DISTRACTIVE EFFECTS IN PERFORMING VISUAL AND AUDITORY TASKS AS AN INDICATOR OF DISCOMFORT

by

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INTRODUCTION

Much research has been concerned with factors affecting efficiency in task situations, both visual and auditory. Research has also been directed toward specifying the effects of extraneous variables, such as heat, noise and varied auditory and visual stimulation upon performance. These experiments have been designed to provide answers to specific practical questions and the results 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 theoretical 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 test the distractive effects of an extraneous stimulus upon performance of a task.

Efficiency of a task situation cannot be studied in terms of performance measures alone. A person might maintain a high level of performance overcoming the distractive effects of the extraneous stimulus. Ryan, Cottrell 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. It is therefore desirable to design a situation, to secure a high level of productivity in the optimum environmental conditions of work.

Corlett (1973) proposed a concept of comfort as a criteria to evaluate the conditions of work : if an extraneous sensation distracts attention from the task at hand, then a state of discomfort can be said to exist. According to Corlett, based on this concept, a distractive stimulus present in a work situation will cause discomfort to the worker. The present study was designed to test this Corlett's hypothesis and seeks to determine distraction as an indicator of discomfort.

Background

The capacity of the human to engage in two independent activities simultaneously, has been a subject of interest for a long time. For years an argument has raged as to whether stimulation of one sensory modality has any effect, either of a facilitory (arousal) nature or an inhibitory (filter) nature, on the sensitivity of some other modality. The body of literature concerned with the argument is vast and contradictory. Reviews covering this are available (Gilbert, 1941; London, 1954; Ryan, 1940).

There is good reason to believe that a human can engage in more than one activity at the same time. A man walking down the street and talking to his companion, or he driving a car and whistling a tune are common occurences; an experienced telegrapher can receive or send a message practically unhindered while conversing. In all these instances at least one of the activities is a skill which through overtraining might have become automatic. Generally, when a highly practiced motor performance is controlled by a sensory channel (vision, for instance) that performance can be carried on adequately, simultaneous with reception of information through another modality (audition, for example) (Peterson, 1969; Mowbray and Gebhard, 1961).

However, the problem differs when conscious activity rather than highly practiced motor skills must accompany other stimulation. There are considered to be few limitations on concurrent activity. One such limitation is a fairly well-documented conclusion that an individual cannot attend to two different sensory inputs requiring independent discriminations at precisely the same moment (Peterson, 1969). Mowbray (1954) found that when auditory and visual stimulations of a symbolic sort overlap completely, with no chance for rapid alteration between the two channels, then only one sensory input can be utilized. Information on the other will be completely lost. Several investigations have been carried out with two stimulus inputs, a task stimulus and an extraneous stimulus, to find the effects of extraneous stimulation in attending to the task stimulation. As a prelude to examining these effects it would be of interest to briefly review the theoretical models developed to explain perception and information processing of multiple stimulus inputs.

Information processing of simultaneous stimulus inputs. Boradbent (1958) described a single-channel model of information processing. He put forward the idea that multiple inputs precede a single-channel perceptual mechanism of limited capacity and that a filter protects the mechanism from overload by simultaneous stimulus inputs. The filter blocks all but one selected input. To deal with simultaneous multiple inputs, attention is switched from channel to channel and a certain amount of time is wasted in switching over to the other channel (Figure 1). To counteract the effects of a limited central processing mechanism and switching time, a short term storage is postulated as part of the perceptual system. The information received from one modality (say, visual) is held briefly in the storage, while information arriving from the other modality (say, auditory) is being processed. Essentially, this filter theory of Broadbent (1958) states that attention controls perception because of the limited capacity of the cognitive system.

In contrast, Moray (1967) provided a capacity theory of attention which assumed that there is a general limit on man's capacity to perform mental work. He assumes a fixed capacity central processor which may distribute the capacity among concurrent activities to perform several functions concerned with input and output. Thus, parallel operations may occur at any point if the total capacity of the processor is not exceeded.

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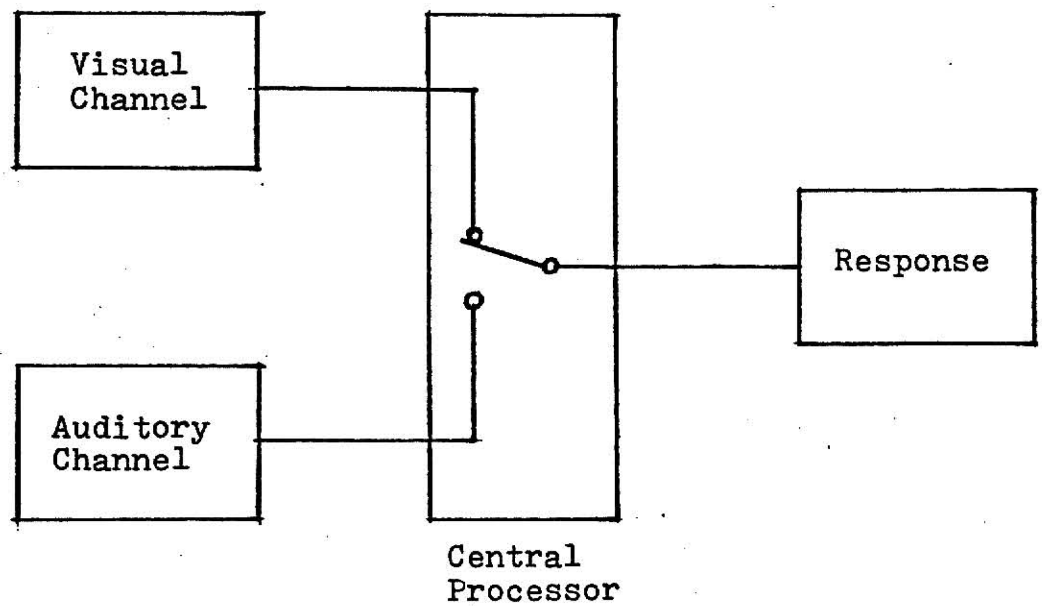

Figure 1. - An attention-switching single-channel model of information processing described by Broadbent (1958).

This contradicted the single channel view, in which switching between inputs is necessary to have multiple tasks.

A serious objection to Broadbent's theory arose from Treisman (1960), who observed that under some circumstances, subjects do respond to the content of the rejected channel. Treisman (1960) then proposed that the filter merely attenuates input from rejected channels rather than blocking it altogether. Broadbent accepted Treisman's suggestion that there is instead an attenuation of unattended channels which will still permit messages of unusual strength to be perceived (Broadbent and Gregory, 1964).

On the basis of the single channel model, it seems unlikely that duplication of the same information presented in the auditory and visual modalities will increase operator performance, since one item of information must be processed before another item can enter the processing system. But, there is ample experimental evidence to substantiate the fact that comprehension of material presented is enhanced when it is identically presented both visually and aurally at the same time (Day and Beach, 1950; Schafer and Shewmaker, 1953; Tolhurst and Peters, 1954). Thus, Treisman's suggestion adds credibility to Moray's assertion of division of processing capacity. In any event, the attention stage could only be sequential and the available experimental evidence does not favor simultaneous attention to more than one input (Lindsay, Cuddy and Tulving, 1965; Moray and Reid, 1967).

Peterson (1969) presented a modal incorporating features of both filter theory and capacity theory. Kahneman (1973) also advocates that a comprehensive treatment of attention must incorporate considerations of both structural (filtering) and capacity limitations. Peterson's model suggested a sequential attention mechanism and, distribution of processing capacity over the activities (Figure 2). The findings of his experiment fitted into such a modal. Four stages from input to output are indicated. In stage 1, information from inputs of various kinds are held briefly in storages associated with those sensory organs, S1 and S2. In stage 2 the parallel inputs are reduced to sequential passage where attention, A, is given to one input at a given moment. In stage 3 there is again parallel processing where long-term storage, L, and short term storages, P1 and P2, cooperate to maintain processing of varying degrees of complexity. It is at this stage that highly trained motor activities (like, driving a car and participating in a conversation) may be easily coordinated with little involvement of the attention mechanism. The two short-term storages, P1 and P2, maintain the continuity of diverse types of processing. Finally, in stage 4, output mechanisms can engage in parallel to give the resultant responses, R1 and R2, of processed information.

The capacity of the human to attend to different sensory inputs is clearly related to the complexity in processing each stimulus and the corresponding degree of attention needed. Different activities impose different demands on the limited capacity and the total amount of attention which can be deployed

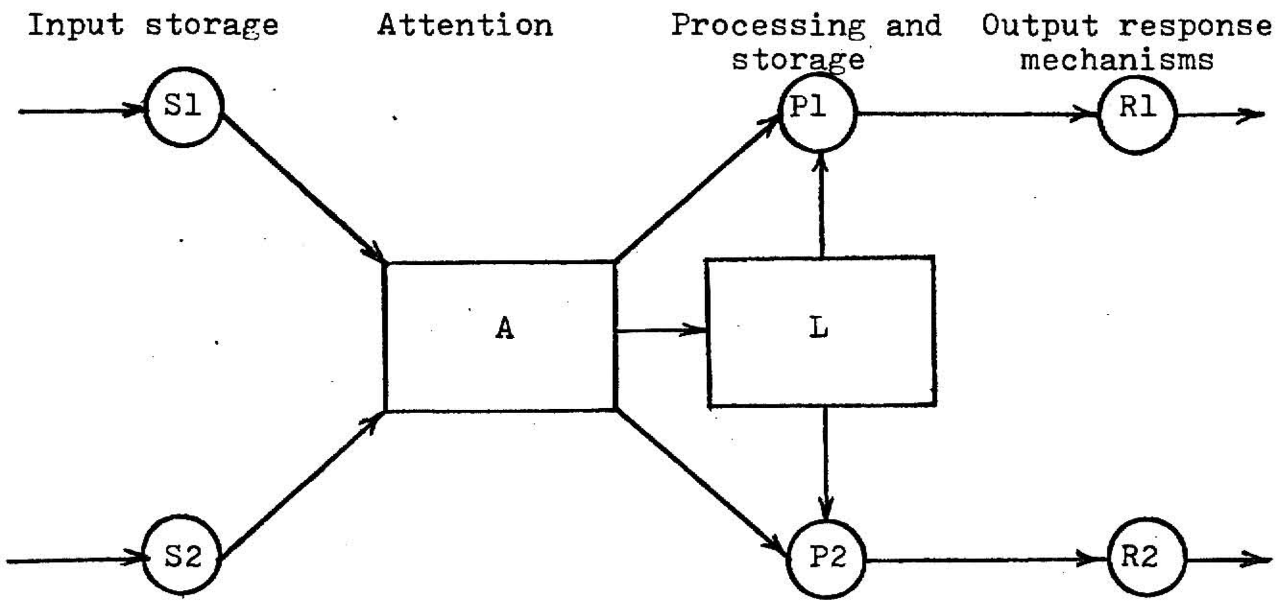

Figure 2. - Stages in concurrent information processing.

at any time is limited. An easy task demands little attention and a difficult task demands much. When the supply of attention does not meet the demands, performance falters, or fails entirely.

A number of studies have been devoted to find the effects that occur due to the division of attention to multiple simultaneous signals in producing output responses.

Effects due to simultaneous stimulus inputs. 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 may perform the task more effectively. On the other hand, noise might induce muscular tension and cause a detrimental effect in attending to the task.

Another effect of multiple inputs is distraction. Distraction can be thought of as lapse in attention or a diversion of attention from the task at hand (Miller, 1971). In a simultaneous inputs system, when one of the stimuli is sufficiently intense, it might momentarily overload the capacity on that channel, reducing the capacity distributions to other channels and result in a momentary lapse or diversion of attention (Miller, 1971; Kahneman, 1973).

Besides arousal and distraction, a few other specific effects due to simultaneous stimulus presentation have been reported, which include masking, muscular activation such as startle responses, fatigue, loudness, and the like (Kryter, 1970). These effects are specific to the type and intensity of the stimuli that are present.

Therefore, in summary, the effects of multiple stimuli inputs have been conceptualized into arousal, distraction and certain other specific effects.

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).

<u>The Yerkes-Dodson law</u>. 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 schematically illustrated in Figure 3. When arousal is at a low level, a response that produces increased stimulation and greater arousal will tend to

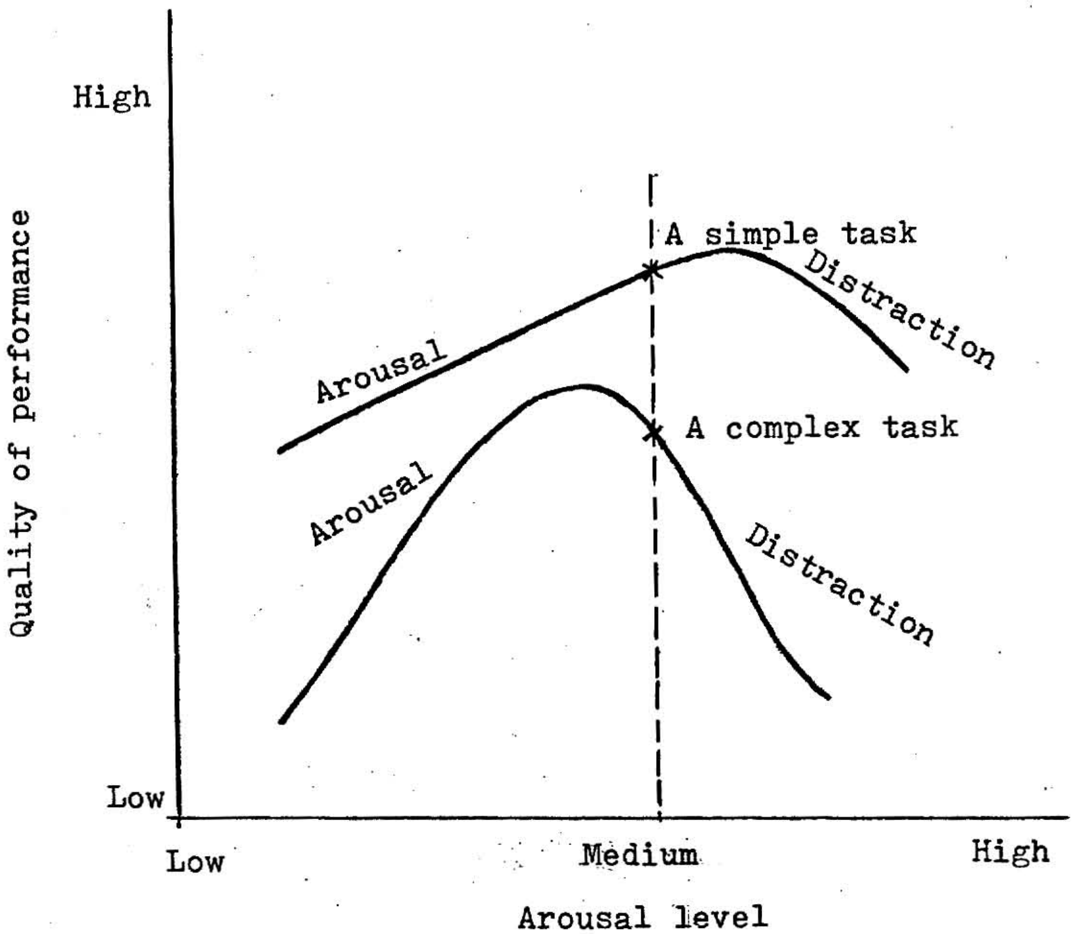

Figure 3. - Schematic of the relationship between performance and arousal level.

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.

When the arousal function is controlled by an extraneous stimulus, it may have both arousal effect with increase in performance, and, distractive effect, with decrease in performance, depending on the level of arousal. For a simple task, the range over which performance improves with increasing level of arousal is higher than that for a complex task, as illustrated in Figure 3.

Therefore, the Yerkes-Dodson law agrees with Broadbent's (1958) view, that the extraneous stimulus would have both arousal and distraction effects, but, the single effect that prevails during the particular situation depend on the complexity of the task. As seen in Figure 3, when the level of the extraneous stimulus is "medium", it could have an arousal effect on a simple task and distractive effect on a complex task.

However, it can be deduced for the purpose of this study that the distractive effects are bound to occur under a high level of arousal function of the extraneous stimulus and a difficult task situation.

These distractive effects due to the extraneous stimulus on performing the task were explained by Corlett (1973).

Concept of comfort. Corlett (1973) provided a concept of comfort in order to properly evaluate the work situation along with performance. He stated that, if the balance under a given situation is such as not 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.

But when a distracting extraneous stimulus is present as an input in a multiple stimulus input system, two different effects may be produced. One effect may be due to the complexity involved in one or more of the stimulus employed. In such a situation, a rapid transformation of attention between the stimuli is not possible due to a heavy load on the limited capacity mechanism. As a result the performance will be affected. Another effect of a distracting stimulus may be to cause feelings of annoyance or discomfort without any detectable impairment in performance; it can be associated with the irrelevant information which the perceptual system avoids perceiving but transmits its presence as a complaint to the brain. People may thus overcome the distractive effects and maintain a high performance. This distraction between the two effects is similar to the two effects produced by glare, disability glare and discomfort glare. In the disability glare the light diffused inside the eye casts a veiling across the scene, affecting performance by reducing the visual efficiency. Discomfort glare, on the other hand, refers to the feelings of annoyance because of some glare source in the visual field, without necessarily any decrement in the performance.

Therefore the effects of a distractive stimulus, from the understanding of the simultaneous information processing, can be summarized as impairment in performance and feelings of discomfort and, according to Corlett (1973) when there is distraction effect, there will be discomfort.

Though there have been many experiments to relate the arousal and distraction effects of simultaneous inputs with the physiological measures, like, muscular tension, there has not been a study relating distraction effects and discomfort, which was the purpose of the present investigation.

Problem

As discussed there has not been a study on discomfort produced due to the effects of distraction. The only reference was from Corlett (1973) who relates distraction and discomfort as a theoretical concept and not as a result from a controlled research.

The objective of this study was to relate the distractive effects on performance of a task as an indicator of discomfort, and more specifically, to verify Corlett's hypothesis that, when a sensation distracts attention from the task then discomfort exists. Two types of experimental situations were considered so that a measure of distraction related to discomfort can be attempted: 1) performing a visual task in the simultaneous presence of an auditory secondary (distracting) stimulus and, 2) performing an auditory task in the simultaneous presence of a visual secondary (distracting) stimulus.

Pilot Study

A pilot study was conducted for the purpose of selecting proper task stimuli and secondary stimuli so that, the secondary stimuli used would have distracting effects on the task. 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 as the secondary stimuli. The task stimulus was also of two types, visual and auditory. The specific task chosen was a "reproducing" kind, as a higher degree of attention is postulated for activities dependent on extraneous events for which reproduction is required (Peterson, 1969). Noise and glare were at levels of 85 dbA and 3000 foot lamberts, respectively.

Ten subjects individually attended to two stimuli, a task stimulus and a secondary stimulus, which were presented concurrently. For the visual task noise was presented as the secondary stimulus and, for the auditory task, glare was the secondary stimulus. Subjects performed reproduction of task signals and also made judgments on a comfort rating scale about the effect of the secondary stimulus.

Within the limits of this experiment, from the results of this pilot study, it was observed that the glare stimulus caused discomfort in reproducing auditory task signals and noise stimulus caused discomfort in reproducing visual task signals. But neither noise nor glare had any measurable distractive effect on performance of the task. These results are not in line with the hypothesis this investigation seeks to prove, which is, when distraction occurs discomfort arise. Although the intensities of noise and glare stimulus were high and within the safe limits, they were not sufficient to cause distracting effects. Subjects were able to overcome the distractive effects to maintain a higher level of performance. As discussed earlier distractive effects are bound to occur only under a high level of arousal function of the extraneous stimulus and a difficult task situation. But, increasing the intensities of glare and noise might be hazardous to the health of the subjects, as higher intensities over the safe limits needed to be maintained to create distractive effects. Therefore, a revised situation was considered for this study.

In this study, instead of noise and glare, secondary stimuli similar to the task stimuli were employed. Also the task situation was made more difficult over that of the situation employed in the pilot study to ensure distraction effects.

Hypotheses

It was hypothesized that, 1) performance will be lower for a task in the presence of the secondary stimulus compared to the control condition which is, performing the task without the secondary stimulus (a distraction effect), and 2) discomfort produced due to the presence of a secondary stimulus along with a task will be more compared to the presence of the secondary stimulus alone without the task. These were tested for visual and auditory tasks.

A set of interactions between the tasks and the hypothesized effects of performance and discomfort were predicted. The direction of the interaction predicted was that both the hypothesized effects of performance and discomfort will be greater for the visual task than for the auditory task.

METHOD

Experimental Design

The experiment involved two types of tasks, visual and auditory. Each of these was performed under three different conditions, totalling six experimental situations. The three conditions were: 1) the task alone as a control condition; 2) the secondary stimulus alone, to establish individual comfort ratings of the secondary stimulus; 3) the task in the presence of the secondary stimulus, to measure performance and comfort ratings when the task was associated with the secondary stimulus. Similar to the task the secondary stimulus was also of visual and auditory types.

The attempt from this was to associate the changes in performance and the changes in comfort ratings in performing tasks under two types of secondary stimulus.

Dependent and Independent Variables

Performance of task and subjective judgments of comfort about the secondary stimulus were the two dependent variables.

The absence of the secondary stimulus while performing the task and the presence of it along with task were the two independent variables affecting the performance. The presence of secondary stimulus alone and the presence of it along with task were the two independent variables affecting the subjective judgments of comfort.

Task

Two types of task stimulus and two types of secondary stimulus were involved. The situation was designed such that a close attention to the task was required. The deduced result from the Yerkes-Dodson law, also suggested by McGrath (1963), that the distractive effects appear when the task is more difficult, was followed.

Task stimulus. The two types of task stimulus were: visual and auditory. 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. "91621").

The visual task required that the subjects read the digits of the task signal when flashed on a white screen from a slide projector. Random numbers of five digits typed on paper, were reproduced onto a transparent plastic sheet. The sheet was then cut and fitted into a 2X2 inch slide frame.

The string of five digits projected was 11.25 inches long, and each digit was 3.1 inches in height and 2 inches in width. The subject was seated 90 inches from the screen. Each digit subtended an angle of 116.8 minutes of arc. Noise measured from the projector was 54 db(A).

The luminance of the white screen when the signal projected was 108 foot lamberts. The projected black numbers on the screen had a luminance of 20 foot lamberts. Thus the black signals on the white screen had a brightness contrast of 0.82.

The angle subtended by the digits, the noise level and, the contrast of the visual signals were all in the desired levels for the experiment.

Forty-four slides were used for two different conditions of the visual task (Figure 4). The duration of the stimulus presentation was 0.5 second under both conditions. The distribution of signals over time was same under the two conditions, the time between the signals being 14.5, 19.5, 24.5, and 29.5 seconds.

The auditory task required that the subject listen to a tape recording of task signals, spoken with a intensity of about 74 db(A). Forty-four such randomly selected five digits signals were used for two conditions of the auditory task (Figure 5). The duration of the spoken signal was 1.5 seconds. The same distribution of signals over time, as was under visual task, was maintained and also it was same for both the two conditions, the time between signals being 13.5, 18.5, 23.5, and 28.5 seconds.

Secondary stimulus. The two types of secondary signals were: visual and auditory. The signal from this stimulus was referred to as a "secondary signal". These secondary signals were also strings of five characters. Therefore it can be noted that the task and the secondary signals under visual and auditory tasks were all similar sets of five character digits, like 53594, 09847, 85489, ... The difference between the task and the secondary stimulus was that for any particular condition of the experiment the mode of presentation was reversed. When the task signals were received visually, the secondary signals

Signal serial	Auditory secondary stimulus not employed	Auditory secondary stimulus employed
1	91621	37204
2	54284	47361
3	17852	23930
4	27491	53249
5	89415	27083
6	79152	98326
7	53829	87719
8	20190	50948
9	69942	97365
10	95763	30976
11	61527	73695
12	39435	67382
13	11859	69831
14	86819	48708
15	74921	90361
16	99547	71281
17	17918	39564
18	68089	97501
19	72373	21108
20	97017	81369
21	41273	74261
22	12952	32592

Figure 4. - Visual task signals.

Signal serial	Visual secondary stimulus not employed	Visual secondary stimulus employed
1	15707	50741
2	96256	87024
3	23068	96574
4	13782	29065
5	08467	97518
6	89469	61891
7	93842	06235
8	07521	98342
9	56898	24591
10	39102	34936
11	62315	80972
12	85941	41632
13	40756	95068
14	82414	64865
15	65978	16874
16	01385	57412
17	83091	13215
18	62481	73917
19	06318	82802
20	50423	53256
21	12479	86352
22	80621	75486

Figure 5. - Auditory task signals.

were presented aurally; when the task signals were received aurally, the secondary signals were presented visually.

The visual secondary stimulus was presented the same way as the visual task stimulus was presented. Slides of five random digits were projected onto the screen. A total of 210 visual secondary signals were used for two conditions (Figure 6). The duration of presentation of the stimulus signal was 0.5 second, the interstimulus interval was 4.5 seconds.

The auditory secondary stimulus of five character digits was presented from a tape-recorder, the same way as done for auditory task signals. Two hundred and ten signals were employed for two conditions (Figure 7). The duration of spoken signal was 1.5 seconds, the interstimulus interval was 3.5 seconds thus maintaining the same distribution of signals over time for both the visual and auditory secondary stimuli.

Performance of task. In performing the task, the subject was instructed to receive the task signal (visual or auditory depending on the condition), keep in memory, wait for the occurrence of a signal and then reproduce the task. The signal for making the reproduction response was referred to as a "response signal". It was understood that the individual performances are reliable with this kind of task (Bakan, 1959). The response signal was a special occurrence of the secondary signal. It was to be identified by the occurrence of the same digit on the first and the last (fifth) character of the five digits string of the secondary signal (e.g. 29642, 07380, 91569). In reproducing the task signal, when the response signal was

Signal serial	Auditory task stimulus not present	Auditory task stimulus present
1	05359	27705
2	40899	57182
3	00881	95108
4	47366	95425
5	31753	20902
6	19184	78744
7	67079	39285
8	59058	10154
9	94089	96579
10	36028	19774
11	80801	17676
12	90535	72305
13	82859	91020
14	84747	27041
15	42524	18431
16	81007	87610
17	79169	37231
18	39220	35355
19	80830	67879
20	94815	76236
21	74617	64716
22	83666	00333
23	77312	28039
24	66324	25325
25	08810	24162
26	58923	65172
27	01808	96926
28	84318	63936
29	96488	46299
30	10089	68328

Figure 6. - Visual secondary signals.

Signal serial	Auditory task stimulus not present	Auditory task stimulus present
31	23466	65355
32	79421	28420
33	24254	63369
34	13491	31443
35	54440	41067
36	61921	58923
37	41180	47176
38	39693	51445
39	21009	60871
40	48805	72570
41	66164	08548
42	20002	06670
43	78233	09243
44	77250	88629
45	59814	64559
46	83463	42626
47	80584	36555
48	84508	83678
49	44105	12740
50	00544	28715
51	75270	78258
52	29471	69249
53	47420	85651
54	02540	67106
55	03845	63462
56	40467	41943
57	64886	46924
58	65988	06902
59	29575	89904
60	75818	41757

Figure 6. - continued.

Signal serial	Auditory task stimulus not present	Auditory task stimulus present
61	76287	62056
62	97202	20297
63	85532	04724
64	83942	05872
65	02757	32404
66	32664	70219
67	47534	37503
68	96325	71249
69	72612	82171
70	31310	74373
71	85178	96659
72	89872	64157
73	42917	72095
74	60960	57027
75	49908	53556
76	03638	82995
77	10651	16861
78	29157	19275
79	05437	92496
80	83378	38043
81	34770	05219
82	55659	59888
83	86679	33728
84	48951	81257
85	42594	69936
86	92294	75192
87	41417	94522
88	27612	92479
89	79365	74358
90	08186	71659

Figure 6. - continued.

Signal serial	Auditory task stimulus not present	Auditory task stimulus present
91	54463	62038
92	23410	46326
93	76287	62386
94	72092	79643
95	69999	45880
96	03887	44741
97	55751	39550
98	02263	24636
99	63956	27762
100	30506	39038
101	05615	13163
102	81619	48085
103	56705	93459
104	92511	13428
105	84502	97155

Figure 6. - continued.

Signal serial	Visual task stimulus not present	Visual task stimulus present
1	09847	86141
2	53594	60277
3	85489	07105
4	69944	82847
5	21432	37403
6	51089	13858
7	99943	16269
8	84989	15345
9	52615	57715
10	73631	36466
11	05375	62481
12	09054	75779
13	15417	67372
14	75112	54656
15	84318	63116
16	25200	80182
17	62173	96887
18	02132	66223
19	14878	02432
20	87687	53342
21	46134	96739
22	30101	43877
23	60251	60609
24	02146	89380
25	39693	82718
26	81366	98656
27	34598	59337
28	65706	79387
29	66762	06468
30	72781	45141

Figure 7. - Auditory secondary signals.

Signal serial	Visual task stimulus not present	Visual task stimulus present
31	17002	82627
32	61547	58680
33	57430	13160
34	42054	04190
35	00549	46716
36	43648	72655
37	75888	30329
38	81378	36863
39	33444	52098
40	25991	91530
41	65959	90464
42	58625	80428
43	25878	27101
44	86413	37855
45	33475	55368
46	42740	31721
47	06175	94335
48	67126	73917
49	12477	14530
50	09965	33020
51	96657	52967
52	57994	39936
53	61699	41642
54	17771	35213
55	76330	62233
56	24596	31855
57	27062	09840
58	09577	74441
59	91871	17217
60	83266	04838

Figure 7. - continued.

Signal serial	Visual task stimulus not present	Visual task stimulus present
61	32803	92889
62	29793	97720
63	07216	31389
64	45548	15369
65	76970	69620
66	80876	13699
67	84148	82758
68	63664	43269
69	39652	56720
70	40646	71628
71	13841	10421
72	81741	75691
73	26538	09847
74	84149	61547
75	56797	85489
76	82487	69944
77	28662	40914
78	05845	51089
79	98131	93965
80	82068	74307
81	78630	69361
82	18116	05375
83	91705	75112
84	86224	30485
85	40054	83048
86	57071	14878
87	54570	45548
88	63806	20872
89	25730	34598
90	87623	48228

Figure 7. - continued.

Signal serial	Visual task stimulus not present	Visual task stimulus present
91	92692	72856
92	31432	66762
93	<u>12731</u>	<u>57325</u>
94	42507	90540
95	70163	89469
96	84362	43648
97	05967	72159
98	86904	21511
99	<u>93459</u>	<u>61046</u>
100	21627	65959
101	54374	64721
102	45356	86413
103	<u>70987</u>	<u>90849</u>
104	12693	12477
105	27928	96657

<u>Figure 7. - continued</u>.

identified, the subject was asked to write down first the single character which characterized the response signal, that is, the digit which was same on the first and the last characters of the five digit string, then follow it with the task signal. Thus, the result reproduced was of six characters. Examples are illustrated (Figure 8).

Response signal. As the response signal was to be identified from the secondary signals, it was in the same modality as that of the secondary stimulus, which means, it was in the opposing modality to the task stimulus. Therefore, similar to the task and the secondary stimulus, two types of response signals were involved: visual and auditory. The occurrence of visual response signals in the sequence of visual secondary signals are identified in Figure 6 by underlining them. Similarly, the auditory response signals are underlined in the list of auditory secondary signals of Figure 7.

For visual presentation of the response signals, slides for five character random numbers of same first and last digits were made. Forty-four such slides were used for two conditions of the auditory task (Figure 9). For auditory presentation, recorded response signals, 44 of them, were presented for two conditions of the visual task (Figure 10). As the duration of the visual response signal was 0.5 second and that of the spoken auditory signal was 1.5 seconds, the signals were presented at intervals that would give five seconds for the subject to make the reproduction response of writing the six digits result after completely perceiving the response signal and prior to

1. If the task signal received was 85742, and the response signal identified was 39573 then, the result reproduced was 385742.
2. If the task was 60935 and the response signal was 04990 then, the result was 060935.

Figure 8. - Examples, illustrating reproduction of results in task situations.

Response serial	Visual secondary stimulus not present	Visual secondary stimulus present
1	90669	20902
2	69296	96579
3	74897	18431
4	83048	64716
5	20872	24162
6	01240	63836
7	41894	31443
8	87118	51445
9	57325	06670
10	64016	83678
11	90849	67106
12	26002	46924
13	51945	62056
14	62036	37503
15	01990	96659
16	40254	16861
17	42274	38043
18	61046	69936
19	12691	92479
20	08480	62386
21	61446	27762
22	14971	93459

Figure 9. - Visual response signals for reproducing auditory task signals.

Response serial	Auditory secondary stimulus not present	Auditory secondary stimulus present
1	98149	37403
2	27552	57715
3	80648	63116
4	36993	96739
5	49134	82718
6	16721	79387
7	63846	04190
8	45794	36863
9	30983	80428
10	87648	73917
11	90369	35213
12	52885	09840
13	71627	92889
14	08240	82758
15	96859	10421
16	18551	40914
17	20592	74307
18	48224	83048
19	91359	20872
20	32973	57325
21	01660	61046
22	82498	90849

Figure 10. - Auditory response signals for reproducing visual task signals.

the arrival of the next task signal.

Subjective judgments of comfort. In conditions of the presence of the secondary stimulus, the subject was requested to make evaluations of comfort or discomfort of the secondary stimulus on a 1 to 7 scale (Figure 11). The comfort ratings on the scale were defined to be associated with the experimental situations due to the presence of the secondary stimulus and it varied from "not uncomfortable" to "extremely uncomfortable".

Experimental Conditions and Procedure

There were six experimental conditions. In all these conditions, the subject was seated facing the screen. The projector was operated from behind, away from the subject. Tape-recorder also was played from behind the subject, from a corner of the room.

Condition 1: Visual task stimulus alone. This was a control condition to measure performance levels of the visual task. Therefore there were no secondary signals. The task signals were flashed on the screen. Response signals were heard from the tape-recorder. Subject read the signal, waited and reproduced the result when the response signal was heard. As the signals heard were only response signals, the subject was instructed to write the result immediately after the signal was heard without the need to verify for the response signal.

Condition 2: Visual task with auditory secondary stimulus. Task signals were flashed on the screen and secondary signals were heard from the tape-recorder. Both occurred simultaneously.

1	not uncomfortable
2	
3	
4	average
5	
6	
7	extremely uncomfortable

Figure 11. - Comfort rating scale.

The subject read the task flashed on the screen, kept in memory and simultaneously heard the secondary signals to identify the response signal before writing the result. Twenty-two task signals were presented to the subject. At the end of performing this condition, the subject judged the auditory secondary stimulus on the comfort rating scale.

Condition 3: Auditory secondary stimulus alone. This was to establish subject's feelings about the secondary stimulus. Therefore, there were no task signals. Subject heard the secondary signals, identified the response signals and wrote the single characters which characterized such an identification (e.g. if the response signal identified was 97059, the subject wrote the result as 9). Subject's judgment on the rating scale was based on identifying 22 such response signals when attended to the secondary stimulus alone.

Condition 4: Auditory task stimulus alone. This was a control condition to measure performance levels of auditory task. The secondary stimulus was not present. The task signal was heard from the screen and was reproduced when the response signal was flashed on the screen.

Condition 5: Auditory task with the visual secondary stimulus. Task signals were heard from the tape-recorder and secondary signals were read on the screen. The signals occurred simultaneously. The subject heard the task, kept in memory and read the secondary signals to identify the response signal before reproducing the result. At the end of this condition, after 22 task signals, the subject judged about the secondary signals on the comfort scale.

Condition 6: Visual secondary stimulus alone. There were no task signals. The subject read the secondary signals on the screen and identified the response signals. Twenty-two response signals were present in the secondary stimulus. Judgment on comfort scale was made about the secondary stimulus.

This procedure for each of the six conditions were detailed out to the subject, with examples, in the data forms used (Figure 12). The order of the six conditions were randomized to balance the effects of learning and fatigue. Table 1 shows the sequence in which the conditions were presented to the subjects.

Each condition of the experiment lasted for about eight minutes. A five minute break was given after the first three conditions of the randomized sequence of the experiment. At the beginning of each condition, the subject was asked to read the experimental procedure detailed on the data sheet. A short practice session preceded the actual experiment for each condition. Subjects were encouraged to write their comments about the experimental situation at the end of each session. The experiment lasted for a total time of 1 hour 15 minutes.

Equipment

The experiment was performed in I.E. Lab. I. A Kodak projector was used to project the slides. When the forward indexing of the slide projector was allowed to operate automatically, the built-in feature controlled only the 'on' timing, for which time the slide was projected onto the screen. But, the

VISUAL TASK (Control)

PROCEDURE : Read the task signals on the screen
Keep in memory
Wait
Hear the response signal from tape recorder
Reproduce the result quickly
Be ready to read the next task signal, and proceed on...
Work fast in writing the result; otherwise you may fail to perceive the next task signal

EXAMPLE : If task signal read 17943
and response signal heard 64076
then reproduce result as 617943

Note: No secondary stimulus present in this condition; you will be hearing only the response signals. That is, you will be hearing only the signals in which the first character and the last character will always have the same digit. Therefore start writing the result immediately after you hear the signal without verifying to check for response signal.

TRIALS	RESULTS

REMARKS :

Figure 12. - Data forms for six conditions of the experiment.

VISUAL TASK WITH AUDITORY SECONDARY STIMULUS

PROCEDURE : Read the task signal on the screen
Keep in memory
Hear the secondary stimulus from tape recorder
Check if it is response signal
If you identify the response signal, reproduce the result, read the next task signal and proceed ...
Work fast in writing the result; otherwise you may miss the next task signal

**At the end of this session please judge your feeling about the auditory secondary signals on the scale given below. Indicate by circling one number.

EXAMPLE :	Task read	Secondary signal heard	Result
		34376	
	27809	09248	
		75643	
		85428	827809
		13917	

TRIALS	RESULTS

RATING SCALE :	1	2	3	4	5	6	7
	Not Uncomfortable			Average			Extremely Uncomfortable

REMARKS :

Figure 12. - continued.

AUDITORY SECONDARY STIMULUS ONLY

PROCEDURE : There will be no task signals
Hear the secondary signals from tape recorder
Check if it is response signal
If so write down the single digit which characterize the identification of response signal
You will be hearing the secondary signals continuously; keep checking for response signals and write the results

*At the end of this session please evaluate your feelings about the stimulus on the scale given below. Circle one number.

EXAMPLE :

Secondary signal heard	Result produced
39056	
87453	
77478	
49574	4
42563	
09320	0

TRIALS	RESULTS

RATING SCALE : 1 2 3 4 5 6 7

1	2	3	4	5	6	7
Not Uncomfortable			Average			Extremely Uncomfortable

REMARKS :

Figure 12. - continued.

AUDITORY TASK (Control)

PROCEDURE : Hear the task signal from tape recorder
Keep in memory
Wait
Read the response signal from the flashing on the screen
Reproduce the result
Be ready to hear the next task signal and go on ...
Work fast in reproducing the result

EXAMPLE : If task signal heard 57542
and response signal read 71487
then reproduce result as 757542

Note : No secondary stimulus present in this condition; you will be receiving only the response signals from the screen.

TRIALS	RESULTS

REMARKS :

Figure 12. - continued.

AUDITORY TASK WITH VISUAL SECONDARY STIMULUS

PROCEDURE : Hear the task signals from tape recorder
Keep in memory
Read the secondary signals completely, when flashed on the screen
Check if it is response signal
If it is not keep checking the successive secondary signals
When response signal is identified reproduce the result, hear the next task signal and continue ...
Work fast in reproducing the result; otherwise you may miss to hear the next task signal

*At the end of this session please judge your feeling about the visual secondary signals on the scale given below. Indicate by circling one number.

EXAMPLE :

Task signal heard	Secondary signal read	Result
04921	17482	
	30014	
	74417	704921
	82739	

TRIALS	RESULTS

RATING SCALE :

1	2	3	4	5	6	7
Not Uncomfortable			Average			Extremely Uncomfortable

REMARKS :

Figure 12. - continued.

VISUAL SECONDARY STIMULYS ONLY

PROCEDURE : There will be no task signals
Read the secondary stimulus signals
Check if it is a response signal
If yes, write down the single digit which characterizes the occurence of response signal
The secondary signals will be flashed continuously; keep checking for response signals and write the results.

*At the end of this session please evaluate your feelings about the stimulus on the scale given below. Circle one number.

EXAMPLE :

Secondary signal read	Result produced
87549	
31862	
25182	2
01432	
97059	9

TRIALS	RESULTS

RATING SCALE :

1	2	3	4	5	6	7
Not Uncomfortable			Average			Extremely Uncomfortable

RESULTS :

Figure 12. - continued.

TABLE 1

Experimental Design of Randomized Sequences

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

experiment required that the slide be 'on' for 0.5 second and 'off' for 4.5 seconds. For this, an electrically-operated shutter was used, which was fitted externally to the lens. The timing of the shutter was adjusted such that the shutter opened for 0.5 second to expose the signal on the screen and closed for 4.5 seconds. The timing of the shutter mechanism and that of the automatic forward indexing of the projector were synchronized. The subject was seated in a desk chair when performing the tasks.

Subjects

Twenty graduate and undergraduate students at Kansas State University served as subjects. There were four females and 16 males, with an age range of 20 to 39 years of age. Subjects were paid three dollars each for their service.

Informed Consent and Instructions

Subjects were given "Informed Consent and Instructions" sheets in advance, informing them the nature of the experiment, what they were required to do and the like (Figure 13). They were asked to sign expressing their willingness to participate, before the experiment was begun.

R. SRINIVASAN

Graduate Student
Industrial Engineering dept.

To : Subjects of this experiment.

I thank you for your interest in participating in this experiment.

Please read the attached instructions carefully. If you have any questions on any context please feel free to ask me. This experiment will have six sessions and will last for a total time of about 1hr.15min. The task involved is a 'vigilance' kind, which means that your sincere attention to the task will be required during the entire experiment period. Four sessions of the experiment will require you to make judgment ratings on a scale of 1 to 7.

I request your cooperation for the success of this study.

Thanking you again.

Figure 13. - "Informed Consent and Instructions" sheet.

INFORMED CONSENT AND INSTRUCTIONS

The experiment involves two types of tasks, visual and audio. Each of these will be performed under three different conditions, totalling six distinct experimental situations. The three conditions are :

1. To perform the task alone,
2. To perform the task in the presence of a secondary stimulus, and
3. To attend to the secondary stimulus alone.

Similar to the task the secondary stimulus is also of two types, visual and auditory.

Essentially, this experiment involves two types of task under two types of secondary stimulus.

TASK

Two types - visual and auditory.

The specific task to be performed is similar in both types, which is reproduction of strings of five character digits. Each string of five digits is referred to as a '<u>task signal</u>' (e.g. 51843). In the visual part, the task signal will be flashed before you for a very brief time. You are required to read it, keep in your memory, wait for a signal and then reproduce the task signal. The signal for making the reproduction response is referred to as '<u>response signal</u>'. In the audio part, you will be hearing the task signals from a tape recorder. Again, you are required to keep this in memory and wait till you get the response signal for reproduction.

Figure 13. - continued

SECONDARY STIMULUS Two types - visual and auditory.

The signals from this stimulus, referred to as 'secondary signal', are similar to task signals. That is, strings of five character digits will be presented. It should be noted that the task and secondary signals under both visual and audio types are all similar sets of five character digits, like 51749, 28307, 08653..... The difference between the task and secondary stimulus is that for any particular condition of the experiment the mode of their presentation will be reversed. That is, when the task signals are received visually, the secondary signals will be presented as auditory signals and, when the task signals are received auditorially, the secondary signals will be presented for visual perception.

EXPERIMENT

There will be six short sessions for six different experimental conditions. The experimental procedure varies between the conditions in the type of stimulus used. This will be explained later for each condition at the beginning of each session of the experiment. But, the general procedure of attending to the task signal is same for all conditions.

You are asked receive the signal (visual or audio depending on condition), keep in memory, wait to get the response signal and reproduce the result. The response signal is to be identified by the occurence of same digit as the first and last character of the secondary signal (e.g. 29642, 07380, 91569, 42394, ...).

Figure 13. - continued.

It should be noted here that the response signal is a special occurence of secondary signal. In reproducing the task when response signal is identified, you are asked to write down first the single character which characterizes the response signal, that is, the digit which is same on the first and fifth (last) character of the five digit string. Then follow it with writing the task signal. Examples are illustrated. It is very important for this study that you do not write the task signal until you receive the response signal. Remember this always please.

Examples

1. If the task signal received is 85742, and the response signal identified is 39753, then reproduce the result as 385742.

2. If the task is 60935 and the response signal identified is 04990, then the reproduction should be 060935.

Each session of the experiment will last for about 9 min. In conditions of presentation of the secondary stimulus you are requested to make your evaluation about the comfort or discomfort of the secondary stimulus on a 1 to 7 scale. You are invited to make your remarks which you may think fit, at the end of each session.

The experimental review given thus far is aimed to give you the general idea of the nature of this experiment. Please ask me if you have any questions. The experimental procedure to be followed under each condition of the task will be given in detail at the beginning of each session. Also there will be a trial session for each task situation before the actual experiment

Figure 13. - continued.

begins.

There will be no discomfort nor risk in this experiment, however you are free to stop your participation at any time. I would prefer that you continue until the end so that I can get all the needed data for this study.

If you have any questions feel free to ask now or later.

<u>Figure 13. - continued</u>.

RESULTS

The performance of reproduced results was scored and a record was kept for each subject, for the number of correct responses made. A compilation of these scores for two conditions of the visual task situation is given in Table 2. Means, averaged over the 20 subjects are also indicated. Table 3 shows the records of performance for two conditions of the auditory task and their means. The conditions were: no secondary stimulus (control) and, with the presence of the secondary stimulus.

The subjective evaluations about the secondary stimulus were also compiled. Judgments about the secondary stimulus presented for visual task and which was evaluated under two conditions can be seen in Table 4. Table 5 shows the judgments about the secondary stimulus presented for auditory task, which was evaluated for two conditions. The two conditions were: the secondary stimulus alone and, the secondary stimulus presented with the task.

Statistical Tests

The results were compared by means of an analysis of variance on the IBM 370 computer system using AARDVARK programming. Performance and subjective judgments were designed individually as a function of the main and interactive effects of two types of task and, two conditions for each task. With the repeated measures design the 20 subjects contributed a total of 80 observations. Significance was tested for an alpha level of five percent. Significant results from the analysis

TABLE 2

Performance of Visual Task - Number of Correct Responses Out of a Total of 22.

Subject	Control	Task with auditory secondary stimulus
1	19	9
2	17	8
3	20	14
4	13	6
5	18	11
6	22	17
7	21	16
8	14	16
9	16	8
10	19	14
11	21	13
12	17	5
13	8	11
14	19	13
15	21	21
16	18	11
17	15	6
18	21	14
19	17	7
20	21	9
Mean :	17.85	11.45

14.65

TABLE 3

Performance of Auditory Task - Number of Correct Responses Out of a Total of 22

Subject	Control	Task with visual secondary stimulus
1	21	22
2	22	19
3	17	17
4	18	22
5	21	13
6	20	19
7	21	20
8	18	20
9	18	14
10	22	18
11	22	21
12	20	18
13	15	18
14	10	10
15	20	20
16	22	19
17	19	17
18	21	20
19	18	15
20	19	20
Mean :	19.20	18.10
	18.65	

TABLE 4

Subjective Judgments of Secondary Stimulus for Visual Task

Subject	Auditory secondary stimulus alone	Task with auditory secondary stimulus
1	1	5
2	1	7
3	1	7
4	4	7
5	3	7
6	2	7
7	1	6
8	1	2
9	2	7
10	1	5
11	2	7
12	4	7
13	5	3
14	3	7
15	1	2
16	3	6
17	2	6
18	1	5
19	3	7
20	4	6
Mean :	2.25	5.80
	4.025	

Rating scale range from 1-Not uncomfortable to 7-Extremely uncomfortable.

TABLE 5

Subjective Judgments of Secondary Stimulus for Auditory Task

Subjects	Visual secondary stimulus alone	Task with visual secondary stimulus
1	3	2
2	1	2
3	1	5
4	1	4
5	1	5
6	3	5
7	1	1
8	1	2
9	2	5
10	2	4
11	1	5
12	1	2
13	4	5
14	1	5
15	1	1
16	1	4
17	1	2
18	1	2
19	1	4
20	5	3
Mean :	1.65	3.40
	2.525	

Rating scale range from 1-Not uncomfortable to 7-Extremely uncomfortable.

of variance tests were further checked with Tukey's test to check the directional effects of the variables, at significance levels of five percent. Analysis was computed for the performance of number of correct responses and, the subjective judgments about the secondary stimulus.

Performance

The analysis of variance is shown in Table 6 and the results of Tukey's test in Table 7.

The analysis of variance showed a significant difference in the main effects of tasks and conditions. Tukey's test on the means of task performance revealed that the performance of auditory task was higher than the performance of visual task (18.65 for auditory tasks versus 14.65 for visual tasks) and, the means of performance under the two conditions indicated that the performance under control conditions was higher than the performance in the presence of the secondary stimuli (18.52 for control conditions versus 14.77 for conditions of the presence of the secondary stimuli).

The interactions between tasks and conditions also showed a statistical significance. The main effects of two tasks and two conditions gave four combinations for evaluating the performance:

1) visual task - no secondary stimulus (control)
2) visual task - auditory secondary stimulus
3) auditory task - no secondary stimulus (control)
4) auditory task - visual secondary stimulus.

TABLE 6

Analysis of Variance of Performance

Source of Variation	Sum of Squares	D.F.	Mean Square	F
Task (T)	320.00	1	320.00	21.95 *
Condition (C)	281.25	1	281.25	35.21 *
Subject (S)	403.20	19	21.22	5.27 *
T X C	140.45	1	140.45	34.86 *
T X S	277.00	19	14.58	3.62 *
C X S	151.75	19	7.99	1.98
Error	76.55	19	4.03	
Total	1650.20	79		

*denotes significance, at levels of 0.05.

TABLE 7

Tukey's Test on Performance Means

Non-significant groupings connected by column of asterisks.

Entry	Means	
Task (T):		
Auditory T(2)	18.65	Number of means = 2
Visual T(1)	14.65	Significant range = 0.9401
Condition (C):		
Control C(1)	18.52	Number of means = 2
With secondary stimulus (C(2)	14.77	Significant range = 0.9401
T X C:		
TC(2,1)	19.20 *	Number of means = 2 to 4
TC(2,2)	18.10 *	Significant range = 1.7882
TC(1,1)	17.85 *	
TC(1,2)	11.45	

Alpha level = 0.05, for all tests.

The Tukey test had shown that the visual task in the presence of the auditory secondary stimulus (condition 2) was significantly lower in performance than the other three task-condition combinations (conditions 1, 3, and 4).

The differences among subjects were statistically significant as well as the interactions between subjects and tasks. But the interactions between subjects and conditions were not significant.

Subjective Judgments

The analysis of variance is shown in Table 8 and the results of Tukey's test in Table 9.

The analysis of variance showed significant differences between the two tasks and between the two conditions. The Tukey test indicated that, the subjects evaluated the secondary stimulus employed in visual task as relatively more uncomfortable than the secondary stimulus employed in the auditory task (mean subjective ratings of 4.025 for visual task situation versus 2.525 for auditory task situation) and, the means of judgments of two conditions of secondary stimulus presentation indicated that the secondary stimulus when presented during the task situation was relatively most uncomfortable than when the secondary stimulus was individually attended to (rating of 4.60 for the condition of secondary stimulus with the task versus 1.95 for the secondary stimulus alone).

Also the tasks and conditions interactions were significant. The four combinations, from two tasks and two conditions, under

TABLE 8

Analysis of Variance of Subjective Judgments

Source of Variation	Sum of Squares	D.F.	Mean Square	F
Task (T)	45.00	1	45.00	33.53 *
Condition (C)	140.45	1	140.45	61.99 *
Subject (S)	65.45	19	3.44	3.22 *
T X C	16.20	1	16.20	15.16 *
T X S	25.50	19	1.34	1.26
C X S	43.05	19	2.27	2.12
Error	20.30	19	1.07	
Total	355.95	79		

*denotes significance, at levels of 0.05.

TABLE 9

Tukey's Test on Judgment Means

Non-significant groupings connected by column of asterisks.

Entry	Means	
Task:		
Visual T(1)	4.025	Number of means = 2
Auditory T(2)	2.525	Significant range = 0.4841
Condition:		
With secondary stimulus C(2)	4.600	Number of means = 2
Control C(1)	1.950	Significant range = 0.4841
T X C:		
TC(1,2)	5.800	Number of means = 2 to 4
TC(2,2)	3.400	Significant range = 0.9208
TC(1,1)	2.250 *	
TC(2,1)	1.650 *	

Alpha level = 0.05, for all tests.

which judgments evaluated were:

1) no visual task - auditory secondary stimulus

2) visual task - auditory secondary stimulus

3) no auditory task - visual secondary stimulus

4) auditory task - visual secondary stimulus

Tukey's test showed no significant difference for auditory secondary stimulus and visual secondary stimulus when judged alone (conditions 1 and 3), but these were significantly different from the visual task with auditory secondary stimulus and auditory task with visual secondary stimulus conditions (conditions 2 and 4).

Subjects differences were statistically significant. But the interactions between subjects and tasks and, subjects and conditions were not significant.

DISCUSSION

The hypothesized main effects, for both the tasks combined, showed a significant difference and in the expected direction. That is, the performance was lower in the condition of task and secondary stimulus compared to the control condition; and the subjects rated the presence of the secondary stimulus along with the task as more uncomfortable compared to the condition when only the secondary stimulus was presented. But these effects were not the same for the two tasks. There was a significant difference in the effects of the two tasks. Auditory task performance was higher than the visual tasks performance; and the secondary stimulus for visual task was judged significantly more uncomfortable than the secondary stimulus for auditory task.

It was also predicted that the task interacts with the hypothesized effects of performance and discomfort. Tasks x conditions of performance and tasks x conditions of discomfort judgment interactions were obtained. The hypothesized effects of performance and discomfort were inferred for the two tasks from the results of these interactions.

Performance

Tukey's test showed that the visual task performed in the presence of the auditory secondary stimulus was lower in performance compared to the other interactive effects of tasks and conditions of performance.

Visual task. The hypothesized effect was significant. Performance was significantly lower for visual task with the auditory secondary stimulus (11.45) when compared with the control condition of performing visual task without the auditory secondary stimulus (17.85).

Auditory task. The hypothesized effect of performance was not significant. There was no statistical difference between the task performed in the presence of the visual secondary stimulus (18.10) and the control task (19.20).

Discomfort

Tukey's test showed no difference in discomfort rating when the two secondary stimulus were individually presented, but these two differed significantly from the two secondary stimulus judged when presented with the task.

Visual task. The hypothesized effect was significant. The presence of the auditory secondary stimulus along with task was judged more uncomfortable (5.8) than when the auditory secondary stimulus alone was presented (2.25).

Auditory task. The hypothesized effect was significant. Visual secondary stimulus along with task was judged as more uncomfortable (3.40) than the visual secondary stimulus alone (1.65).

The results of the two tasks discussed indicates that the visual task situation of the experiment was in complete accordance with the hypothesis tested, while the auditory task differed. In the case of the visual task, the distracting auditory secondary stimulus resulted in impairment in performance and apparently caused feelings of discomfort. In the case of the auditory task, the distracting visual secondary stimulus apparently caused discomfort without any detectable decrement in performance.

Findings and Interpretations

The effects of distraction as a result of this experiment can be termed as feelings of discomfort with or, without impairment in performance. This result complements Corlett's (1973) hypothesis and lends support for his concept of comfort which states that, if there is distraction in a situation discomfort also exists.

The other objective of this study was to relate the distractive effects of performance as an indicator of discomfort. The hypothesis was designed to test this relation. But the results arrived under the two situations did not suggest a possibility for such a common indicator. In one situation (visual task) the effects of distraction resulted in a direct loss of performance and also caused discomfort feelings. But in the other situation (auditory task), although the distractive stimulus caused discomfort there was no loss of performance. The subjects were able to overcome the distractive effect, perhaps by expending more effort, and maintain a higher level of performance. These two contrasting situations suggest that the measure of performance alone cannot be related with discomfort to evaluate the distraction effect, because other factors intrinsic to the situation might also control the performance besides the distraction effect. A correlational analysis which was carried out confirmed this view.

Correlation between distraction and discomfort. The difference in performance due to the secondary stimulus and the difference in ratings about the secondary stimulus were correlated over the 20 subjects. Table 10 shows the differences in performance and comfort ratings for visual and auditory tasks. The obtained correlation was tested by t-test for significance at 0.05 level. The correlations and t-tests are shown in Table 11. The visual task situation related distraction and discomfort with a significant correlation of 0.5946 where as the auditory task situation gave a non-significant correlation of 0.3481. These correlations suggested that all the subjects reacted in the same way to explain the effects of distraction on performance and discomfort that were discussed.

Therefore the correlational analysis strengthened the results discussed. In the visual task situation the significant correlation indicates that the performance loss is an indicator of discomfort. But in the auditory task situation, there was no detectable decrement in performance as can be seen by the non-significant correlation. In performing the auditory task, the subjects might have expended more effort to overcome the visual distracting effects. Therefore in evaluating the performance, the effort should also be identified along with performance to relate as an indicator of discomfort.

From these considerations it can be concluded that further investigation is required in order to relate the distractive effects of performance along with effort as a true indicator of discomfort.

TABLE 10

Differences of Reduced Performance and Increased Comfort Ratings due to the Secondary Stimulus, for Visual and Auditory Tasks

Subjects	Visual Task		Auditory Task	
	Performance difference	Rating difference	Performance difference	Rating difference
1	10	4	-1	-1
2	9	6	3	1
3	6	6	0	4
4	7	3	-4	3
5	7	4	8	4
6	5	5	1	2
7	5	5	1	0
8	-2	1	-2	1
9	8	5	4	3
10	5	4	4	2
11	8	5	1	4
12	12	3	2	1
13	-3	-2	-3	1
14	6	4	0	4
15	0	1	0	0
16	7	3	3	3
17	9	4	2	1
18	7	4	1	1
19	10	4	3	3
20	12	2	-1	-2

TABLE 11

Correlational Analysis of Distraction Effects on Performance and Discomfort, for Visual and Auditory Tasks

		Visual Task	Auditory Task
Mean of performance difference	:	6.40	1.10
Standard deviation	:	4.07	2.73
Mean of rating difference	:	3.55	1.75
Standard deviation	:	1.90	1.74
Correlation	:	0.5946	0.3481
T-Statistic	:	3.1376	1.5470
Statistical significance	:	Yes	No

Significance level = 0.05

General Results

It was observed in general, the nature of the task and the secondary stimulus used in the present study had the necessary characteristics that were desired. The difference in correlation of responses under visual and auditory task situations was due to the factors specific to the type of task and the type of secondary stimulus. Many of the subjects expressed the view that performing the visual task in the presence of the auditory secondary stimulus as "very difficult" compared to the other conditions of the experiment. No such remark was expressed about performing the auditory task in the presence of the visual secondary, though this differs from above only in the modality. No learning or fatigue effects were detected. It was important for this study that these effects were not present because, the learning effects could counteract the action of distraction over the 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. As the task was a vigilant kind and for a brief duration, "boredom and monotony" did not exist.

Future Research

Further research is needed to confirm the findings of this study about the effects of distraction in performing tasks. Different tasks and extraneous stimulus should be used and it should be borne in mind that the distractive effects are present and, the learning effects and fatigue are greatly reduced. In such a study the effort expended should be measured and identified along with performance and a relation to discomfort should be sought.

Measuring effort. The problem of defining and measuring effort has been discussed at length by Ryan (1947). In cases of heavy muscular work effort is clearly related to energy consumption (Ryan, 1947). But, in cases of light or sedentary and mental tasks the problem is formidable because, the activities are so varied it is difficult to fit a common unit among them. Adequate methods of evaluating effort have not been developed. An attempt was made to solve this problem by using "information theory" (Garner, 1962). In the context of this theory, man is viewed as a communication channel that transmits information. The capacity of such a channel is given in bits/second, reflecting the rate at which information is transmitted through it. Channel capacity has been measured in various human activities. Unfortunately, estimates of human channel capacity in different tasks have been too inconsistent to be useful. Physiological measures of effort have been tried and among them muscular tension seemed to have held the attention of many investigators. Ryan, Bitterman and Cottrell (1950) suggested from available results that muscular tension is related to the difficulty of a task, to the distractions which accompany the task, and to the level of performance. They continue to write that, while these results are promising, it must be noted that many of them were obtained with methods of recording or conditions of experimentation which would preclude the use of muscular tension in studying many practical problems of work.

The author suggests, the subjective evaluations about the difficulty of the task can be tried as an indicator of additional effort expended due to the effects of the secondary stimulus, before complicated assessments of effort can be attempted. In such an experiment, the tasks chosen should be such that their difficulties are identifiable under the experimental conditions.

Practical Implications

The benefit underlies this study was that the concept of comfort can be employed as a criterion for improvement in job design. 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 of the worker. If the enfironmental 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 toward the difficulty of the job due to discomfort, then opportunities arise for the redesign of work tasks using comfort as a criterion.

In general, the concept outlined in this research can be applied in situations where the study of the physical environment is important.

CONCLUSIONS

1. The results verified Corlett's (1973) hypothesis on discomfort: if a sensation distracts attention from the task, then discomfort will exist.

2. Two effects due to a distractive stimulus in a multiple stimulus system have been found. One effect, for the visual task, was an impairment in performance and also feelings of discomfort. The other effect, for the auditory task, was only discomfort feelings without an impairment in performance.

3. The attempt to relate the distraction effects of performance and discomfort was discussed. In the situation where the effect of the distractive stimulus was to cause only feelings of discomfort it was concluded that the effort need to be identified along with the performance to relate as an indicator of discomfort.

4. Suggestions for future research were made. It was suggested that, in the wake of inadequate methods for the measurement of effort, subjective evaluations about the difficulty of the task can be tried as an index of extra effort expended due to the distracting effects. Selection of tasks for such an approach was indicated.

5. The implication of this study was that the concept of this research can be applied, in situations where the study of the physical environment is important, as a criterion for improvement in job design.

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DISTRACTIVE EFFECTS IN PERFORMING VISUAL AND AUDITORY TASKS AS AN INDICATOR OF DISCOMFORT

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ABSTRACT

An experiment was performed to test the distractive effects of an extraneous stimulus in performing a task as an indicator of discomfort. The distractive effect of an auditory extraneous stimulus in performing a visual task and a visual extraneous stimulus in performing an auditory task were tested. Performance was used as a measure of the distractive effect, and a rating scale was employed for the evaluation of feelings of discomfort. Three conditions were considered: task alone, task in the presence of a secondary stimulus and secondary stimulus alone.

Twenty subjects worked in the three conditions for each of the two tasks, visual and auditory. Their performance in the conditions of the presence of the task stimulus and their discomfort feelings in the conditions of the presence of the secondary stimulus were recorded.

For the visual task discomfort occurred along with a loss in performance and for the auditory task there was only discomfort feeling without any detectable impairment in performance. The results showed that the feelings of discomfort exist for both the visual and the auditory task situations.

Possible interpretations and implications of these research findings are discussed.