/DISTRACTION TYPE AND INTENSITY ON TASK PERFORMANCE/

by

SREE KAILASH

B.S (Mechanical), Trivandrum, India, 1970

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1984

Approved by:

Major Professor

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The author wishes to express his sincere thanks to Dr. Corwin A. Bennett, major advisor, for his invaluable recommendations concerning both the execution and writing of this thesis and also for his continued encouragement throughout this research. I am indebted to Professor Jacob J. Smaltz and Dr. Alexander Mathews for serving on the graduate committe.

I wish to express my appreciation to Mr. Michael Deaton and Mr. Rob Harris for helping me with the statistical analysis and to Dr. Raj for his cooperation in making available the special equipment needed.

My thanks goes to Mr. Dale Dubert for setting up the equipments for the experiment and to the 20 subjects whose cooperation made this study possible.

Last but not the least, I am sincerely thankful to my wife Padma for her patience and effort in typing this thesis. Also my appreciation goes to my daughter Vidya for the temporary abstinence from her pranks.

INTRODUCTION

The critical problems in modern industry more and more tend to be human problems. As organizations grow and become more complex, technical problems form a smaller share of difficulties faced by management (Schultz, 1970). At the same time, the social complexity of large organizations leads to an increase in the rate and proportion of "people" problems.

There are two main features for the approach of the human factor specialist to the design of jobs (Norman, 1965). (1) use of experimental procedures to study the effects of variations in job characteristics on human performance; and (2) development of links between characteristics of people and their job performance. Behind this approach is the assumption that our knowledge of how people behave on the job must be developed on the basis of empirical studies of their behavior, not on "logical" assumptions about it, based on a mechanistic analysis of jobs.

Background

Much research has been concerned with factors affecting efficiency in task situations. Research has also been directed toward specifying the effects of environmental variables, such as heat, noise and glare upon performance. The results of these experiments constitute a mass of empirical data from a variety of situations. In an effort to bring an understanding to these accumulated empirical findings, several investigators have attempted to devise suitable theoritical models to explain them. J.D. Miller (1971) on reviewing the literature on the effects of extraneous variables, conceptualizes these effects into three classes: arousal, distraction and specific effects. The research reported here was designed to study the distractive effects of an extraneous stimulus upon performance of a task.

Efficiency of a task situation cannot be studied in terms of performance measure alone. A person might maintain a high level of performance overcoming the distractive effects of the extraneous stimulus. Ryan, Coltrell and Bitterman (1950) write that in determining optimal environmental conditions of performance, the crucial problem of the "human engineer" is to evaluate the efficiency of performance in the proper sense of the term, which is, productivity in relation to cost to the individual. When a person maintains high performance in the presence of an extraneous stimulus, as opposed to performing without the extraneous stimulus, there may be a cost. This may include fatigue effects after completion of the task (Finkelman and Glass, 1970) or other physiological effects like, rise in blood pressure (Lovell, 1941), increase in pulse rate (Corso, 1952), etc., which constitute a stress on the individual.

Cost Adaptive Hypothesis

Each act which one does, every performance, is potentially susceptible to stress. While reviewing the literature Cohen (1980) discusses the "cost adaptive hypothesis". This says that even though people adapt to stressful conditions, they do so at a cost. This cost will show up in deterioration of later performance.

As an example to the above hypothesis Bennett, Jha and Janasak (1983) write that in an experiment people might be subjected to one of a number of stressors, say noise, then their performance on stress-susceptible-validated tests (or any psychological tests) measured. In comparison to a control group, test performance might be lower, signifying lesser stress effects. It is therefore desirable to design a situation to secure a high level of productivity in the optimum environmental conditions of work.

Concept of Comfort

Distractive effects due to the extraneous stimulus on performing the task were explained by Corlett (1973). Corlett provided a concept of comfort in order to evaluate the work situation along with performance. He stated that, if the balance under a given situation is such as to draw attention to any one sensation, a person can be said to be comfortable. If a sensation distracts attention from the task at hand, then a state of discomfort can be said to exist.

Discomfort, whether from glare, noise or other stimulation must inevitably be triggered by stimuli received through the various sensory systems of the body (Bennett and others, 1983). They write that thus, in discomfort glare, Fry and King (1975) suggested that detection of the sudden reduction in pupil size associated with the onset of a bright, contrasty light in such a signal. In seating discomfort, undue pressure on some of the supporting parts of the body, buttocks, thighs or back provide such a trigger (Bennett, C.A., 1977). Presumably, similar initiating stimuli exist for other sources of discomfort such as noise or high temperature or low temperature.

Distraction can be thought of as lapse in attention or diversion of attention from the task at hand (Miller, 1971). The effects of two or more stimuli competing for attention simultaneously have been defined into different classes. Hebb (1958) asserted that a variety of stimulation has the effect of maintaining arousal; Berlyne (1960) suggested that the intensity of attention is related to the level of arousal. Arousal effects could either be detrimental or beneficial to performance and the direction of the effect will depend mainly on the nature of the task stimulus (Kahneman, 1973) and also on the person's state prior to exposure to the stimuli (Miller, 1971). For example, in attending to a task stimulus and a noise stimulus, a sleepy person might be aroused by noise and therefore perform the task more effectively. On the other hand, noise might induce muscular tension and cause a deterimental effect in attending to the task.

In this research the distractive effects of an extraneous stimulus upon performance of a task was studied. The distractive sources were created by glare or noise.

The effects of distraction upon task performance would appear to be obvious. By decreasing the amount of time and or attention spent on the task, distraction should impair performance (Sanders and Baron, 1975). There are, however, both theoritical and empirical grounds for questioning the validity of such a conclusion. Allport (1924), in his classic work on social facilitation, mentioned overcompensation as one possible explanation of superior group performance: "We work so hard to overcome the distraction incident to group activity that we actually accomplish more than we would without these hindrances". According to this view, the reaction to distraction is some increase in motivation, which results in a net performance improvement.

In cases of performing a task in the presence of an extraneous stimulus Broadbent (1958) favored a combined theory of arousal-distraction effects. He suggested that the extraneous stimulus would have both arousal and distraction effects, but depending on the nature of the task only one will be prevalent. Buckner and McGrath (1963) complemented this theory from their experiments. Perhaps this theory can be better explained from the fundamental law, relating arousal to performance, pioneered by Yerkes and Dodson (1908).

The Yerkes-Dodson Law

This law states that the quality of performance on any task is an inverted U-shaped function of the arousal level, and the range over which performance improves with increasing arousal level varies with task complexity (Yerkes and Dodson, 1908). These relations are systematically illustrated in Figure 1. When arousal is at a low level, a response that produces increased stimulation and greater arousal will tend to be repeated. This is represented by the rising curve at the left. But, when arousal is at a high level, as at the right, it might interfere or distract, perhaps by facilitating irrelevant responses, and cause a deterioration in performance. For a simple task, the range over which performance improves the increasing level of arousal is higher than that for a complex task, as illustrated in Figure 1.

Literature Review

Sanders and Baron (1975) conducted two studies to assess whether distraction has drivelike effects on task performance. In both, the effects of distraction over all trials interacted significantly with the nature of the task, distraction tended to facilitate the performance of simple tasks and significantly impaired performance on complex tasks. Kimble (1967) suggested that conflict, defined as competing reaction tendencies, is a

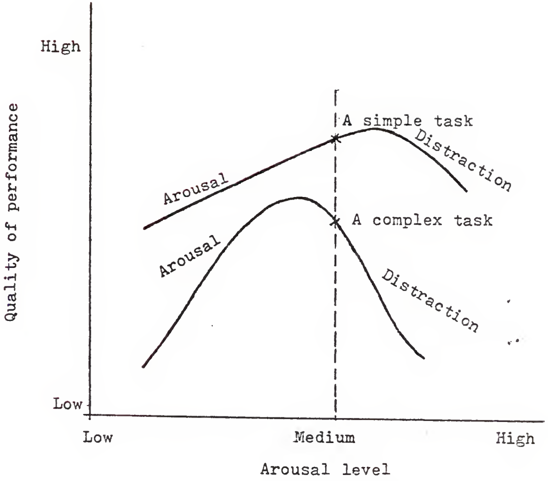

Figure 1. Schematic of the Relationship between Performance and Arousal Level.

source of drive. Distraction, by definition, represents such a conflict: Responses caused by the task at hand are brought into conflict with reactions to the distracting stimulation. In this way, distraction could increase the drive level of the performer and consequently improve performance on simple tasks (Spence, Taylor and Ketchel, 1956).

Writing about the effect of noise on human performance, Karl D. Kryter (1970) reports that increasing the noise level in the room used for postal letter sorters, increased the number of sorting errors. The increase in errors was systematic with an increase in noise level. He further writes that sound or noise may on occasion mask other sounds or noises that can disturb or distract a worker thereby reducing productivity. For some purposes, in generally quiet surroundings, a low-level broad noise may be introduced to increase a sense of privacy with some possible beneficial effects. The presumptions have been that work output will be increased because of improved morale, or that people are kept more aroused and alert than they otherwise become in monotonous jobs.

Teichner (1963) used a visual search task for the study of the effects of noise on human performance which took into account the psychological factors of distraction. The task was to find certain letter combinations appearing on displays before the subject. The subjects responded by throwing a switch which measured how quickly he or she had reached a decision. The time required for the decision-response was taken as the basic measure of performance. The results showed that a change in noise level increased the time required for decisions. The distraction studied in terms of changes in ambient noise levels was found to be a function of the amount of change.

In a research study by Klotzbucher and Fichtel (1979), subjects were exposed to white noise of 55 or 70 or 85 dbA during a concentrated visual task and it was found that exposure to a noise level of 85 dbA resulted in more faults. They recommended that for concentrated visual tasks a noise level of 55 dbA should be allowed, but not a noise level of 70 dbA.

Taking into considerations the above findings, it had been the purpose of this research to determine the effect of distraction from glare and noise upon task performance as a function of task intensity. Glare distraction was used for an auditory task and noise for a visual task.

The author has not come across many studies relating the effect of glare on an auditory task. Research study by Srinivasan (1976) in which glare and noise were used as secondary stimuli for auditory and visual tasks respectively indicated that neither noise nor glare had any measurable distractive effect on performance, even though glare stimulus caused discomfort in reproducing auditory task signals and noise caused discomfort in reproducing visual task signals. He reported that although the intensity of noise and glare stimuli were high and within the safe limits, they were not sufficient to cause distractive effects.

Pilot Study

An inspection task was chosen and the distractive source was from seating discomfort. Two seating conditions were used, "comfortable", and "uncomfortable".

20 subjects individually attended to a penny inspection task. The subject was to mark defective pennies mounted on paper boards which moved over a conveyor in front of the seated subject. The number of defective pennies missed was the measure of performance. The task was repeated for

four different speeds of the conveyor and at the end of the experiment the subjects made judgements on a comfort rating scale about the seating condition.

Within the limits of this experiment, from the results of this pilot study it was observed that the seating discomfort had no significant effect on task performance.

With reference to the pilot study, some extensions are proposed. First, it is desired to extend the performance period to increase the likelihood of distractive effects because one of the possible interpretations of the results of the pilot study may be that the duration of the experiment (30 minutes) was too short for the subject to have felt any discomfort. Second, while doing the literature survey for this thesis, the author came across an interesting finding by Age C. Mandal (1976). He writes that a work-chair with tilted seat (tilted down towards the front- similar to the one used in the pilot study by this author) is more suitable in work situations involving bending forward, with support of the arms on rests. Therefore it is possible that the chair used in the pilot study happened to be comfortable for the penny inspection task which involved bending forward. This was contrary to the expectation to create discomfort. So there was a need to redesign the chair. But due to practical difficulties in redesigning the chair, it was decided to avoid any (possible) distraction due to seating discomfort in this research.

PROBLEM

Few problems have attracted a wider range of professional interests than the problems of noise and glare. Therefore, white noise and light glare were used in this study as the distractive sources.

It was desired to find the effect of distraction on task performance. Two types of experimental situations were considered: 1) performing a visual task in the presence of noise and, 2) performing an auditory task in the presence of light glare. It was also desired to study the interaction between noise and glare without the task employed.

Hypotheses

It was hypothesized that, 1) performance will be lower for a task with higher degree of distraction, and 2) susceptibility to noise will be more in low glare conditions and vice-versa. Hypothesis 1 was tested for visual and auditory tasks.

METHOD

Task

There were two types of task, visual and auditory. Glare and noise distraction were used for auditory and visual tasks respectively. The specific task to be performed was the same under both the types. This was reproduction of strings of five character digits. Each string of digits was referred to as a "task signal" (e.g. "95101"). Two task conditions were involved, "easy" and "difficult", based on the task speed.

Visual Task

The visual task required that the subjects read the digits of the task signal when they appeared on a computer screen (CRT) and reproduced them on a sheet of paper.

In the easy task condition the time interval between the signal presentation was 3 seconds. This was long enough for the subjects to write the signals down in the normal pace. But in the difficult task condition this time was reduced to 1 second. White noise was used as a distractive source.

Auditory Task

The auditory task required that the subjects listen to a tape recording of task signals and reproduce them on a sheet of paper, while looking at a glare source. As in the visual task there were "easy" and "difficult" task conditions based on task speed. For the easy task the signal time was 2 seconds and the time between signals was 3 seconds. For the difficult task the signal time was 1.5 seconds and the time between signals was

1 second.

Informed Consent and Instructions

Subjects were given "Informed Consent and Instructions" sheets in advance, informing them the nature of the experiment and what they were asked to do (Figure 2). They were asked to sign expressing their willingness to participate, before the experiment was begun.

Independent Variables

The independent variables were, 1) the glare levels 2) the noise levels 3) the types of task and 4) the task levels.

Three levels of glare and three levels of noise were employed. These three levels represented conditions 1, 5, and 9 on the "New North American Discomfort Scale" (Figure 3). The nNAD scale ranged from 1 to 9, 1 being pleasant or unnoticeable and 9 being intolerable or unbearable. Condition 5 was borderline between comfort and discomfort (BCD) or "just admissible". Each subject fixed his or her own levels of these three conditions before starting the experiment. This data is shown in Table 1. For this purpose subjects were seated in the same positions as in the task situations and the same lighting and sound conditions were employed.

The two types of task employed were visual and auditory. The two levels of task were "easy" and "difficult".

Dependent Variables

The dependent variables were, 1) performance of task 2) subjective judgments of task conditions in the presence of glare or noise.

Sree Kailash
Graduate student
Dept. of Industrial Engg.

Subject #

INSTRUCTIONS

I thank you for your interest in participating in this experiment. There are two tasks- visual and auditory. You will perform both the tasks while sitting.

Visual task

You will be presented with "signals" of 5 digit numbers at a regular interval on the Tektronix screen in front of you. Your task is to view the signals and "reproduce" them, ie. write them down on the sheet of paper given. Stop when you see no more signals. The task will be repeated at different conditions. Example of a visual signal: 13846

Auditory task

Your task is the same as in the visual task, except that you will hear the signals from a tape recorder behind you. You will be seated in front of the hemisperical booth with a glare source. As you hear the signals write them down in the sheet of paper given. While writing please try to keep looking at the glare source. Look down only to locate the space for writing. Stop when you hear no more signals. This task also will be repeated at different conditions.

I will score your work by counting the total number of signals missed and wrongly reproduced.

Please rate the difficulty of the task under each condition on the scale given.

On completion of these tasks, you will be asked to give your evaluation of certain conditions of glare in the presence of a noise and vice-versa (without the task).

There will not be any kind of risk in this experiment. If you have any questions now or later, please feel free to ask.

I request your co-operation for the success of this study.

INFORMED CONSENT

Having read the instructions, I agree to participate in this experiment.

Date: Name: Age: Sex: Signature:

Figure 2. Informed Consent and Instructions

9 INTOLERABLE (UNBEARABLE)

8

7 BORDERLINE BETWEEN UNCOMFORTABLE AND INTOLERABLE (DISTURBING)

6

5 BORDERLINE BETWEEN COMFORT AND DISCOMFORT (BCD) (JUST ADMISSIBLE)

4

3 BORDERLINE BETWEEN COMFORTABLE AND PLEASANT (SATISFACTORY)

2

1 PLEASANT (UNNOTICEABLE)

Figure 3. New North Ameriacan Discomfort Scale

TABLE 1

Levels of Glare and Noise Fixed by the Subjects on the nNAD Scale

Subject	Noise (dbA)			Glare($x10^{3}$ Foot-Lamberts)		
nNAD scale*	1	5	9	1	5	9
1	70	74	82	.0038	.3	7
2	71	78	93	.0012	.024	2
3	71	96	104	.006	2.4	50
4	70	76	86	.82	9	42
5	70	76	89	.54	8	50
6	70	72	82	.16	2	11
7	70	74	86	.03	2	25
8	70	74	93	.0012	.47	25
9	71	76	88	.47	2.4	13.5
10	71	76	82	.08	.47	2.4
11	72	78	86	.06	2	22
12	70	76	91	.63	5.6	20
13	70	78	88	.009	.94	30
14	70	78	88	.009	3	36
15	71	76	84	.16	1	4.6
16	70	76	98	.0023	3.5	1
17	70	76	86	.0023	1	5.6
18	71	76	88	.13	11	42
19	71	78	89	.3	2	11
20	70	80	91	.0023	.3	4.3

* 1-pleasant; 5 -borderline between comfort and discomfort(BCD); 9-intolerable

The total number of task signals missed and wrongly reproduced was the measure of performance. This happened to be a percentage since the total number of task signals per treatment was 100.

At the end of each treatment, the subject was asked to rate the difficulty of the task (in the presence of glare or noise) on Borg Perceived Exertion scale (Borg, 1962) shown in Figure 4.

Noise and Glare Judgments by Subjects

At the end of the final treatment condition, the subject was subjected to the glare and noise levels fixed by him or her at the beginning of the experiment (on the nNAD scale). Under each glare and noise level (assigned randomly) the subject was asked to fix the same levels (on the nNAD scale) of noise and glare respectively.

Task Signals

The "task signals" were five-digit numbers (e.g. "14732") and there were 100 such signals per treatment. For each treatment a different set of task signals was used. Figures 5-16 show the different sets of visual and auditory task signals used for both easy and difficult tasks.

Experimental Design

The experiment was considered to be of "Completely Randomized Design" (CRD) in which all subjects performed under all conditions randomly. The duration of the experiment was approximately 2 hours.

The easy and difficult visual and auditory tasks, performed under 3 noise levels and 3 glare levels respectively, constituted 12 different

6	
7	VERY VERY EASY
8	
9	VERY EASY
10	
11	FAIRLY EASY
12	
13	SOMEWHAT HARD
14	
15	HARD
16	
17	VERY HARD
18	
19	VERY VERY HARD
20	
21	

Figure 4. Borg Perceived Exertion Scale

Signal Serial	Signal	Signal Serial	Signal
1	34778	26	37171
2	82441	27	92612
3	59747	28	58735
4	73513	29	16532
5	99646	30	23732
6	70949	31	71431
7	15283	32	10662
8	37662	33	68589
9	22347	34	18556
10	81100	35	44954
11	51937	36	78435
12	45002	37	64350
13	35492	38	11788
14	10598	39	80245
15	47569	40	77294
16	56251	41	84623
17	16481	42	64894
18	41576	43	93677
19	45139	44	65118
20	23641	45	89817
21	48648	46	24652
22	81662	47	76659
23	26564	48	92331
24	53371	49	53505
25	96561	50	70454

Figure 5. Auditory Task Signals for Condition 1 (Easy)

Signal Serial	Signal	Signal Serial	Serial
51	55058	76	10375
52	86331	77	62112
53	97155	78	79028
54	15428	79	25594
55	54704	80	24418
56	23541	81	25447
57	33520	82	49545
58	89911	83	88619
59	94204	84	71428
60	42468	85	98382
61	27254	86	89412
62	38246	87	51963
63	78703	88	57761
64	90035	89	10145
65	28328	90	53079
66	41393	91	99612
67	50171	92	16513
68	94637	93	10302
69	34156	94	75838
70	70330	95	77909
71	91560	96	31238
72	63706	97	13870
73	49629	98	25419
74	56582	99	62293
75	57180	100	73178

Figure 5. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	50818	26	72248
2	29218	27	30134
3	10748	28	32414
4	22789	29	20669
5	97323	30	85093
6	95994	31	77362
7	57935	32	15404
8	39565	33	60405
9	11836	34	43278
10	88901	35	58835
11	41450	36	77339
12	95675	37	60393
13	84929	38	27853
14	77781	39	72494
15	71557	40	94341
16	93337	41	16111
17	65076	42	24091
18	51755	43	80057
19	12706	44	29862
20	31010	45	72587
21	22849	46	31160
22	86474	47	16234
23	55595	48	42184
24	76676	49	17209
25	30840	50	52308

Figure 6. Auditory Task Signals for Condition 2 (Easy)

Signal Serial	Signal	Signal Serial	Signal
51	17695	76	62516
52	39505	77	36031
53	19324	78	98172
54	11169	79	60266
55	29705	80	76686
56	88506	81	52696
57	72442	82	56582
58	97052	83	39965
59	24519	84	56710
60	69862	85	61781
61	32644	86	40467
62	49799	87	85069
63	71486	88	58823
64	99387	89	79704
65	24743	90	18151
66	70998	91	33277
67	83303	92	90136
68	64523	93	77883
69	12577	94	13460
70	69321	95	83606
71	80185	96	23204
72	78185	97	37357
73	88665	98	96274
74	42208	99	26910
75	18192	100	97436

Figure 6. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	10386	26	70069
2	48915	27	68071
3	98511	28	41908
4	66064	29	91880
5	90641	30	65302
6	62485	31	51843
7	41460	32	17298
8	31393	33	93555
9	22537	34	35644
10	40566	35	38354
11	22392	36	20221
12	55028	37	63494
13	92099	38	49583
14	40727	39	64523
15	26521	40	97126
16	12737	41	13614
17	68617	42	39969
18	43868	43	24765
19	75557	44	68216
20	55309	45	64620
21	66724	46	19185
22	24930	47	43517
23	75754	48	73867
24	42436	49	21632
25	26787	50	52539

Figure 7. Auditory Task Signals for Condition 3 (Easy)

Signal Serial	Signal	Signal Serial	Signal
51	25311	76	85416
52	58090	77	90708
53	92932	78	13027
54	93702	79	29091
55	76899	80	81109
56	25932	81	15632
57	63467	82	88243
58	32924	83	70152
59	98345	84	90593
60	47139	85	59394
61	17744	86	36324
62	37142	87	99698
63	24931	88	33836
64	49459	89	44294
65	32757	90	84664
66	85412	91	76806
67	42412	92	85417
68	24185	93	50681
69	26418	94	76474
70	15466	95	91083
71	70807	96	93629
72	45108	97	15173
73	39211	98	52614
74	21092	99	49451
75	74541	100	86939

Figure 7. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	88093	26	56219
2	50500	27	62208
3	80991	28	60711
4	32020	29	57289
5	20720	30	87723
6	64104	31	55534
7	93575	32	80490
8	32263	33	24336
9	40298	34	65578
10	75145	35	11709
11	70348	36	44510
12	91251	37	38380
13	87180	38	64188
14	10789	39	40666
15	78307	40	45780
16	15541	41	93826
17	50508	42	36381
18	22330	43	24607
19	85583	44	21924
20	49741	45	53888
21	10526	46	79044
22	21399	47	89556
23	98185	48	95101
24	83202	49	77743
25	16814	50	30064

Figure 8. Visual Task Signals for Condition 4 (Easy)

Signal Serial	Signal	Signal Serial	Signal
51	91827	76	91186
52	52410	77	43911
53	20328	78	14061
54	71936	79	15529
55	51839	80	84720
56	13046	81	24549
57	87486	82	75211
58	28028	83	55273
59	23953	84	73830
60	80232	85	64527
61	82632	86	88181
62	53532	87	73311
63	50530	88	29742
64	16732	89	18410
65	60362	90	78472
66	98003	91	27716
67	32644	92	27472
68	18981	93	51692
69	84627	94	93572
70	89193	95	10209
71	82692	96	82670
72	51937	97	93740
73	30605	98	18259
74	42421	99	95157
75	55967	100	64371

Figure 8. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	43467	26	79961
2	92172	27	58428
3	82006	28	67254
4	38920	29	46209
5	54735	30	68165
6	77898	31	38329
7	41808	32	78704
8	15270	33	40707
9	24001	34	26006
10	89731	35	91318
11	93567	36	86371
12	10504	37	57751
13	67959	38	60829
14	14488	39	12125
15	20919	40	36871
16	41931	41	55083
17	19198	42	21550
18	55161	43	20165
19	28232	44	22187
20	58707	45	22772
21	60909	46	41964
22	39181	47	80883
23	36444	48	36466
24	73315	49	42148
25	73562	50	88263

Figure 9. Visual Task Signals for Condition 5 (Easy)

Signal Serial	Signal	Signal Serial	Signal
51	23900	76	95059
52	31912	77	75483
53	73746	78	69800
54	53045	79	32184
55	60420	80	79328
56	23959	81	43655
57	82800	82	95368
58	23015	83	90078
59	97916	84	72472
60	73342	85	30169
61	78322	86	41512
62	26673	87	20832
63	54971	88	66985
64	88569	89	45366
65	84093	90	66026
66	19219	91	45478
67	75063	92	58939
68	95110	93	41214
69	99342	94	31827
70	29819	95	31481
71	93879	96	72576
72	73038	97	34827
73	85011	98	19637
74	45319	99	34393
75	78266	100	75227

Figure 9. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	80484	26	11359
2	10580	27	85503
3	50640	28	70041
4	41073	29	82886
5	98409	30	71453
6	51017	31	11463
7	88412	32	79143
8	49799	33	12479
9	89161	34	61004
10	39367	35	49067
11	41870	36	99922
12	64293	37	25411
13	73183	38	56541
14	68869	39	25721
15	10049	40	35616
16	53983	41	37552
17	52597	42	57693
18	10459	43	88013
19	83550	44	13083
20	31379	45	28808
21	69890	46	66983
22	76237	47	70828
23	98902	48	26098
24	94806	49	42676
25	54327	50	44343

Figure 10. Visual Task Signals for Condition 6 (Easy)

Signal Serial	Signal	Signal Serial	Signal
51	40268	76	87592
52	77865	77	80910
53	44613	78	75199
54	53086	79	19894
55	36306	80	28766
56	13609	81	61116
57	72383	82	36069
58	27997	83	99180
59	87861	84	37179
60	24452	85	78560
61	32434	86	46059
62	74242	87	62429
63	11438	88	89893
64	25045	89	78535
65	58213	90	84418
66	56027	91	99306
67	76041	92	56370
68	96339	93	76669
69	81771	94	62114
70	38087	95	12635
71	43917	96	40206
72	27501	97	27256
73	94186	98	78798
74	83444	99	68671
75	50817	100	41009

Figure 10 (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	93187	26	32590
2	98049	27	62132
3	45300	28	48895
4	21397	29	44947
5	25290	30	38535
6	99912	31	52181
7	14693	32	38965
8	35226	33	64093
9	43182	34	89059
10	97690	35	21884
11	45083	36	58097
12	94991	37	19212
13	77486	38	39914
14	74047	39	68268
15	50847	40	89706
16	60316	41	51604
17	17074	42	43753
18	73658	43	36272
19	44248	44	36139
20	40106	45	65604
21	76321	46	47843
22	50347	47	88111
23	40369	48	94233
24	76903	49	61361
25	25063	50	48176

Figure 11. Auditory Task Signals for Condition 7 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	78283	76	97617
52	24761	77	47379
53	67569	78	41860
54	31986	79	50078
55	80416	80	70144
56	23949	81	14785
57	62449	82	71656
58	61382	83	68559
59	11308	84	12493
60	57409	85	21252
61	70010	86	38898
62	16883	87	45698
63	78002	88	17204
64	83624	89	30736
65	71009	90	55082
66	41310	91	98177
67	82693	92	29505
68	96372	93	11231
69	80589	94	32818
70	75308	95	20728
71	45029	96	93888
72	16825	97	47431
73	16282	98	44706
74	99912	99	45353
75	26959	100	79640

Figure 11. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	25978	26	71519
2	30417	27	17313
3	84722	28	61922
4	36615	29	96562
5	78243	30	98660
6	68136	31	70761
7	81265	32	84736
8	71676	33	54106
9	99203	34	88426
10	43700	35	64744
11	16347	36	95551
12	82442	37	28286
13	66240	38	68676
14	89203	39	66631
15	76881	40	26231
16	28425	41	47802
17	18994	42	19942
18	50254	43	25918
19	34969	44	90799
20	93747	45	57739
21	68228	46	80959
22	35706	47	50769
23	94322	48	82328
24	76726	49	68333
25	15482	50	46192

Figure 12. Auditory Task Signals for Condition 8 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	90643	76	53617
52	12937	77	18465
53	21204	78	62442
54	84604	79	96779
55	49244	80	75501
56	22259	81	96316
57	87275	82	20186
58	99936	83	90582
59	32612	84	19742
60	20394	85	49549
61	65651	86	36790
62	31991	87	48667
63	32844	88	46099
64	59749	89	23501
65	42617	90	77465
66	85010	91	99131
67	65123	92	95087
68	54368	93	76517
69	15263	94	22456
70	41675	95	56178
71	63311	96	84948
72	11602	97	96997
73	56294	98	54871
74	50217	99	72434
75	90498	100	39637

Figure 12. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	66406	26	29088
2	59241	27	42830
3	95877	28	91996
4	90382	29	42160
5	17992	30	58940
6	13759	31	19171
7	27316	32	66887
8	22889	33	92140
9	90306	34	57573
10	70862	35	47445
11	48893	36	37134
12	60981	37	12476
13	87686	38	27771
14	97847	39	34340
15	40478	40	91135
16	10153	41	46101
17	18069	42	58362
18	52752	43	29808
19	86539	44	13164
20	35120	45	73976
21	35367	46	43613
22	69031	47	80330
23	11029	48	86045
24	57936	49	29862
25	93939	50	28215

Figure 13. Auditory Task Signals for Condition 9 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	88412	76	71668
52	90882	77	98674
53	80910	78	41757
54	76350	79	16320
55	22914	80	69169
56	10912	81	36157
57	32906	82	62165
58	67796	83	20518
59	82135	84	33153
60	62062	85	69890
61	32380	86	26294
62	19156	87	19935
63	95660	88	35185
64	40031	89	10635
65	82948	90	32996
66	11247	91	13896
67	60085	92	99427
68	87447	93	93766
69	45811	94	96723
70	94054	95	52581
71	17476	96	75122
72	35397	97	11547
73	42022	98	68692
74	49715	99	56427
75	67329	100	25442

Figure 13. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	95359	26	84297
2	15790	27	62431
3	38197	28	30465
4	49911	29	96502
5	30038	30	20815
6	40871	31	13311
7	30852	32	10458
8	94892	33	50291
9	60151	34	82477
10	53383	35	48644
11	89483	36	47518
12	88463	37	63492
13	84301	38	88034
14	97923	39	42902
15	19683	40	33144
16	54570	41	97336
17	81447	42	40447
18	22921	43	27867
19	57248	44	33668
20	19366	45	71367
21	29860	46	97025
22	78116	47	74876
23	81432	48	94137
24	12670	49	21607
25	16832	50	93817

Figure 14. Visual Task Signals for Condition 10 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	99189	76	78589
52	83056	77	69613
53	23265	78	72593
54	39354	79	42340
55	58680	80	49218
56	55036	81	45936
57	82339	82	64459
58	51430	83	57109
59	32883	84	89214
60	43601	85	12381
61	36020	86	57371
62	96367	87	12550
63	90819	88	54821
64	76712	89	67112
65	54041	90	99380
66	62743	91	44957
67	49749	92	63059
68	34221	93	45183
69	51917	94	26881
70	62878	95	56722
71	65878	96	43521
72	62492	97	52274
73	92202	98	55988
74	98405	99	18056
75	70452	100	35614

Figure 14. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	68472	26	11926
2	60332	27	11165
3	98575	28	42874
4	79217	29	38531
5	52584	30	63418
6	55612	31	50063
7	80197	32	93624
8	41323	33	19035
9	84492	34	25009
10	36280	35	47828
11	78911	36	98985
12	12805	37	57206
13	97038	38	43897
14	49660	39	61470
15	32999	40	89718
16	64485	41	33324
17	89192	42	81714
18	76034	43	54652
19	74754	44	53242
20	23804	45	27835
21	34598	46	99498
22	36988	47	43135
23	37877	48	46131
24	36099	49	80561
25	95424	50	43280

Figure 15. Visual Task Signals for Condition 11 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	59879	76	49204
52	10538	77	92325
53	56197	78	70161
54	96623	79	45121
55	40836	80	30567
56	39785	81	70909
57	38765	82	28107
58	33306	83	96564
59	30850	84	24837
60	68758	85	94809
61	84985	86	62091
62	18938	87	70397
63	60957	88	96018
64	88005	89	57489
65	55421	90	11615
66	30308	91	97468
67	45704	92	95955
68	67323	93	59390
69	90172	94	28543
70	63786	95	85730
71	51384	96	75033
72	15020	97	94164
73	46250	98	84855
74	69189	99	36036
75	93729	100	79453

Figure 15. (Continued)

Signal Serial	Signal	Signal Serial	Signal
1	70229	26	30655
2	26928	27	70681
3	55664	28	74621
4	46113	29	54328
5	67589	30	22293
6	77097	31	62943
7	79018	32	61888
8	26949	33	43521
9	96584	34	58464
10	51955	35	70865
11	56467	36	14736
12	42262	37	36638
13	57051	38	83287
14	50215	39	16920
15	42861	40	55458
16	53951	41	79619
17	87741	42	16020
18	63330	43	76587
19	54926	44	26035
20	19771	45	85553
21	17144	46	37919
22	46196	47	95691
23	93909	48	99724
24	42229	49	27156
25	25901	50	60045

Figure 16. Visual Task Signals for Condition 12 (Difficult)

Signal Serial	Signal	Signal Serial	Signal
51	97280	76	95579
52	21110	77	44881
53	70206	78	15138
54	91399	79	37682
55	40426	80	47863
56	76395	81	85440
57	21279	82	27788
58	23453	83	27047
59	17130	84	30986
60	59601	85	61634
61	71144	86	40313
62	87656	87	49972
63	87019	88	73966
64	63532	89	98906
65	40946	90	81066
66	28631	91	23392
67	59977	92	77670
68	33742	93	96577
69	14476	94	87754
70	62387	95	42625
71	72019	96	33593
72	71907	97	21255
73	78671	98	16544
74	29260	99	83298
75	61676	100	55517

Figure 16. (Continued)

conditions. Table 2 shows the randomized sequence in which the 12 conditions were presented to the subjects.

Subjects and Recruitment Procedures

There were 20 subjects, 15 males and 5 females. All of them were students of a junior level engineering management class. Their ages ranged from 20 to 24. They were given extra course credit for participating in this experiment.

Equipment

The experiment was conducted in the Visual Simulation Laboratory of the Industrial Engineering department.

Figures 17 and 18 give a general idea about the equipment used and the positions of the subjects for the auditory and visual tasks respectively.

For both the auditory and the visual tasks the subject was seated in a standard wooden class-room chair with a right-hand desk top.

For the auditory task, the subject was seated in front of a two-foot radius hemisphere set on edge. An incandescent lamp (CTT, 1000W, 120V) was arranged behind a 1.25 inches diameter hole in the hemisphere along the horizontal axis from the viewer. The glare source size was 3.14×10^{-4} steradian. The glare source luminance could be adjusted from 0 to 165,000 cd/m^2. Background luminance of the hemisphere was set at 1 cd/m^2 provided by a separate incandescent light source projected on to the surface from behind the subject. The subject viewed from about 48 inches from the glare source while performing the auditory task.

Subjects heard the task signals from a cassette tape-recorder, spoken with an intensity of about 75 db(A).

TABLE 2

Experimental Design of Randomized Sequence

Subject	Sequence of Conditions*										
1	11	3	4	7	1	5	2	9	10	12	6	8
2	5	9	10	7	1	2	8	11	3	12	4	6
3	1	11	8	5	4	9	10	2	7	12	3	6
4	10	1	2	11	8	9	4	12	3	5	7	6
5	2	6	4	3	7	12	1	11	5	9	10	8
6	9	4	1	12	3	7	5	11	8	6	10	2
7	12	1	10	2	5	3	4	6	7	8	11	9
8	8	10	11	3	12	2	6	7	4	9	5	1
9	6	8	5	2	11	7	4	1	3	12	9	10
10	9	5	7	8	11	1	3	6	2	10	12	4
11	6	12	7	10	2	3	11	1	5	8	4	9
12	7	5	11	2	10	9	6	3	1	4	8	12
13	10	1	6	4	2	5	3	7	12	8	11	9
14	2	4	7	6	3	12	10	8	11	9	5	1
15	10	1	4	2	11	12	7	9	6	3	5	8
16	8	1	5	9	4	7	12	3	6	2	11	10
17	3	6	9	12	2	11	7	4	1	8	10	5
18	4	12	3	11	2	5	7	8	9	10	6	1
19	8	5	2	12	1	4	7	10	3	11	9	6
20	3	9	12	5	11	4	8	10	2	6	7	1

* 1,2,3- Easy auditory tasks with glare conditions 1,5,9 respectively on nNAD scale.

4,5,6- Easy visual tasks with noise conditions 1,5,9 respectively on nNAD scale.

7,8,9- Difficult auditory tasks with glare conditions 1,5,9 respectively on nNAD scale.

10,11,12- Difficult visual tasks with noise conditions 1,5,9 respectively on nNAD scale.

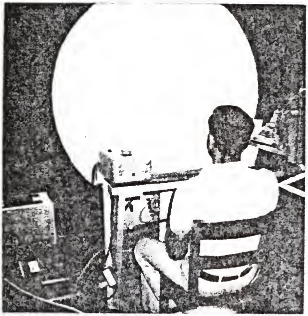

Figure 17. Subject at an Auditory Task

Figure 18. Subject at a Visual Task

A Tektronix computer was used to generate visual task signals. Subjects were seated in front of the screen of the computer, about 25 inches away. The string of five digits appeared on the screen was 7/8 inch long and each digit was 3/16 inch in height and 1/8 inch in width. Each digit subtended an angle of 27 minutes of arc. Noise measured from the computer was 50 db(A).

The computer screen, when in operation, had a luminance of 0.046 Foot-Lamberts. The green numbers appeared on the screen had a luminance of 2.5 Foot-Lamberts. Thus the green signals on the dark screen had a brightness contrast of .6. The angle subtended by the digits, and the contrast of visual signals were in the desired levels for the experiment (Winkler, 1979).

Noise was generated by a white noise generator. The volume and tone control knobs of the noise generator were kept fixed at positions 2 and 5 respectively. The various noise levels were obtained by adjusting the attenuator. A noise range of 70-104 db(A) could be achieved.

During the experiment, the lights in the laboratory were switched off. Separate table lamps were provided to illuminate the desk top of the chair for the visual and auditory tasks. These lamps provided just sufficient illumination for the subjects to reproduce the task signals.

The cooling fan for the glare source was on throughout the experiment. The noise measured from this fan was 65 db(A).

RESULTS

The performance of the reproduction tasks is shown in Table 3. The total number of task signals missed and wrongly reproduced was the measure of performance. Table 4 gives the ratings by the subjects of each treatment condition on the Borg Perceived Exertion scale. Table 5 shows the noise and glare levels fixed by the subject in the presence of one another (without the task).

Statistical Tests

For analysis purposes the experiment was separated into two parts. The first part of the experiment employed the tasks and the second was without the task. An analysis of variance (ANOVA) was carried out for performance and subjective ratings of each treatment condition. Significance was tested for an alpha level of five percent. A multivariate analysis of variance (MANOVA) was done on the results of the second part of the experiment in which the subject fixed noise and glare levels in the presence of one another (without the task). Significant results from the ANOVA were further checked with Duncan's multiple range test at significance levels of five percent. Separate MANOVA was carried out for glare and noise as dependent variables. Significance of overall glare and noise effect on noise and glare judgments respectively was further confirmed through Wilks' test criteria.

Performance

The analysis of variance corresponding to the data shown in Table 3 is shown in Table 6 and the results of the Duncan's multiple range tests

TABLE 3

Total Number of Task Signals Missed and Wrongly Reproduced

Subject	Treatment Conditions											
	1	2	3	4	5	6	7	8	9	10	11	12
1	2	9	7	2	2	0	13	21	30	22	32	18
2	4	5	3	0	0	0	23	34	40	4	10	10
3	3	5	1	0	0	0	7	15	31	43	54	45
4	0	0	0	0	1	1	4	10	22	27	25	32
5	0	0	0	0	1	0	6	22	35	44	57	54
6	1	1	3	0	0	0	14	28	43	14	17	9
7	0	0	0	0	0	0	3	7	15	5	4	7
8	2	2	10	0	0	0	35	39	49	38	37	48
9	0	0	0	0	0	0	1	17	8	3	6	6
10	12	24	29	1	0	3	24	38	55	15	10	8
11	2	8	4	0	0	2	12	22	29	28	32	38
12	2	10	5	0	0	0	34	36	30	25	33	27
13	12	11	12	0	1	1	54	64	63	52	64	60
14	7	24	15	0	0	0	50	45	49	13	14	12
15	2	2	2	0	0	0	9	21	33	16	16	12
16	6	1	4	1	0	0	14	20	38	35	33	36
17	17	8	7	0	6	0	49	58	55	93	37	44
18	3	1	3	3	0	2	9	8	14	29	21	20
19	3	21	13	0	2	1	39	62	57	49	30	55
20	5	10	7	1	1	1	13	20	16	6	8	7
Mean:	4.15	7.1	6.25	.4	.7	.55	20.7	29.4	35.6	28.1	27	27.4
					15.6							

TABLE 4

Rating by the Subjects of Each Treatment on the Borg Perceived Exertion Scale

Subject	Treatment Conditions											
	1	2	3	4	5	6	7	8	9	10	11	12
1	11	13	11	12	12	11	15	13	17	18	17	18
2	15	15	15	15	12	15	17	18	18	16	17	17
3	12	12	11	8	12	11	13	15	18	17	21	21
4	8	9	8	9	8	9	10	13	15	17	17	19
5	10	13	13	12	13	13	16	17	17	17	17	17
6	9	8	12	10	11	11	15	16	18	14	15	18
7	7	9	11	9	11	11	15	17	17	15	17	15
8	7	8	12	7	7	9	13	12	16	12	13	16
9	11	13	10	10	12	12	11	17	14	13	15	15
10	10	15	15	13	8	11	13	15	18	16	11	17
11	11	12	13	8	7	12	14	17	17	17	16	17
12	9	11	11	8	7	11	13	17	16	16	14	18
13	11	14	15	14	14	14	17	19	20	13	20	19
14	11	13	11	9	11	9	17	18	17	16	13	17
15	9	9	13	9	11	11	15	13	19	13	17	17
16	10	11	11	8	8	10	12	17	18	15	11	16
17	14	14	15	13	17	15	18	19	19	19	18	19
18	6	9	11	12	8	11	15	16	17	17	15	17
19	7	9	10	7	11	9	14	17	20	18	18	17
20	7	9	14	9	10	15	12	15	18	17	18	18
Mean :	9.8	11.3	12.1	10.1	10.5	11.5	14.3	16.1	17.5	15.8	16	17.4
						13.5						

TABLE 5

The Levels of Glare and Noise Judged by the Subject in the Presence of One Another (Without the Task)

Subject	Glare($x10^3$fL)*	Noise(dbA)*	nNAD scale Noise(dbA) 1	5	9	Glare($x10^3$fL) 1	5	9
1	0.0038		70	78	86			
	0.300		70	78	86			
	7.000		71	80	88			
		70				0.0016	0.840	4.300
		74				0.010	0.940	4.700
		82				0.006	2.000	7.000
2	0.0012		71	78	88			
	0.024		70	78	86			
	2.000		70	80	86			
		71				0.0012	0.160	2.000
		78				0.0016	0.220	1.500
		93				0.0016	0.84	3.300
3	0.006		70	88	104			
	2.400		70	91	104			
	50.000		70	91	104			
		71				0.018	3.200	25.000
		96				0.130	4.600	25.000
		104				0.190	13.500	25.000
4	0.820		76	82	88			
	9.000		71	76	82			
	42.000		72	76	82			
		70				0.023	0.840	4.300
		76				0.080	0.840	5.600
		86				0.040	2.200	13.500

* These glare and noise levels were fixed by the subjects at the beginning of the experiment (see Table 1)

TABLE 5. (Continued)

Subject	Glare($x10^3$fL)	Noise(dbA)	Noise(dbA) 1	5	9	nNAD scale Glare($x10^3$fL) 1	5	9
5	0.540		70	78	86			
	8.000		70	72	78			
	50.000		72	78	84			
		70				0.490	1.400	10.000
		76				1.200	8.000	30.000
		89				13.500	36.000	50.000
6	0.160		70	76	86			
	2.000		71	74	86			
	11.000		70	76	86			
		70				30.000	0.940	7.000
		72				0.060	1.000	8.600
		82				0.760	5.200	16.000
7	0.030		70	80	88			
	2.000		70	82	89			
	25.000	70	70	80	88	0.006	2.200	10.000
		74				1.000	7.200	30.000
		86				2.800	9.000	30.000
8	0.0012		70	78	89			
	0.470		70	78	88			
	25.000		70	80	89			
		70				0.001	1.400	25.000
		74				30.000	2.600	30.000
		93				0.060	1.300	25.000

TABLE 5. (Continued)

Subject	Glare($x10^{3}$fL)	Noise(dbA)	nNAD scale Noise(dbA) 1	5	9	Glare($x10^{3}$fL) 1	5	9
9	0.470		72	78	86			
	2.400		72	80	86			
	13.500		74	82	89			
		71				0.350	2.000	22.000
		76				1.300	5.200	42.000
		88				4.300	20.000	50.000
10	0.080		71	76	80			
	0.470		71	74	78			
	2.400		72	76	82			
		71				0.023	0.700	2.400
		76				0.350	0.940	3.000
		82				0.490	2.600	7.200
11	0.060		71	76	82			
	2.000		72	78	84			
	22.000		71	78	84			
		72				0.060	2.600	25.000
		78				0.130	7.000	25.000
		86				0.350	10.000	25.000
12	0.630		76	82	89			
	5.600		70	76	82			
	20.000		71	76	82			
		70				0.400	2.000	9.000
		76				0.400	3.500	10.000
		91				0.400	5.200	13.500
13	0.009		71	74	82			
	0.940		71	74	84			
	30.000		72	80	88			
		70				0.001	0.840	13.500
		78				0.004	1.700	9.000
		88				0.220	1.300	25.000

TABLE 5. (Continued)

Subject	Glare($x10^3$fL)	Noise(dbA)	nNAD scale Noise(dbA) 1	5	9	Glare($x10^3$fL) 1	5	9
14	0.009		70	80	89			
	3.000		70	80	86			
	36.000		70	80	88			
		70				0.023	1.400	11.000
		78				0.130	3.200	9.000
		88				0.080	4.300	14.000
15	0.160		71	74	80			
	1.000		70	74	80			
	4.600		70	76	82			
		71				0.015	0.840	3.800
		76				0.050	1.300	5.000
		84				0.620	4.300	12.000
16	0.0023		70	80	104			
	3.500		70	82	104			
	1.000		70	86	104			
		70				0.0011	0.620	11.000
		76				0.006	1.700	30.000
		98				0.0016	7.000	50.000
17	0.0023		70	74	84			
	1.000		70	74	82			
	5.600		70	72	82			
		70				0.0023	0.130	1.100
		76				0.018	0.540	1.550
		86				0.100	1.100	3.800
18	0.130		80	84	91			
	11.000		74	80	86			
	42.000		76	82	89			
		71				0.300	4.300	11.500
		76				1.000	3.000	30.000
		88				1.300	9.000	30.000

TABLE 5. (Continued)

Subject	Glare($x10^3$fL)	Noise(dbA)	nNAD scale Noise(dbA) 1	5	9	Glare($x10^3$fL) 1	5	9
19	0.300		71	82	88			
	2.000		70	80	86			
	11.000		74	82	88			
		71				0.060	0.840	3.000
		78				0.350	2.000	5.000
		89				1.000	7.200	16.000
20	0.0023		70	74	80			
	0.300		70	74	78			
	4.300		70	74	78			
		70				0.0012	0.023	0.840
		80				0.006	0.100	0.940
		91				0.006	0.490	2.000

TABLE 6

Analysis of Variance of Performance

Source of Variation	Sum of Squares	D.F	Mean Square	F
Subject (S)	15156.43	19	797.70	6.80 *
Distraction Level (L)	707.72	2	353.86	3.02
Task (T)	601.66	1	601.66	5.13 *
Ease (E)	36952.01	1	36952.01	315.05 *
T x L	813.80	2	406.90	3.47 *
E x L	371.80	2	185.90	1.59
T x E	268.81	1	268.81	2.29
T x E x L	466.05	2	233.02	1.99
Error	24513.26	209	117.28	
Total	79851.59	239		

* denotes significance at levels of 0.05

in Table 7.

The analysis of variance showed a significant difference in the main effects of task and ease of task. But there was no significant difference in performance due to the noise and glare levels.

The interaction between the task and treatment conditions showed a statistical significance. The differences among subjects were also statistically significant.

Duncan's multiple range test showed that visual difficult task was significantly different from auditory difficult task.

Subjective Judgments of Task Conditions

The analysis of variance corresponding to the data in Table 4 is shown in Table 8 and the results of the Duncan's multiple range test in Table 9.

The analysis of variance showed significant differences between the easy and difficult tasks and among the treatment conditions. Also the tasks and treatment interactions were significant.

The Duncan's multiple range test indicated that in the case of the difficult auditory task, subjects evaluated the task condition as relatively harder in the presence of higher levels of glare than in the pleasant glare level (means of 16.05 and 17.45 in the BCD and intolerable levels respectively compared to 14.25 in the pleasant level). Similar trends were noticed in the case of the difficult visual task and easy auditory and visual tasks.

Noise Judgments in the Presence of Glare

Results of the MANOVA carried out with the three noise levels

TABLE 7

Duncan's Multiple Range Test for Performance Means

Task	Ease	Distraction Level*	Mean	Grouping**
Auditory	Difficult	G9	35.600	A
Auditory	Difficult	G5	29.350	A B
Visual	Difficult	N1	28.050	B
Visual	Difficult	N9	27.400	C B
Visual	Difficult	N5	27.000	C B
Auditory	Difficult	G1	20.650	C
Auditory	Easy	G5	7.100	D
Auditory	Easy	G9	6.250	D
Auditory	Easy	G1	4.150	D
Visual	Easy	N5	0.700	D
Visual	Easy	N9	0.550	D
Visual	Easy	N1	0.400	D

* G1, G5, G9 - Pleasant, BCD and intolerable conditions of glare on nNAD scale

N1, N5, N9 - Pleasant, BCD and intolerable conditions of noise on nNAD scale

** Means with the same letter are not significantly different

TABLE 8

Analysis of Variance of Subjective Judgments of Task Difficulty

Source of Variation	Sum of Squares	D.F	Mean Square	F
Subject (S)	436.60	19	22.98	7.69 *
Distraction Level (L)	183.10	2	91.55	30.64 *
Task (T)	0.26	1	0.26	0.09
Ease (E)	1674.81	1	1674.81	560.42 *
T x L	23.50	2	11.75	3.93 *
E x L	3.50	2	1.75	0.59
T x E	10.41	1	10.41	3.49
T x E x L	1.10	2	0.55	0.19
Error	624.60	209	2.98	
Total	2957.93	239		

* denotes significance at levels of 0.05

TABLE 9

Duncan's Multiple Range Test for Judgment Means

Task	Ease	Distraction Level*	Mean	Grouping**
Auditory	Difficult	G9	17.45	A
Visual	Difficult	N9	17.40	A
Auditory	Difficult	G5	16.05	B
Visual	Difficult	N5	16.000	B
Visual	Difficult	N1	15.80	B
Auditory	Difficult	G1	14.25	C
Auditory	Easy	G9	12.10	D
Visual	Easy	N9	11.50	D E
Auditory	Easy	G5	11.30	D E
Visual	Easy	N5	10.50	F E
Visual	Easy	N1	10.10	F
Auditory	Easy	G1	9.75	F

* G1, G5, G9 - Pleasant, BCD and intolerable conditions respectively of glare on nNAD scale
N1, N5, N9 - Pleasant, BCD and intolerable conditions respectively of noise on nNAD scale

** Means with the same letter are not significantly different (pleasant-1, BCD-5 and intolerable-9) as dependent variables are shown in Tables 10-12.

Wilks' MANOVA test criteria showed that the overall glare effect on noise judgments was significant. Specifically the glare effect on the judgment of the intolerable condition of noise was significant (Table 10). The difference among the subjects also was statistically significant with respect to all the three noise levels.

Glare Judgments in the Presence of Noise

Results of the MANOVA carried out with the three glare levels (pleasant-1, BCD-5, and intolerable-9) as dependent variables are shown in Tables 13-15.

Wilks' MANOVA test criteria showed that the overall noise effect on glare judgments was significant. Table 13 indicates that noise effect on the judgment of the intolerable and BCD conditions of glare was significant. The difference among the subjects also was statistically significant with respect to all the three glare levels.

TABLE 10

Multivariate Analysis of Variance of Noise

Dependent Variable**	Source of Variation	Sum of Squares	D.F	Mean Square	F
	Subject	150.18	19	7.90	4.74 *
N1	Glare	8.63	2	4.31	2.59
	Error	63.36	38	1.66	
	Subject	825.60	19	43.45	11.74 *
N5	Glare	22.63	2	11.31	3.06
	Error	140.70	38	3.70	
	Subject	2452.26	19	129.06	38.61 *
N9	Glare	34.30	2	17.15	5.13 *
	Error	127.03	38	3.34	

* denotes significance at levels of 0.05

** N1, N5, N9 - pleasant, BCD and intolerable conditions respectively of noise on the nNAD scale

TABLE 11

Noise Means by MANOVA Procedure

Glare Condition	# of subjects	Means (dbA)		
		N1	N5	N9
1	20	71.50	78.60	87.50
5	20	70.60	77.75	85.75
9	20	71.25	79.25	87.15

TABLE 12

Wilks' MANOVA Test Criteria for Overall Glare Effect

$F\ (6,\ 72) = 2.93$; PROB $>$ F = 0.0130 *

* denotes significance at a level of 0.05

TABLE 13

Multivariate Analysis of Variance of Glare

Dependent Variable**	Source of Variation	Sum of Squares	D.F	Mean Square	F
	Subject	78309231.14	19	4121538.5	1.49 *
G1	Noise	16073276.81	2	8036638.4	2.90
	Error	105128087.57	38	2766528.6	
	Subject	757398478.18	19	39863070.0	2.12 *
G5	Noise	360762746.63	2	180381373.3	9.59 *
	Error	714621359.36	38	18805825.2	
	Subject	7237360884.99	19	380913770.0	8.35 *
G9	Noise	1173024403.33	2	586512201.6	12.86 *
	Error	1732720330.00	38	45597903.4	

* denotes significance at levels of 0.05

** G1, G5, G9 - Pleasant, BCD and intolerable conditions respectively of glare on the nNAD scale

TABLE 14

Glare Means by MANOVA Procedure

Noise Condition	# of subjects	Means (Foot-Lamberts)		
		G1	G5	G9
1	20	90.43	1363.65	10087.00
5	20	267.78	2779.00	15294.50
9	20	1266.26	7126.50	20915.00

TABLE 15

Wilks' MANOVA Test Criteria for Overall Noise Effect

$F\ (6,\ 72) = 5.93$; PROB $>$ $F = 0.0001$ *

* denotes significance at a level of 0.05

DISCUSSION

The hypothesized main effects, for both the tasks combined, showed no significant difference. That is, performance was not lower with a higher degree of distraction. This was true for both the visual and auditory tasks with noise and glare distractions respectively. But in the case of the difficult auditory task, subjects evaluated the task condition as relatively harder in the presence of higher levels of glare than in the pleasant glare level (means of 16.05 and 17.04 in the BCD and intolerable levels respectively compared to 14.25 in the pleasant level).

Findings and Interpretations

Data given in Table 7 has been plotted as shown in Figure 19. The fact that the graphs are not horizontal implies that there was an effect on performance due to the three distraction levels, but statistically not significant. It can be seen that the subjects performed poorly in the auditory easy task compared to visual easy task. Also subjects' performance was poorer in the auditory difficult task compared to visual difficult task in the BCD and intolerable levels of distraction. But performance was significantly higher in the pleasant level. This can only be justified as due to mere chance. It can be seen from Figure 19 that in general subjects' performance was poorer in the auditory task compared to visual task. This may be due to the fact that "seeing is better than hearing"; more attention is needed for audition than vision (Broadbent, 1958). Also it should be recalled that subjects were asked to look at the glare source as frequently as possible during the auditory task. Apart

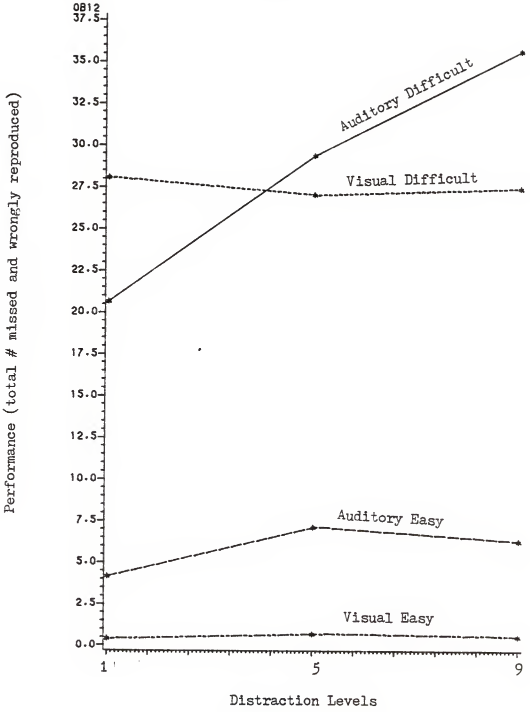

Figure 19. Plot of Distraction Levels Vs Performance

from the distraction caused from the glare, the combined effect of the very act of looking at the glare, listen to the numbers from the tape-recorder and writing them down while looking at the glare would have impaired performance. But this distractive effect was not significant (see Table 9) as judged by the subjects in the Borg Perceived Exertion Scale.

Noise and Glare Judgments

As for the second part of the experiment in which subjects fixed their own levels of noise and glare in the presence of one another (without the task employed) data from Tables 11 and 14 have been plotted in Figures 20 and 21. It can be seen from Figure 20 that in the case of all the three levels of noise, there was a drop in the value of noise level fixed by the subjects at glare level 5 (BCD). Again this can only be justified as due to chance. Wilks' MANOVA test criteria (Table 12) shows that there was a significant overall glare effect on the judgment of noise levels. Table 10 indicates that the glare effect was significant specifically for the intolerable level of noise (level 9). This may be due to the significant drop in noise value fixed at the glare level of 5 (BCD).

It is obvious from Figure 21 that subjects fixed higher levels of glare corresponding to higher levels of noise. This result confirms the hypothesized effect. In other words people do not mind to be exposed to high glare levels at higher noise levels. To the best of knowledge of the author there has not been any studies to substantiate this finding.

General Results

It was observed, in general, light glare or noise distraction had

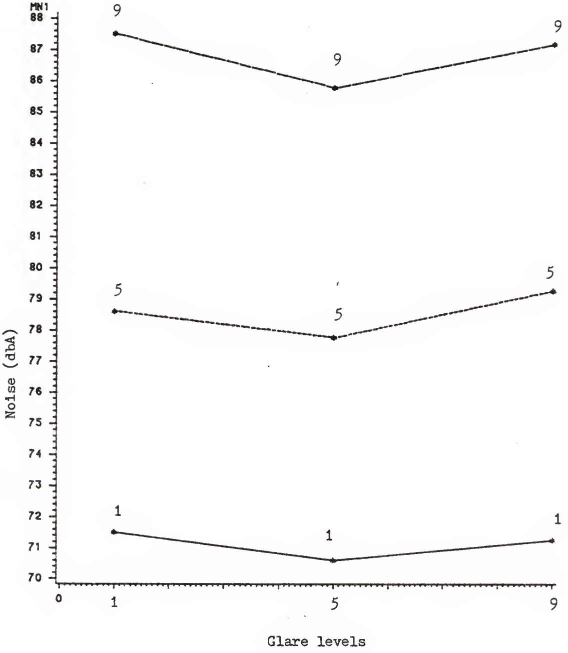

Figure 20. Plot of glare levels Vs noise judgments

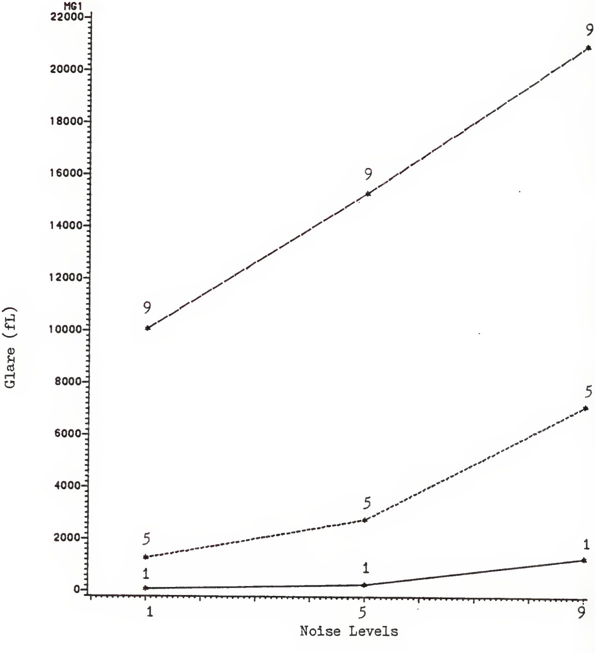

Figure 21. Plot of Noise Levels Vs Glare Judgments

no significant effect on task performance. Also there was no glare effect on noise judgments. No learning or fatigue effects were detected eventhough some subjects felt monotony during the two hour duration of the experiment. It was important for this study that these effects were not present because, for example, the learning effects could counteract the action of distraction over performance and the detrimental effect of fatigue on performance could be construed as a consequence of distraction. These were avoided by designing each experimental condition for a shorter duration and by random assignment of the sequence of conditions.

Future Research

Further research is needed to confirm the findings of this study about the effects of distraction in performing tasks and about noise and glare interaction. Different tasks can be tried and it is important that distractive effects are present and, the learning effects and fatigue are greatly reduced.

With respect to fixing the noise levels, it would have been better if the adjusting knob of the attenuator was continuous rather than having fixed positions. With the latter type there was a tendency to keep the knob at the lowest position for fixing the pleasant level of noise. Therefore, in most of the cases the pleasant value of noise happened to be the same. Also the knob could be adjusted by specific number of increments to get always the same position for the BCD and intolerable levels of noise. This can be avoided by having a continuous type adjustment.

Practical Implications

Productivity alone will not decide the efficiency of a work situation.

The attempt must be to maintain optimum environmental conditions of work to derive a higher level of productivity without undue effects on the worker. If the environmental conditions of work distracts the worker from his job, discomfort will arise. Therefore, if the level of the environmental stimulus and the extent of distraction can be assessed for their contribution towards the difficulty of the job, then opportunities arise for the redesign of work situations. In general, results of this kind of research can be applied in work situations where the study of the physical environment is important.

REFERENCES

Allport, F. Social psychology. Boston: Houghton Miffin, 1924.

Age C. Mandal. Work-chair with tilting seat. Ergonomics, 1976, 19(2), 165-174.

Bennett, C.A. Spaces for people: Human factors in design. Englewood Cliffs, N.J: Prentice-hall Inc, 1977.

Bennett, C.A., Jha, R.S. and Janasek, R.E. Psychological stress testing of bifocals and progressive lenses. Unpublished report. Kansas State University, 1983.

Bennett, C.A., A.Anand, D.Madhavan, B.N.Anantha, F.Hwang and R.Kumar. Discomfort glare: Eight experiments on psychological aspects of discomfort glare. Paper presented at Annual Technical Conference of IESNA, Los Angeles, August 1983.

Berlyne, D.E. Conflict, arousal and curiosity. New York: McGraw-Hill, 1960.

Borg, G. Physical performances and perceived exertion. Lund: Gleerups, 1962.

Broadbent, D.E. Perception and communication. London: Pergamon Press, 1958.

Buckner, D.N. and McGrath, J.J. Vigilance: A symposium. New York: McGraw-Hill, 1963.

Cohen, Sheldon. After effects of stress on human performance and social behavior: a review of research and theory. Psychological Bulletin, 1980, 88(1), 82-108.

Corlett, E.N. Human factors in the design of manufacturing systems: Human Factors, 1973, 15(2), 105-110.

Corso, J.F. The effects of noise on human behavior, WADC Tech. Rep. No. 53-81, 1952.

Finkelman, J.M. and Glass, D.C. Reappraisal of the relationship between noise and human performance by means of a subsidiary task measure. Journal of Applied Psychology, 1970, 54(3), 211-213.

Fry, G.A. and King, V.M. The pupillary response and discomfort glare. Illuminating Engineering Society, 1975, 4(4), 307-324.

Hebb, D.O. A textbook of psychology. Philadelphia: Saunders, 1972.

Kahneman, D. Attention and effort. New Jersey: Prentice-Hall, 1973.

Kimble, G.A. Foundations of conditioning and learning. New York: Appleton-Century-Crofts, 1967.

Klotzbucher, B.E. and Fichtel, K. Effects of noise on visual signal detection. Ergonomics, 1979, 22(8), 919-926.

Kryter, K.D. The effects of noise on man. Academic Press: New York, 1970.

Lovell, G.D. Physiological and motor responses to a regularly recurring sound. Psychological Bulletin, 1941, 38, 715(abstract).

Miller, J.D. Effects of noise on people. U.S. Environmental Protection Agency, Rep. No. NTID 300.7, 1971, 117-124.

Norman, R.F. Maier. Psychology in industry. Boston: Houghton Mifflin Company, 1965.

Ryan, T.A. and Cottrell, C.L. Muscular tension as an index of effort: The effect of glare and other disturbances in visual work. The American Journal of Psychology, 1950, 32(3), 317-341.

Sanders, G.S. and Baron, R.S. The motivating effects of distraction on task performance. Journal of Personality and Social Psychology, 1975, 32(6), 956-963.

Schultz, D.P. Psychology and industry. London: The Macmillan Company, 1970

Spence, K.W., Taylor, J. and Ketchel, R. Anxiety level and degree of competition in paired associates learning. Journal of Experimental Psychology, 1956, 52(5), 306-310.

Srinivasan, R. Distractive effects in performing visual and auditory tasks as an indicator of discomfort. Masters thesis, Kansas State University, 1976.

Teichner, W.H., Arees, E. and Reilley, R. Noise and human performance, a psychological approach. Ergonomics, 1963, 6(1), 83-97.

Winkler, R. Readability of electronic displays. Masters report, Kansas State University, 1979.

Yerkes, R.M. and Dodson, J.D. the relation of strength of stimulus to rapidity of habit-formation. Journal of Comparative and Neurological Psychology, 1908, 18, 459-482.

DISTRACTION TYPE AND INTENSITY ON TASK PERFORMANCE

by

SREE KAILASH

B.S (Mechanical), Trivandrum, India, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1984

ABSTRACT

An experiment was performed to test the effect of distraction on task performance. Distractive effects of light glare in performing an auditory task and of noise in performing a visual task were tested. Performance was used as a measure of the distractive effect and a rating scale was employed for the evaluation of the difficulty of the task in the presence of glare or noise. Pleasant, borderline between comfort and discomfort (BCD) and intolerable conditions of glare and noise were employed. Easy and difficult visual and auditory tasks performed under three levels of noise and three levels of glare respectively constituted 12 treatment conditions.

There were 20 subjects and all subjects performed under all treatment conditions. Their performance and evaluation of the task difficulty in all the treatment conditions were recorded.

At the end of the experiment, the subject fixed pleasant, BCD, and intolerable levels of noise and glare in the presence of one another without the task employed.

The results showed no significant effect on performance due to either glare or noise distraction. But the overall glare and noise effect in judging the noise and glare levels respectively was significant.

Possible implications and interpretations of these research findings are discussed.