versus Sessions for Experiment 1.



	61	69	76
NON I	2.8	3.58	4.28
I	2.45	3.05	3.98

24 HOUR LEQ IN DECIBELS

Figure 9. Mean Potency Rating versus Leq for Experiment 1.

TABLE 6
ANOVA AND MEAN DIFF. FOR POTENCY RATINGS

SOURCE	DF	SS	MS	F	P
Between Ss	11	30.59			
AB(b) - Groups	5	22.77	4.55	3.49	NS
Error(b)	6	7.82	1.30		
Within Ss	60	65.65			
A (Noise)	5	30.34	6.07	17.02	p<.01
B (Sessions)	5	8.36	1.67	4.69	p<.01
AB(w)	25	18.03	.72	2.02	p<.05
Error(w)	25	8.92	.36		

Exp. 1: Potency Ratings

Conditions		A	B	C	D	E	F
A	2.80		-0.35^	0.78"	0.25^	1.48"	1.18"
B	2.45			1.13"	0.60^	1.83"	1.53"
C	3.58				-0.53'	0.70'	0.40^
D	3.05					1.23"	0.93"
E	4.28						-0.30^
F	3.98						

^= Not Significant '= p<.05 "= p<.01

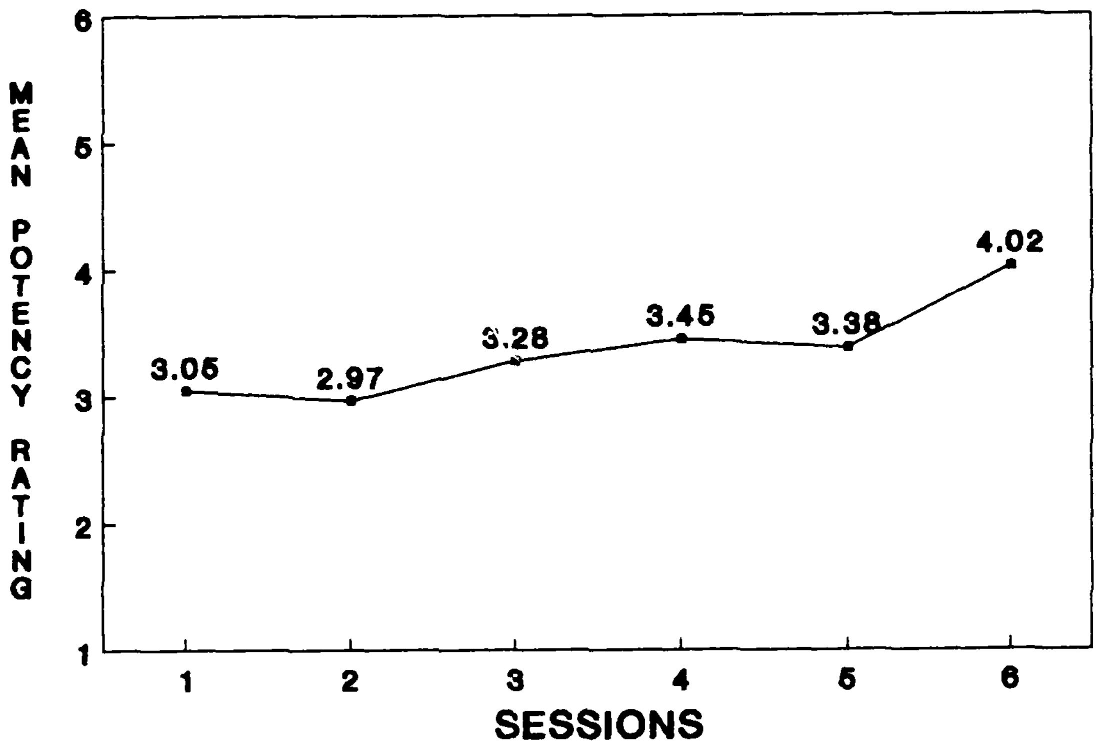
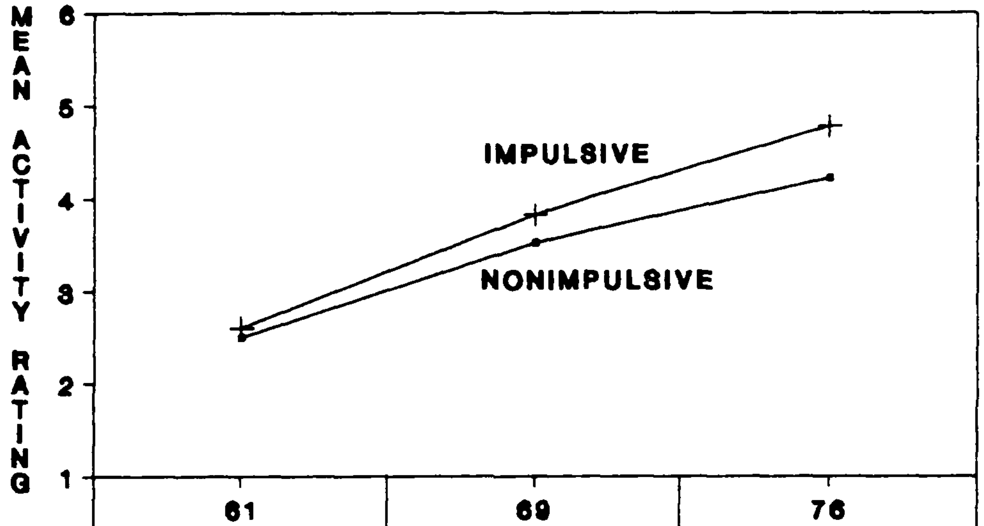


Figure 10. Mean Potency Rating versus Sessions for Experiment 1.



	61	69	76
I	2.6	3.83	4.78
NON I	2.5	3.52	4.22

24 HOUR LEQ IN DECIBELS

Figure 11. Mean Activity Rating versus Leq for Experiment 1.

TABLE 7
ANOVA AND MEAN DIFF. FOR ACTIVITY RATINGS

SOURCE	DF	SS	MS	F	P
Between Ss	11	28.16			
AB(b) - Groups	5	14.67	2.93	1.30	NS
Error(b)	6	13.50	2.25		
Within Ss	60	85.91			
A (Noise)	5	48.58	9.72	15.14	$p<.01$
B (Sessions)	5	11.25	2.25	3.50	$p<.05$
AB(w)	25	10.05	.40	.63	
Error(w)	25	16.04	.64		

Exp. 1: Activity Ratings

Conditions		A	B	C	D	E	F
A	2.50		0.10^	1.02*	1.33*	1.72*	2.28*
B	2.60			0.92*	1.23*	1.62*	2.18*
C	3.52				0.31^	0.70^	1.26*
D	3.83					0.39^	0.95'
E	4.22						0.56^
F	4.78						

^= Not Significant '= $p<.05$ *= $p<.01$

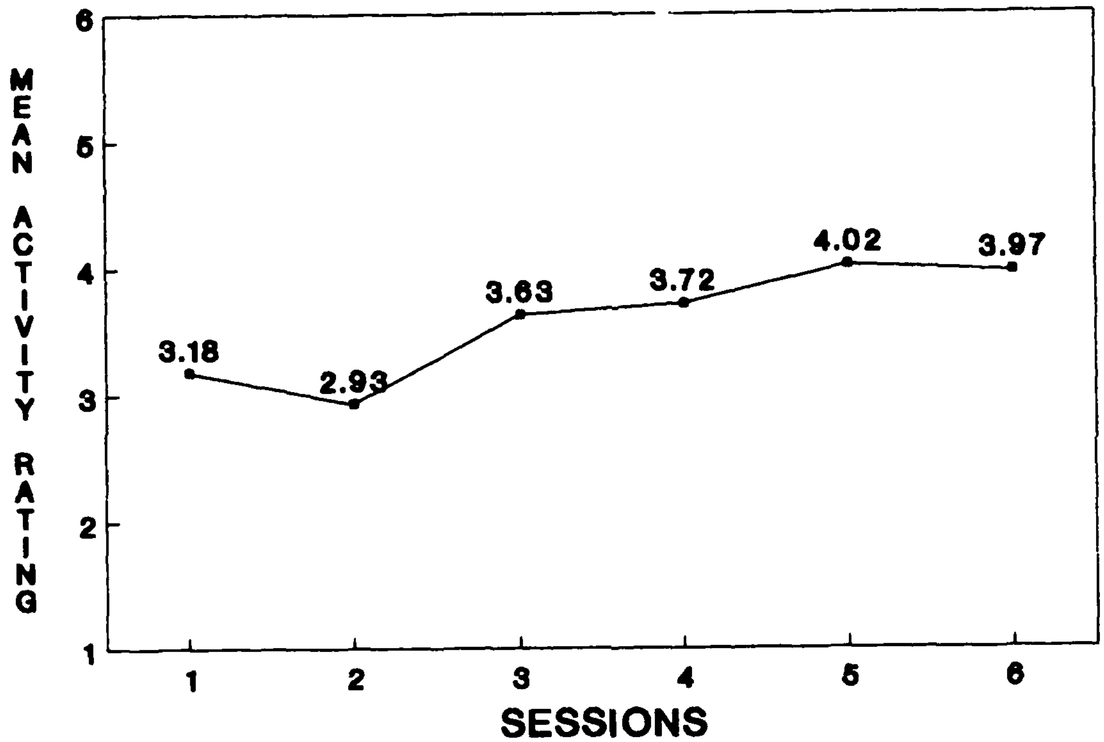
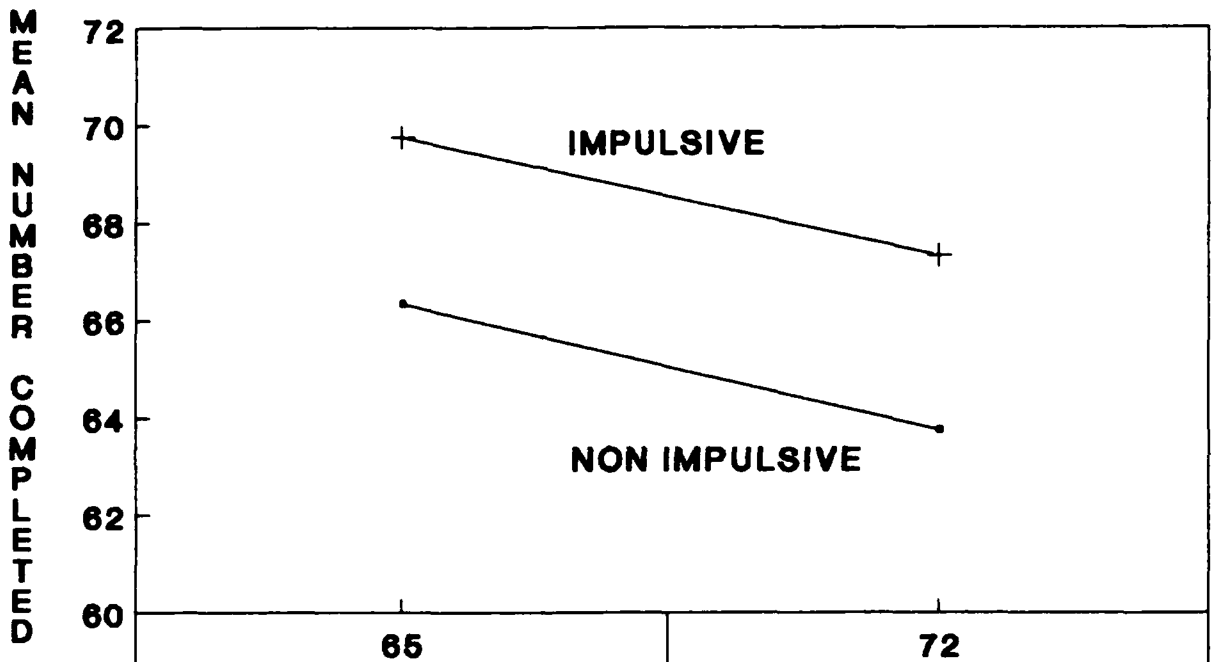


Figure 12. Mean Activity Rating versus Sessions for Experiment 1.



	65	72
NON I	66.33	63.75
I	69.75	67.33

24 HOUR LEQ IN DECIBELS

Figure 13. Mean Number Completed on Serial Search Task versus Leq for Experiment 2.

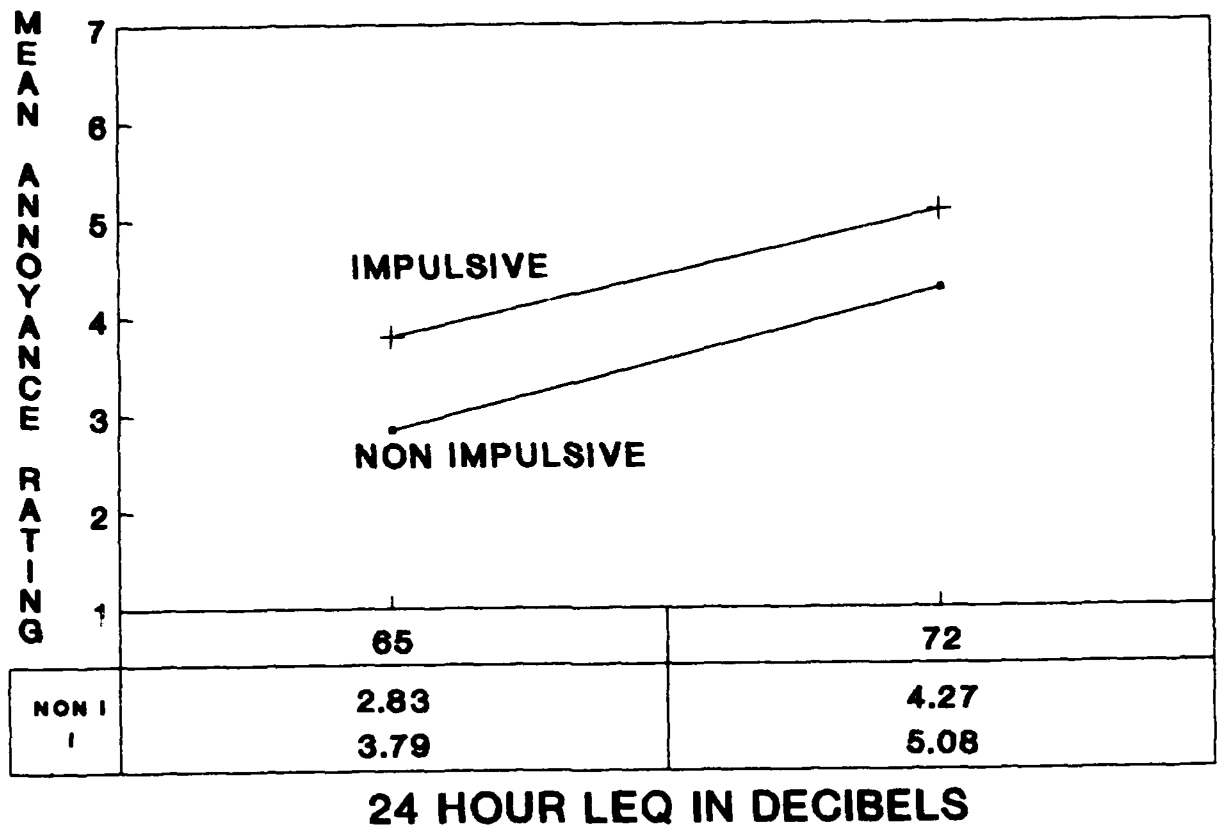


Figure 14. Mean Annoyance for Four Flyovers per Condition versus Leq for Experiment 2.

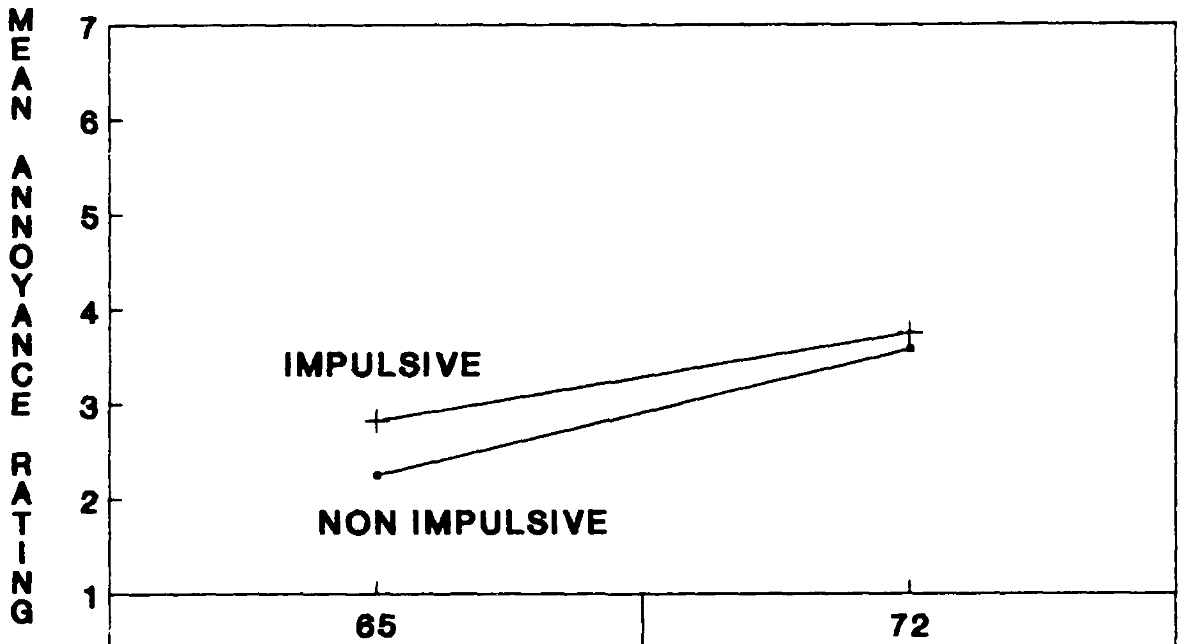
TABLE 8
ANOVA AND MEAN DIFF. FOR ANNOY DURING EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	999.73			
AB(b) - Groups	3	108.56	36.19	.32	NS
Error(b)	8	891.17	111.40		
Within Ss	36	769.25			
A (Noise)	3	509.06	169.69	21.88	p<.01
B (Sessions)	3	62.56	20.85	2.69	NS
AB(w)	9	34.79	3.87	0.50	
Error(w)	21	162.83	7.75		

Exp. 2: Mean Annoy Four Flyovers

Conditions		A	B	C	D
A	2.83		0.96"	1.44"	2.25"
B	3.79			0.48^	1.29"
C	4.27				0.82"
D	5.08				

^=Not Significant '= $p<.05$ "= $p<.01$



	65	72
NON I	2.25	3.58
I	2.83	3.75

Figure 15. Mean Annoyance After Exposures versus Leq for Experiment 2.

TABLE 9
ANOVA AND MEAN DIFF. FOR ANNOY AFTER EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	44.23			
AB(b) - Groups	3	12.06	4.02	1.00	NS
Error(b)	8	32.17	4.02		
Within Ss	36	34.25			
A (Noise)	3	17.40	5.80	10.29	p<.01
B (Sessions)	3	1.73	.58	1.02	NS
AB(w)	9	3.29	.37	0.65	
Error(w)	21	11.83	.56		

Exp. 2: Mean Annoy After Exposure

Conditions		A	B	C	D
A	2.25		0.58^	1.33"	1.50"
B	2.83			0.75'	0.92'
C	3.58				0.17^
D	3.75				

^=Not Significant '= p<.05 "= p<.01

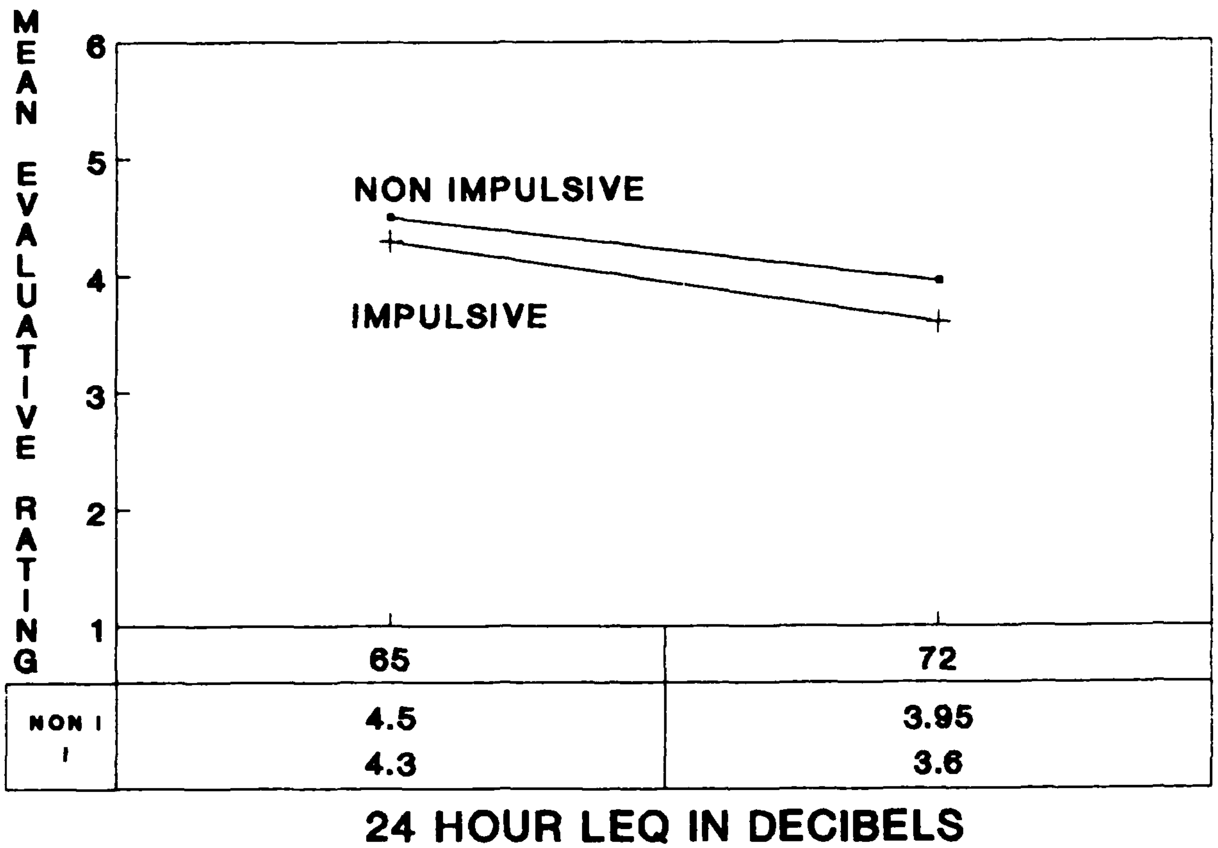


Figure 16. Mean Evaluative Rating versus Leq for Experiment 2.

TABLE 10
ANOVA AND MEAN DIFF. FOR EVALUATIVE RATINGS

SOURCE	DF	SS	MS	F	P
Between Ss	11	463.06			
AB(b) - Groups	3	74.73	24.91	.51	NS
Error(b)	8	388.33	48.54		
Within Ss	36	344.75			
A (Noise)	3	141.56	47.19	7.57	p<.01
B (Sessions)	3	23.73	7.91	1.27	NS
AB(w)	9	48.46	5.38	0.86	
Error(w)	21	131.00	6.24		

Exp. 2: Evaluative Rating

Conditions		A	B	C	D
A	4.50		-0.20^	-0.55'	-0.90"
B	4.30			-0.35^	-0.70"
C	3.95				-0.35^
D	3.60				

^=Not Significant '= p<.05 "= p<.01

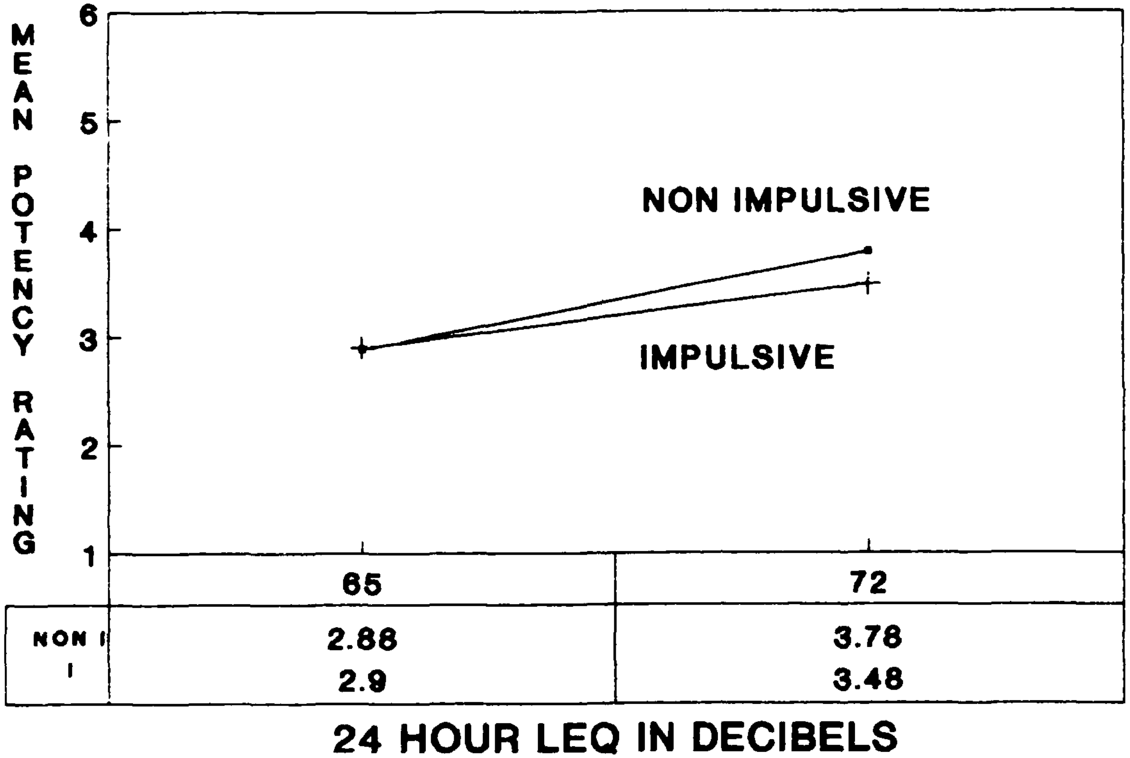


Figure 17. Mean Potency Rating versus Leq for Experiment 2.

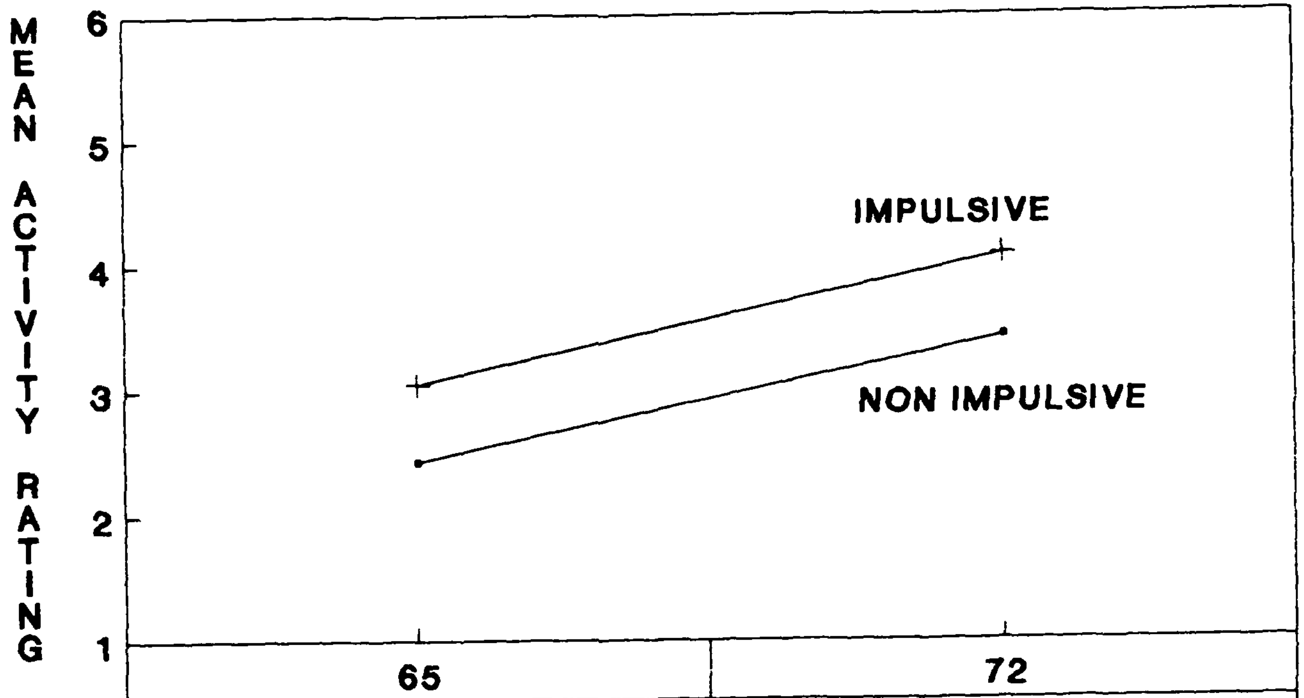
TABLE 11
ANOVA AND MEAN DIFF. FOR POTENCY RATINGS

SOURCE	DF	SS	MS	F	P
Between Ss	11	888.06			
AB(b) - Groups	3	311.06	103.69	1.44	NS
Error(b)	8	577.00	72.13		
Within Ss	36	508.25			
A (Noise)	3	178.56	59.52	5.07	p<.01
B (Sessions)	3	7.06	2.35	0.20	
AB(w)	9	76.29	8.48	0.72	
Error(w)	21	246.33	11.73		

Exp. 2: Potency Rating

Conditions		A	B	C	D
A	2.88		0.02^	0.90'	0.60^
B	2.90			0.88'	0.58'
C	3.78				-0.30^
D	3.48				

^=Not Significant '= p<.05 "= p<.01



	65	72
NON I	2.43	3.42
I	3.05	4.08

Figure 18. Mean Activity Rating versus Leq for Experiment 2.

TABLE 12

ANOVA AND MEAN DIFF. FOR ACTIVITY RATINGS

SOURCE	DF	SS	MS	F	P
Between Ss	11	396.23			
AB(b) - Groups	3	26.73	8.91	0.19	NS
Error(b)	8	369.50	46.19		
Within Ss	36	956.25			
A (Noise)	3	428.73	142.91	9.73	p<.01
B (Sessions)	3	128.90	42.97	2.92	NS
AB(w)	9	90.12	10.01	0.68	
Error(w)	21	308.50	14.69		

Exp. 2: Activity Rating

Conditions		A	B	C	D
A	2.43		0.62^	0.99'	1.65"
B	3.05			0.37^	1.03"
C	3.42				0.66'
D	4.08				

^=Not Significant '= p<.05 "= p<.01

condition C ($p<.05$) and the difference between A and B approached significance ($p<.10$) (See Figure 18 and Table 12).

In experiment 3, all four conditions had an Leq of 67 dB and the difference between condition was onset rate. For the mean annoyance based on the four flyovers the three highest onset rate conditions were all significantly different from the lowest onset rate. In other words conditions B, C and D all differed significantly from condition A and although mean annoyance rating seemed to increase with onset rate, conditions B, C, and D did not differ significantly from one another (see Figure 19 and Table 13). A significant effect was found for the annoyance after exposure between conditions A and D (seen Figure 20 and Table 14). No significant effects were obtained for the SST measure, the Potency measure and the Activity measure (see Figures 21, 22, 23 and Tables 15, 16, 17). A significant effect was obtained for the evaluative rating for the noise factor with the highest onset rate rated lower than the smaller three onset rates, however, condition D was only significantly different from conditions A and C (see Figure 24 and Table 18). A significant effect was found for sessions for the evaluative measure. There did not seen to be a clear cut pattern to explain the differences since session 2 was rated significantly larger than both sessions 1 and 4 (see Figure 25).

In experiment 4, a paired comparison test was used to compare onset rates within a SEL value. The results can be seen in Figure 26 and Table 19. The highest onset rate within a SEL level was rated as more annoying, in most cases it was rated significantly more annoying than at least one of the lower onset rates levels. However, no significant differences in annoyance ratings were obtained for the difference between the two lowest onset rate values and no discernible pattern seems to have been present. At the 100 SEL level they were rated the same, at the 110 SEL the second was rated higher than the first, at 115 and 122 dB the first was rated higher in annoyance than the second.

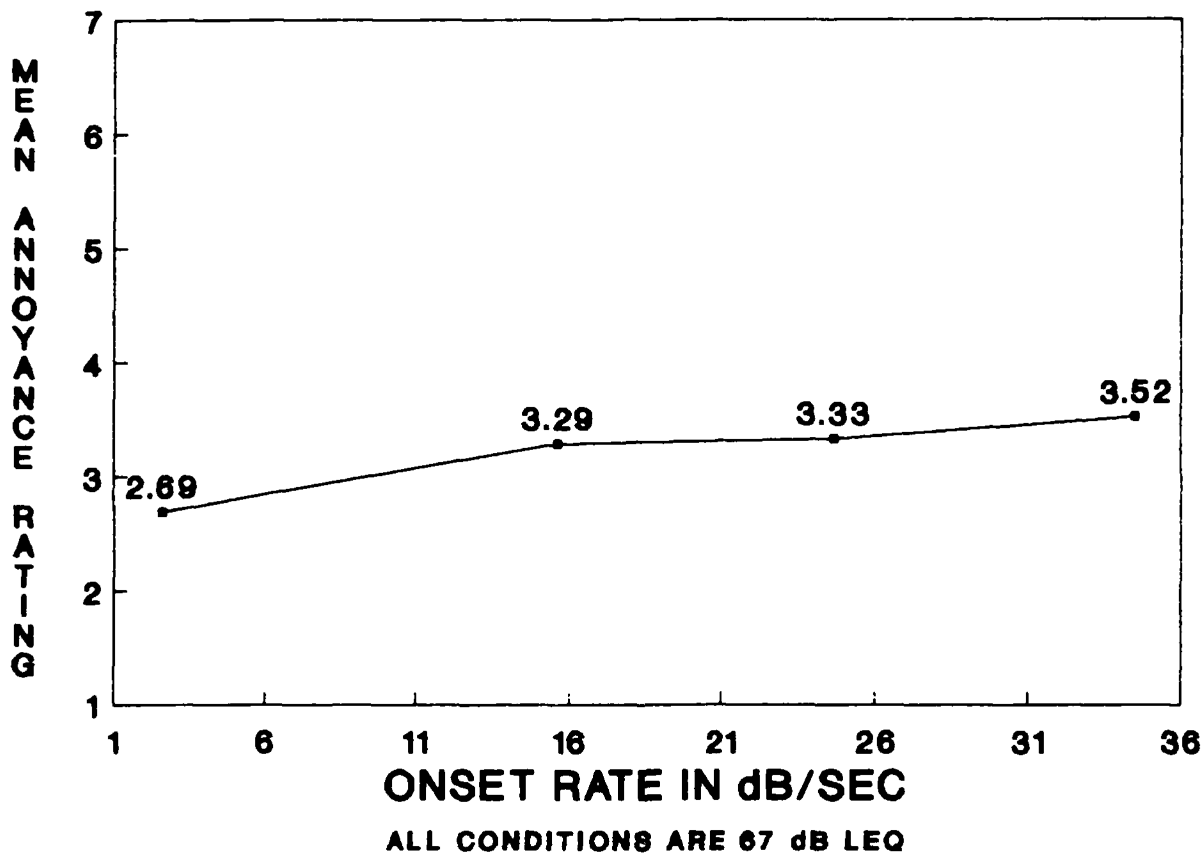


Figure 19. Mean Annoyance for Four Flyovers per Condition versus Onset Rate for Experiment 3.

TABLE 13
ANOVA AND MEAN DIFF. ANNOY DURING EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	350.67			
AB(b) - Groups	3	54.83	18.28	0.49	NS
Error(b)	8	295.83	36.98		
Within Ss	36	306.00			
A (Noise)	3	75.17	25.06	3.15	p<.05
B (Sessions)	3	40.67	13.56	1.71	NS
AB(w)	9	23.33	2.59	0.33	
Error(w)	21	166.83	7.94		

Exp. 3: Mean Annoy Four Flyovers

Conditions		A	B	C	D
A	2.69		0.60'	0.64^	0.83'
B	3.29			0.04^	0.23^
C	3.33				0.19^
D	3.52				

^=Not Significant '= p<.05 "= p<.01

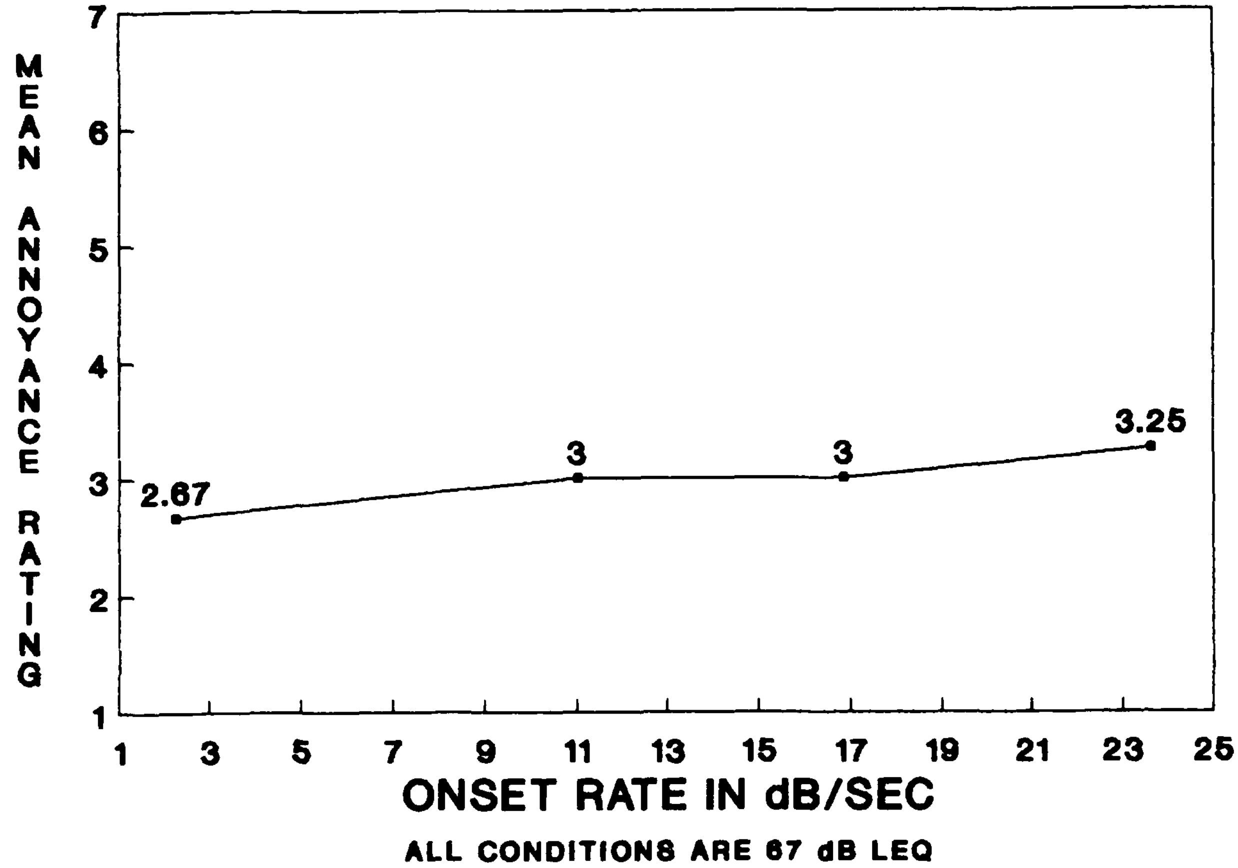


Figure 20. Mean Annoyance After Exposure verus Onset Rate for Experiment 3.

TABLE 14
ANOVA AND MEAN DIFF. ANNOY AFTER EXPOSURE

SOURCE	DF	SS	MS	F	P
Between Ss	11	21.23			
AB(b) - Groups	3	1.23	0.41	0.16	NS
Error(b)	8	20.00	2.50		
Within Ss	36	9.75			
A (Noise)	3	2.06	0.69	2.71	p<.05
B (Sessions)	3	1.23	0.41	1.61	NS
AB(w)	9	1.13	0.13	0.49	
Error(w)	21	5.33	0.25		

Exp. 3: Mean Annoy After Exposure

Conditions		A	B	C	D
A	2.67		0.33^	0.33^	0.58'
B	3.00			0.00^	0.25^
C	3.00				0.25^
D	3.25				

^=Not Significant '= p<.05 "= p<.01

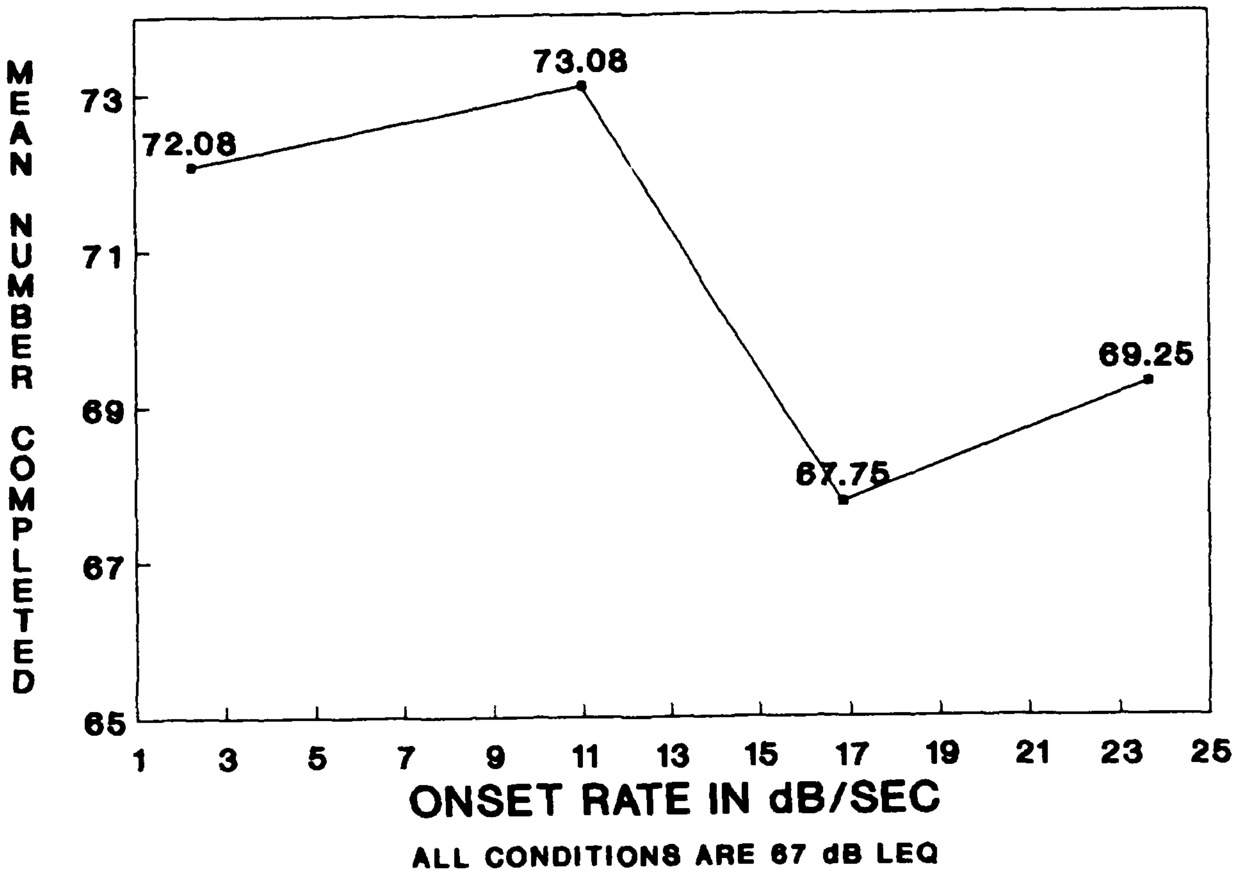


Figure 21. Mean Number Completed on Serial Search Task versus Onset Rate for Experiment 3.

TABLE 15
ANOVA AND MEAN DIFF. NO. COMPLETE SST

SOURCE	DF	SS	MS	F	P
Between Ss	11	3256.92			
AB(b) - Groups	3	75.75	25.25	0.06	NS
Error(b)	8	3181.17	397.65		
Within Ss	36	2045.00			
A (Noise)	3	219.59	73.20	1.24	NS
B (Sessions)	3	463.75	154.58	2.62	NS
AB(w)	9	124.16	13.80	0.23	NS
Error(w)	21	1237.50	58.93		

Exp. 3: No. Completed SST

Conditions		A	B	C	D
A	72.08		1.00^	-4.33^	-2.83^
B	73.08			-5.33^	-3.83^
C	67.75				1.50^
D	69.25				

^=Not Significant '= p<.05 "= p<.01

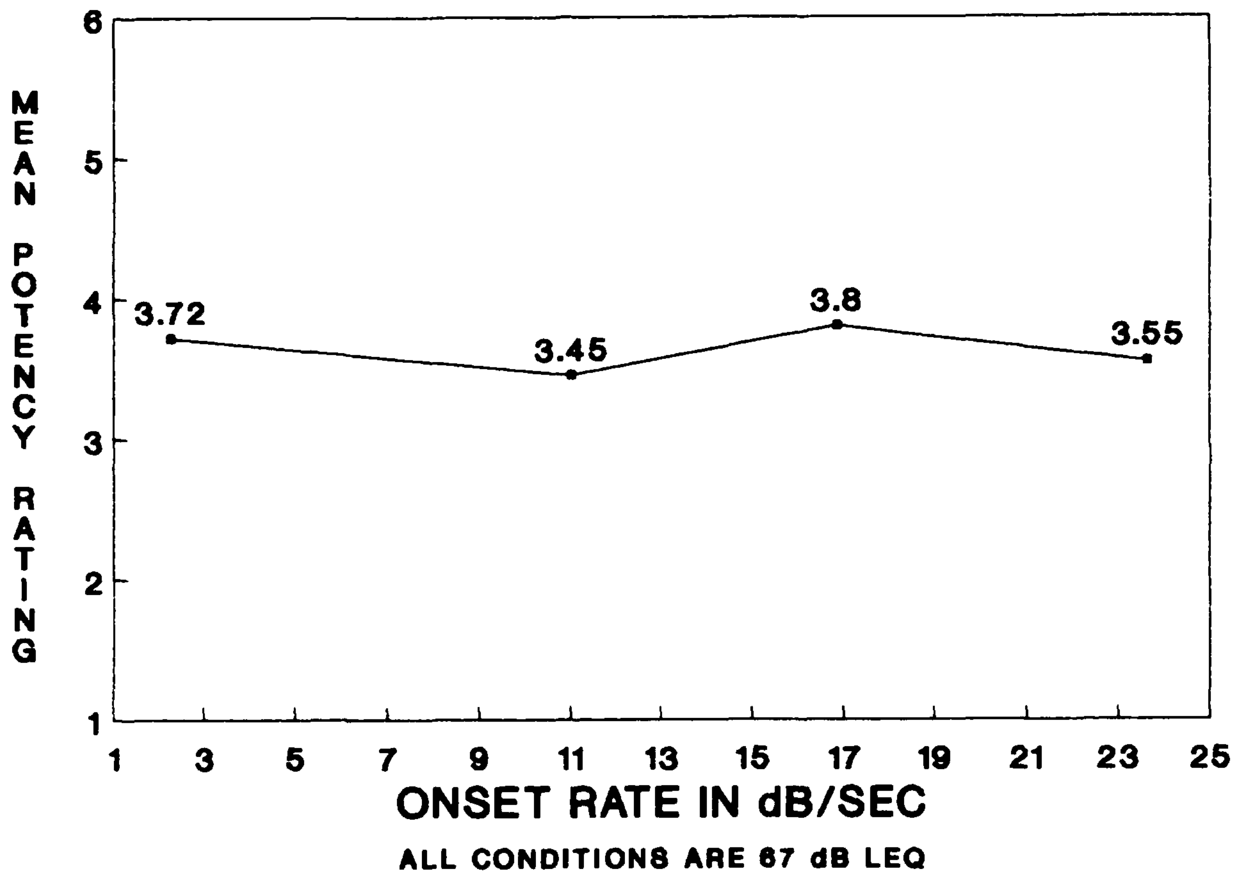


Figure 22. Mean Potency Rating versus Onset Rate for Experiment 3.

TABLE 16
ANOVA AND MEAN DIFF. FOR POTENCY RATING

SOURCE	DF	SS	MS	F	P
Between Ss	11	563.73			
AB(b) - Groups	3	108.56	36.19	0.64	NS
Error(b)	8	455.17	56.90		
Within Ss	36	332.25			
A (Noise)	3	22.56	7.52	0.92	NS
B (Sessions)	3	25.73	8.58	1.05	NS
AB(w)	9	113.13	12.57	1.55	NS
Error(w)	21	170.83	8.13		

Exp. 3: Potency Rating

Conditions		A	B	C	D
A	3.72		-0.27^	0.08^	-0.17^
B	3.45			0.35^	0.10^
C	3.80				-0.25^
D	3.55				

^=Not Significant '= p<.05 "= p<.01

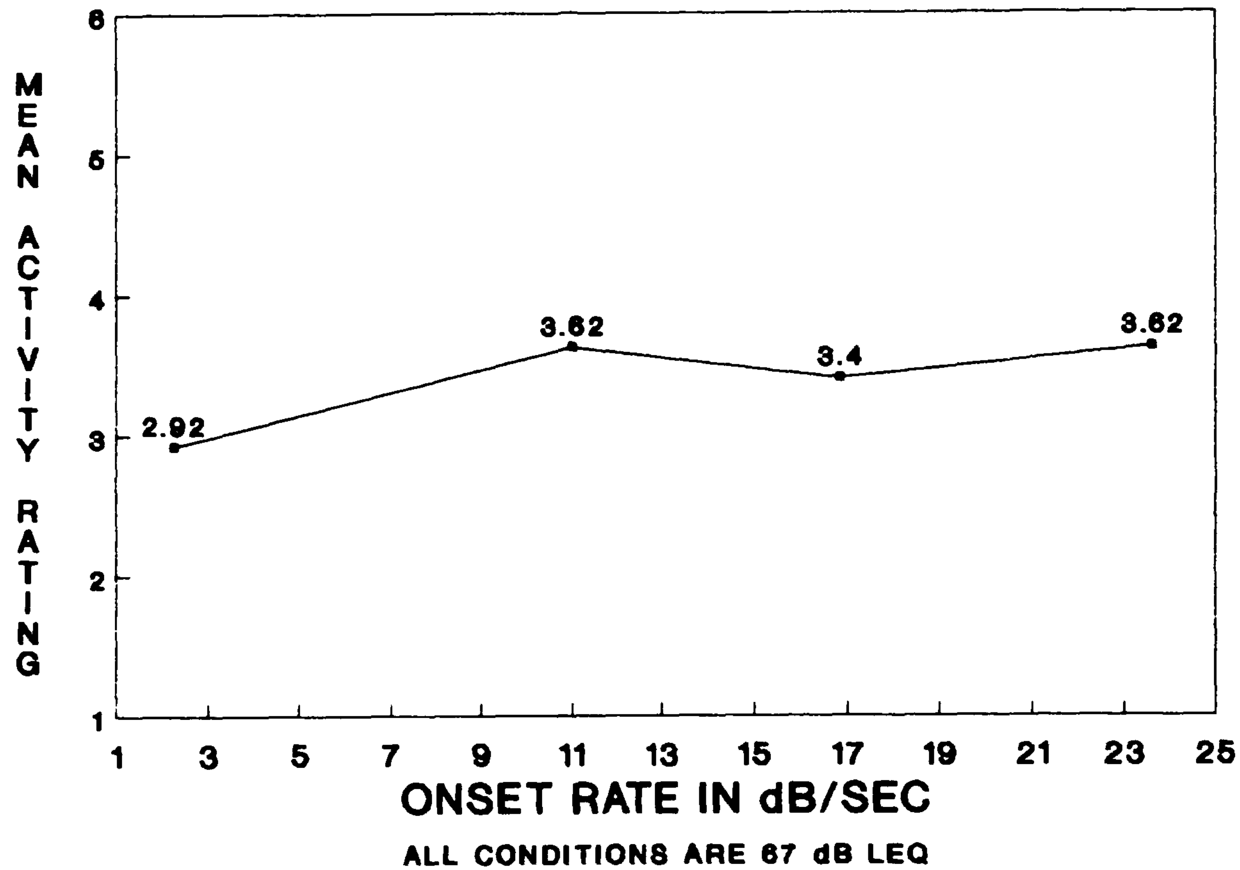


Figure 23. Mean Activity Rating versus Onset Rate for Experiment 3.

TABLE 17
ANOVA AND MEAN DIFF. ACTIVITY RATING

SOURCE	DF	SS	MS	F	P
Between Ss	11	426.56			
AB(b) - Groups	3	9.73	3.24	0.06	NS
Error(b)	8	416.83	52.10		
Within Ss	36	458.25			
A (Noise)	3	98.06	32.69	2.84	NS
B (Sessions)	3	22.06	7.35	0.64	NS
AB(w)	9	96.29	10.70	0.93	NS
Error(w)	21	241.83	11.52		

Exp. 3: Activity Rating

Conditions		A	B	C	D
A	2.92		0.70^	0.48^	0.70^
B	3.62			-0.22^	0.00^
C	3.40				0.22^
D	3.62				

^=Not Significant '= p<.05 "= p<.01

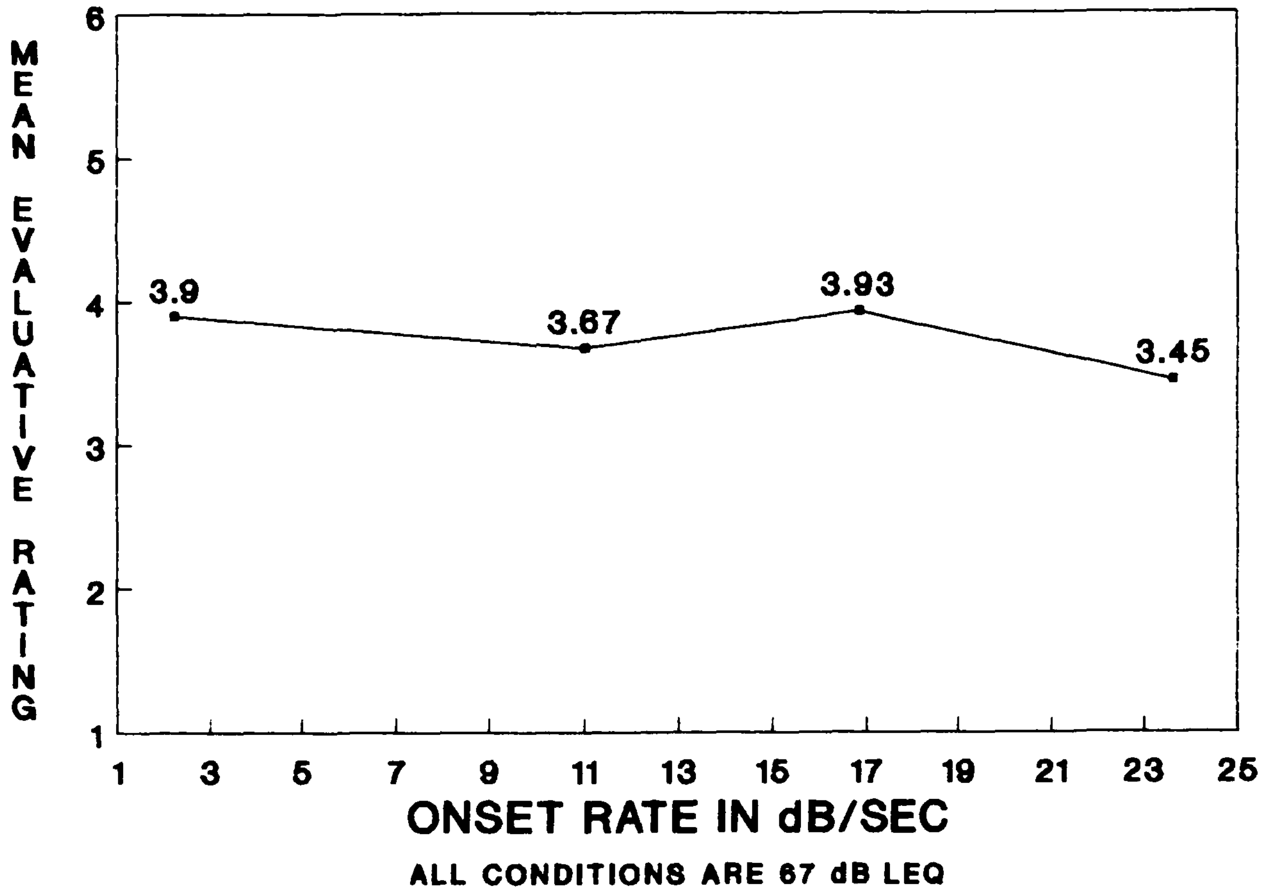


Figure 24. Mean Evaluative Rating versus Onset Rate for Experiment 3.

TABLE 18
ANOVA AND MEAN DIFF. EVALUATIVE RATING

SOURCE	DF	SS	MS	F	P
Between Ss	11	552.06			
AB(b) - Groups	3	16.23	5.41	0.08	NS
Error(b)	8	535.83	66.98		
Within Ss	36	198.25			
A (Noise)	3	45.73	15.24	4.61	p<.05
B (Sessions)	3	47.06	15.69	4.74	p<.05
AB(w)	9	35.96	4.00	1.21	
Error(w)	21	69.50	3.31		

Exp. 3: Evaluative Rating

Conditions		A	B	C	D
A	3.90		-0.23^	0.03^	-0.45'
B	3.67			0.26^	-0.22^
C	3.93				-0.48'
D	3.45				

^=Not Significant '= p<.05 "= p<.01

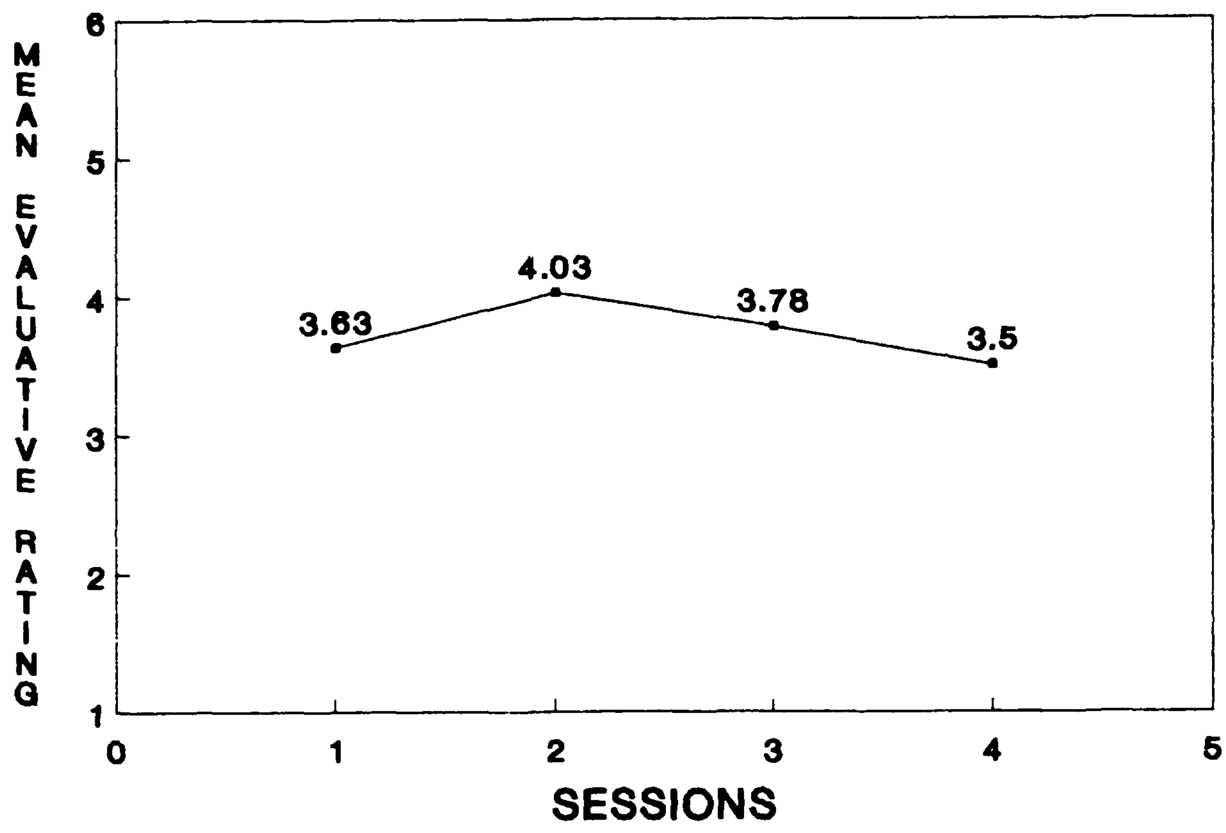


Figure 25. Mean Evaluative Rating versus Sessions for Experiment 3.

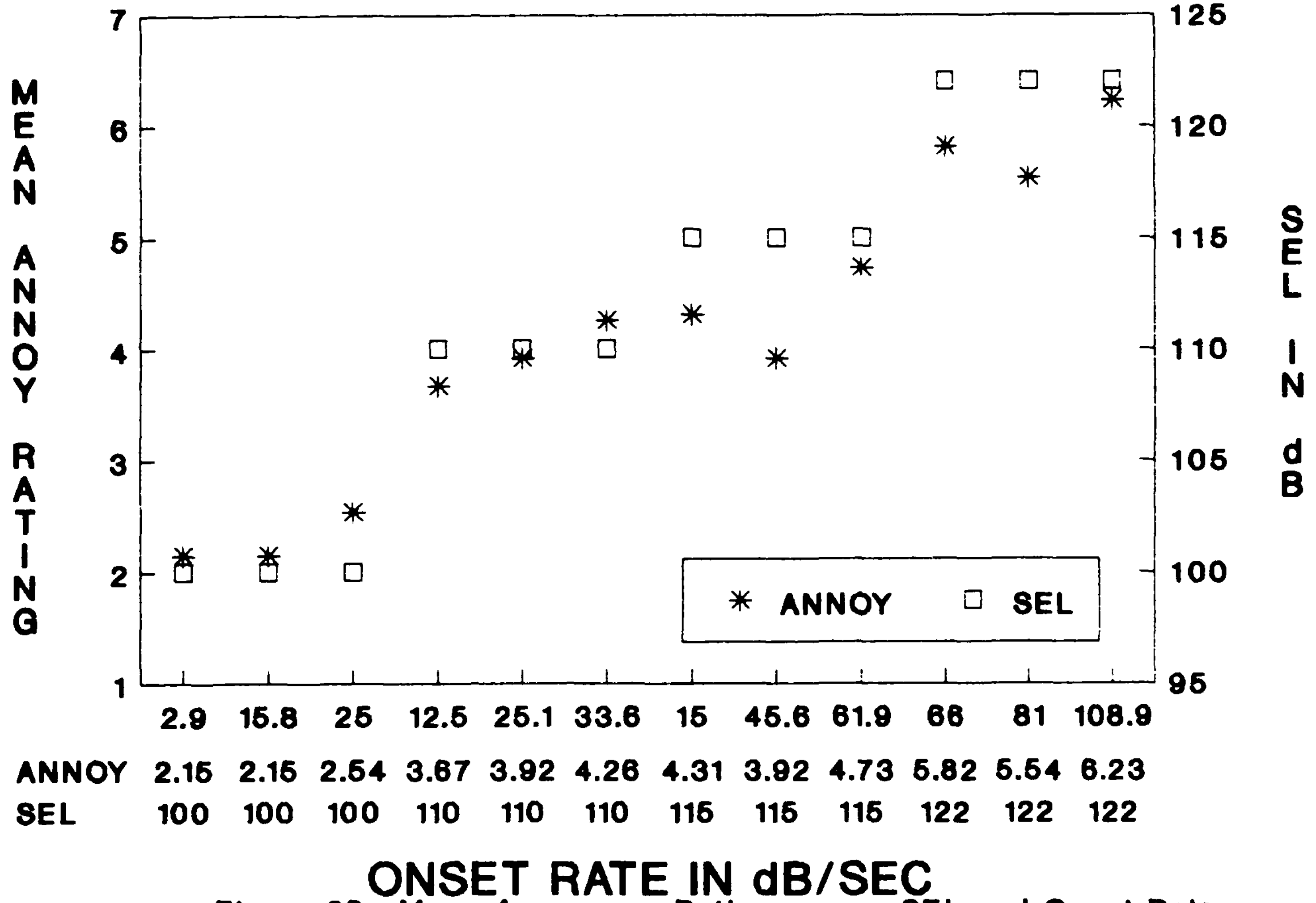


Figure 26. Mean Annoyance Rating versus SEL and Onset Rate for Experiment 4.

TABLE 19
SUMMARY OF MEAN DIFF. FOR EXP. 4

NO.	SEL	ONSET RATE	ANNOY	COMPARE	MEAN DIFF.	SIGNIF.
1	100	2.9	2.15	1 & 2	0.00	NS
2	100	15.8	2.15	1 & 3	.38	$P < .05$
3	100	25.0	2.54	2 & 3	.38	$P < .05$
1	110	12.5	3.67	1 & 2	.25	NS
2	110	25.1	3.92	1 & 3	.59	$P < .01$
3	110	33.6	4.26	2 & 3	.33	$P < .10$
1	115	15.0	4.31	1 & 2	-.38	NS
2	115	45.6	3.92	1 & 3	.42	$P < .10$
3	115	61.9	4.73	2 & 3	.81	$P < .01$
1	122	66.0	5.82	1 & 2	-.28	NS
2	122	81.0	5.54	1 & 3	.41	$P < .05$
3	122	108.9	6.23	2 & 3	.64	$P < .01$

4. DISCUSSION

The overall results seem to indicate that onset rate is an important variable that contributes annoyance that adds to the annoyance produced by the acoustic level of the flyovers. This is seen most clearly in experiment 2 where the effect of onset rate was seen across two levels of flyovers. It is further supported by the results of experiment 3 where the three highest onset rates were all significantly different from the lowest onset rate condition. Furthermore, there is evidence, though not using the annoyance rating, that higher onset rates (with the level held constant) produce greater reactions since there was a significant difference between conditions C and D for the Activity rating and the same was not true for conditions A and B for experiment 2. Similarly, condition D was rated significantly lower than A on the Evaluative rating and the same was not true for A and B or A and C for experiment 3. This same effect was also seen for the annoyance after measure. In experiment 4, the most that can be said of these results is that onset rate does contribute to increased annoyance at several levels of exposure. There were differences in onset rate within levels across a wide range of SEL levels. One cannot state the value of the onset rate within levels where a statistically significant increase in annoyance occurs. Considering the results of all experiments, there is support for the penalty within the interim metric. A penalty for onset rate is needed and it should be applied throughout the range of onset rates.

We are not sure exactly where one would begin applying the penalty but experiment 3 suggests that the value of 15 dB/sec may not be too far off since a significant differences was found between onset rates of 2.23 and 11 dB/sec.

The annoyance rating taken after each flyover was clearly the most sensitive measure of the impulsive - nonimpulsive variable. The reason, of course, is obvious, four ratings were obtained on this annoyance measure for each condition and in all the other ratings the annoyance after rating, the Evaluative, Potency and Activity rating yielded only one measure. In previous research (5, 6), we have used similar measures in continuous noise and all showed good sensitivity to noise level as they did in the present experiments. Therefore, we thought that measures of the Evaluative, Potency, and Activity factors would serve as an "index" of stress. According to our implicit hypothesis, high onset rate flyovers should be rated lower on the Evaluative factor (subject would like these flyovers less), higher on the Potency factor (subject would perceive the flyovers as more powerful), and higher on the Activity factor (subject perceives the flyovers as more active) than equal energy low onset rate noise. This was generally true for the Evaluative factor, although statistical significance was only obtained in experiment 3. It was also true for the Activity factor but statistical significance was only obtained in experiment 2. A different result was obtained for the Potency factor; low onset rate flyovers were rated consistently more powerful than the high onset rate flyovers, although statistical significance was only obtained in experiment 1. These results seem easy to understand, as a post hoc hypothesis, when two flyovers have equal SELs and widely different onset rates, the low onset rate flyover has a considerably longer duration than the high onset rate flyover. And duration may be an important variable for determining potency ratings. In any case, this can only be decided by future research and there are other potential variables to consider when examining the ratings. They were made after a experimental session of six flyovers which in the high onset conditions contained two flyovers that were relatively low level as well as low onset. Therefore, these measures are probably more appropriate for studying the onset rate variable in studies where relatively large numbers of subjects are used.

The SST performance measure showed no effects of level or onset rate as would be expected from previous research with this task (7). Similarly, very few errors were made on this task and this supports the use of the number completed measure. The task was used in the last three experiments because it was thought it would enhance the adverse reaction to the onset rate, because focusing on the task took their attention away from the set in experiment 1 of just waiting for the flyover. Also, task disruption is given as a reason for annoyance in many previous studies. There seems little doubt that performing the SST enhanced the sensitivity of annoyance to onset rate.

5. SUMMARY AND RECOMMENDATIONS

The annoyance measure taken after each flyover was clearly the most sensitive measure of the inpulsive - nonimpulsive variable. Therefore, this is the primary measure of reference in summarizing the results. In experiment 1 a significant difference was obtained at only the highest level (Leq24= 76 dB) and the level with the greatest difference in onset rate (8 and 59.1 dB/sec). All other experiments showed a greater sensitivity to onset rate. The most likely reason for this difference is that in the last three experiments subjects performed the SST. This took the subject's attention away from the noise possibly accentuating the startle or surprise effect. In experiment 2, a significant difference was obtained at both Leqs levels with the difference in onset rate for the 65 dB level of 31 dB/sec and between conditions at the 72 dB level of 49.1 dB/sec. In experiment 3, all four conditions had Leqs of 67 dB with onset rate varying for each condition. Condition A with an onset rate of 2.23 dB/sec differed significantly from B, C, and D with onset rates of 11, 16.83 and 23.62 dB/sec respectively. The most important finding was that a difference of only 8.77 dB/sec was sufficient to produce a significant difference. However, a larger difference between B and D (12.62 dB/sec) did not reach significance. This suggests that the size of the difference in onset rate depends on the value of the initial onset rate. In experiment 4, an attempt was made to examine this possible effect within one experiment. Onset rate varied from 2.9 to 108.9 dB/sec, however, these values were distributed across four SELs and the only thing one can say from this experiment is that differences do occur between relatively low onset rates (2.9 to 25 dB/sec at SEL of 100 dB) and high onset rates (66 and 108.9 dB/sec at SEL of 122 dB).

The generality of the present experiments is limited by the variables chosen for study, by the constants maintained, by the choice of subjects and by the general experimental design and context. Particularly important are the constants. In other experiments these could become the main variables. The flyovers in the present experiments corresponded to outside noise levels, and certainly, we are equally as interested in how flyovers influence annoyance inside structures. Similarly, only one background noise level (45 dB) was used in the present experiment, yet background noise level may change the manner subjects rate the annoyance of flyovers. At the present time it is not possible to predict how annoyance will change as a function of the signal to noise ratio but it may be an important variable for relatively low intensity level flyovers.

Although, the present experiments suggest that performing a task enhances the annoyance reaction to high onset rate flyovers, we know very little about the parameters of tasks that are important for heightening the annoyance. Some possible dimensions are difficulty, inner versus outer directedness, subject versus experimenter paced or even the degree of arousal induced by the task. On the other hand, it may be more important to consider "task" in a more applied sense. The task would be talking on the telephone, reading a book or newspaper, watching television or simply having a conversation.

6. REFERENCES

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APPENDIX A: EXPERIMENTAL CONDITIONS (TAPES)

EXPERIMENTAL CONDITIONS (TAPES)
Experiment 1

TAPE A

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-16	105	7.0
2	B-52G	94	4.4
3	B-52G	106	8.8
4	FB-111	98	4.0
5	B-52G	94	4.4
6	F-4	105	9.4

TAPE B

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	106	29.4
2	F-16	105	44.8
3	B-52G	94	13.1
4	FB-111	98	44.0
5	F-4	105	35.0
6	B-52G	94	13.1

TAPE C

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	94	4.4
2	F-16	109	10.0
3	B-52G	94	4.4
4	FB-111	110	12.7
5	F-4	109	3.0
6	B-52G	116	5.5

TAPE D

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	116	61.0
2	FB-111	109	56.3
3	F-16	109	66.5
4	B-52G	94	13.1
5	B-52G	94	13.1
6	B-52G	110	43.7

EXPERIMENTAL CONDITIONS (TAPES)
Experiment 1 (Continued)

TAPE E

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	115	13.8
2	B-52G	94	4.4
3	F-16	115	6.0
4	FB-111	121	7.0
5	B-52G	94	4.4
6	F-4	121	5.2

TAPE F

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	94	13.1
2	B-52G	94	13.1
3	F-4	121	69.4
4	F-16	115	53.4
5	B-52G	115	47.1
6	FB-111	121	66.5

EXPERIMENTAL CONDITIONS (TAPES)
Experiment 2

TAPE A

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-16	109	7.0
2	B-52G	94	4.4
3	B-52G	110	8.8
4	FB-111	98	4.0
5	B-52G	94	4.4
6	F-4	109	9.4

TAPE B

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	110	29.4
2	F-16	109	44.8
3	B-52G	94	13.1
4	FB-111	98	44.0
5	F-4	109	35.0
6	B-52G	94	13.1

TAPE C

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-52G	94	4.4
2	F-16	112	10.0
3	B-52G	94	4.4
4	FB-111	113	12.7
5	F-4	112	3.0
6	B-52G	119	5.5

TAPE D

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	119	61.0
2	FB-111	112	56.3
3	F-16	112	66.5
4	B-52G	94	13.1
5	B-52G	94	13.1
6	B-52G	113	43.7

EXPERIMENTAL CONDITIONS (TAPES)
Experiment 3

TAPE A

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	C-141A	100	1.4
2	C-18A	100	1.8
3	FB-111A	110	2.4
4	B-1B	110	2.1
5	KC-135A	110	2.8
6	F-4D	110	2.9

TAPE B

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	FB-111	110	15.7
2	F-4	110	15.2
3	B-1	110	15.8
4	C-18	100	1.8
5	C-141	100	1.8
6	KC-135	110	15.7

TAPE C

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	110	25.0
2	KC-135	110	21.1
3	C-18	100	1.6
4	FB-111	110	25.4
5	B-1	110	27.0
6	C-141	100	0.9

TAPE D

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	B-1	110	35.1
2	FB-111	110	35.4
3	F-4	110	33.8
4	F-4	110	33.6
5	C-141	100	1.8
6	C-18	100	2.0

EXPERIMENTAL CONDITIONS (TAPES)
Experiment 4

TAPE A

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	122	81.0
2	F-4	115	61.9
3	F-4	110	25.1
4	F-4	100	25.0
5	F-4	100	15.8
6	F-4	122	108.9

TAPE B

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	115	45.6
2	F-4	122	66.0
3	F-4	110	12.5
4	F-4	115	15.0
5	F-4	100	2.9
6	F-4	110	33.6

TAPE C

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	115	45.6
2	F-4	115	15.0
3	F-4	100	2.9
4	F-4	122	66.0
5	F-4	110	33.6
6	F-4	110	25.1

TAPE D

Flyover	Aircraft	SEL (dB)	ONSET RATE (dB/SEC)
1	F-4	100	15.8
2	F-4	100	25.0
3	F-4	115	61.9
4	F-4	122	81.0
5	F-4	122	108.9
6	F-4	110	12.5

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