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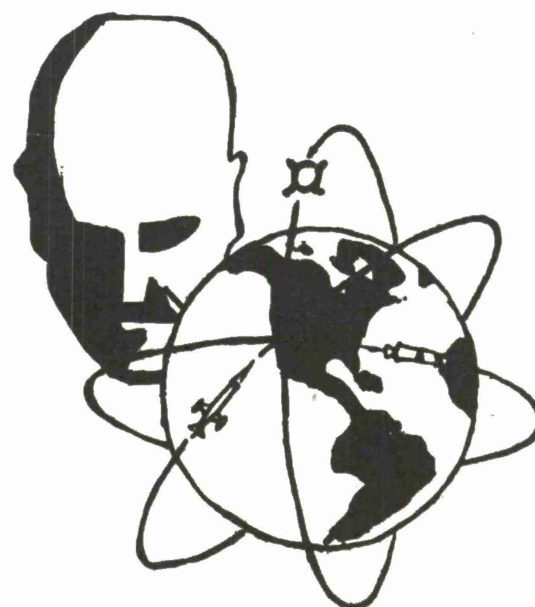
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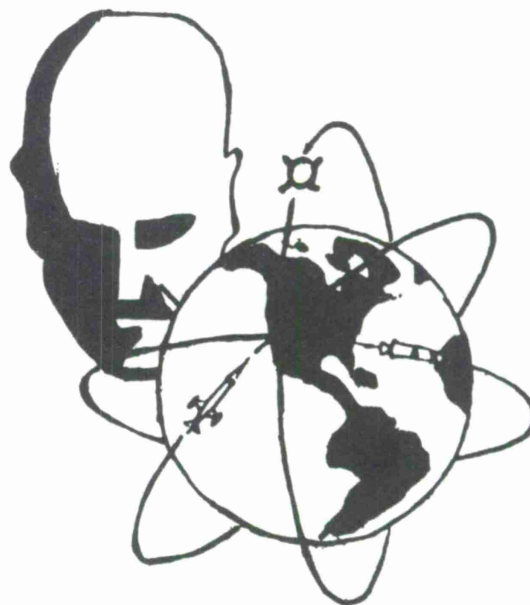
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INVESTIGATIONS OF ACOUSTIC EFFECTS UPON VISUAL SIGNAL DETECTION

William H. Watkins, Major, USAF
Carl E. Feehrer

DECEMBER 1964

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INVESTIGATIONS OF ACOUSTIC EFFECTS
UPON VISUAL SIGNAL DETECTION

ABSTRACT

Several patterns of aural white noise of moderate intensity were presented in 4 forced-choice experiments to investigate acoustic influence upon visual detection. When noise was present, but not continuous, the temporal properties of its bursts or interruptions bore a regular relation to the observation intervals involved in the visual task. Detection rates were highest when bursts of noise coincided with observation intervals. Rates were somewhat higher when there were interruptions at observation intervals than when noise was continuous. Acoustic facilitation was reduced to a (statistically) non-significant level when the visual signal was made spatially coincident with one of four light flashes. Practice effects were present over the full span of the longest of these experiments, but not obvious in each of the experiments.

PUBLICATION REVIEW AND APPROVAL

This Technical Documentary Report has been reviewed and is approved.


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INTRODUCTION

Within this general area of research, a fairly large number of studies have been made of effects of sounds occurring during visual monitoring in vigilance situations. Many of those are discussed in Broadbent (1958). Inhibitory effects appear to be the more common among the vigilance study results, but Kirk and Hecht (1963) have reported data indicative of acoustic facilitation of visual detection in a vigilance task. Experiments by Watkins (1964) and by Watkins and Feehrer (1965) have been concerned with detection by human observers of visual signals in "non-vigilance" situations. The task in these investigations has required an observer (O) to judge which of a set of successive, brief time intervals contained a visual signal: a forced-choice technique.

The results of the forced-choice experiments cited above may be generally stated. The task was detecting a weak light signal in a lighted field, with a conspicuous, visual source of time information, several degrees from the signal site. Signal detectability was somewhat dependent upon acoustic conditions. When random noise at moderate amplitude was sounded in coincidence with all the alternative observation intervals, detectability was highest. Next best was the case having noise presented at all times except during the observation intervals. Continuous presence of noise and silence have been found equivalent and inferior to the intermittent noise conditions. The magnitudes of these differences have varied between experiments and observer groups.

The present experiments, like those above, were empirical studies to determine what effects particular sound conditions have upon visual signal detection.

EXPERIMENTAL SITUATION

Apparatus.

The apparatus used in these experiments is described in detail in Watkins, Nickerson & Schjelderup (1964). The elements were an observer station, control equipment, and a set of computer programs. Auditory and visual displays and a special observer's chair were contained within an anechoic chamber. The visual display panel was located 11 ft. in front of the observer and consisted of a transilluminated panel with attached time-cueing, "Ready," and "Vote" lamps.¹

General Procedure.

For each experiment, instructions concerning the apparatus and the detection and response task were given to the observers (Os) in groups. In no case was the predicted direction of results made known to O, although making comparisons between sound conditions was an announced intention. Each O was given an opportunity to practice the task to at least one full run free of late voting. As O practiced, the experimenters determined a suitable starting signal strength.

These experiments used runs of 48 trials, each trial with four observation intervals. On the rare occasions when O voted late after completing 30 or more trials, the incompleted run was accepted and scored. The duration of each run was 4 min., and a rest period of at least three minutes was given between runs. During some of the

¹ The apparatus was designed and constructed under the direction of John R. Schjelderup.

experiments, adjustments in signal strength were necessary to minimize sets containing near-perfect or chance-level runs. Such adjustments were made only between sets. The photometric brightness of the signal at representative strength settings, and of background areas of the visual display panel, are presented in Table 1.

The percentage correct of all trials comprising a run was used as the score unit. Obtained percentages were rounded to the nearest whole per cent; upward in cases of exact halves of one percent. A score of 25 per cent would be expected by chance, since there were four alternative intervals.

Earphones were worn by Os throughout all runs. Each run was started by O by means of a switch. Knowledge of results was provided to O in the form of numbers of trials correct and incorrect at the end of each run. A PDP-1 digital computer was used to generate signal sequences on paper tape for use in controlling experimental apparatus, and to analyze data.

Observation intervals - Figure 1 shows (I) the four observation intervals (OI's) and (II) one standard trial sequence, where:

C = The period during which a 2 1/2" x 3 1/4" cue panel, at lower left corner of the main display area, bearing the letter L, was lighted, in Experiments II and III.

-1 = The period from C to S.

S = The period during which the signal could have been presented (i. e., an OI).

+1 = The period from S to the next C for OI's One to Three and the period from S to Vote for OI Four.

TABLE 1

Photometric Brightness of Surfaces in Foot-Lamberts

Signal On voltage elevation	Central spot	Timing Spot including central spot ^a
0.0 ^b	25.09	26.79
3.5	25.09	27.39
7.0	25.37	27.71
11.0	25.68	28.07
14.5	25.95	28.21
18.5	26.27	28.36
22.0	26.54	28.50

Note. The panel surrounding the fixation-signal area had photometric brightness of 24.66 ft-L. The L Cue was at 45.08 ft-L.

^aExp. III only.

^bFixation level.

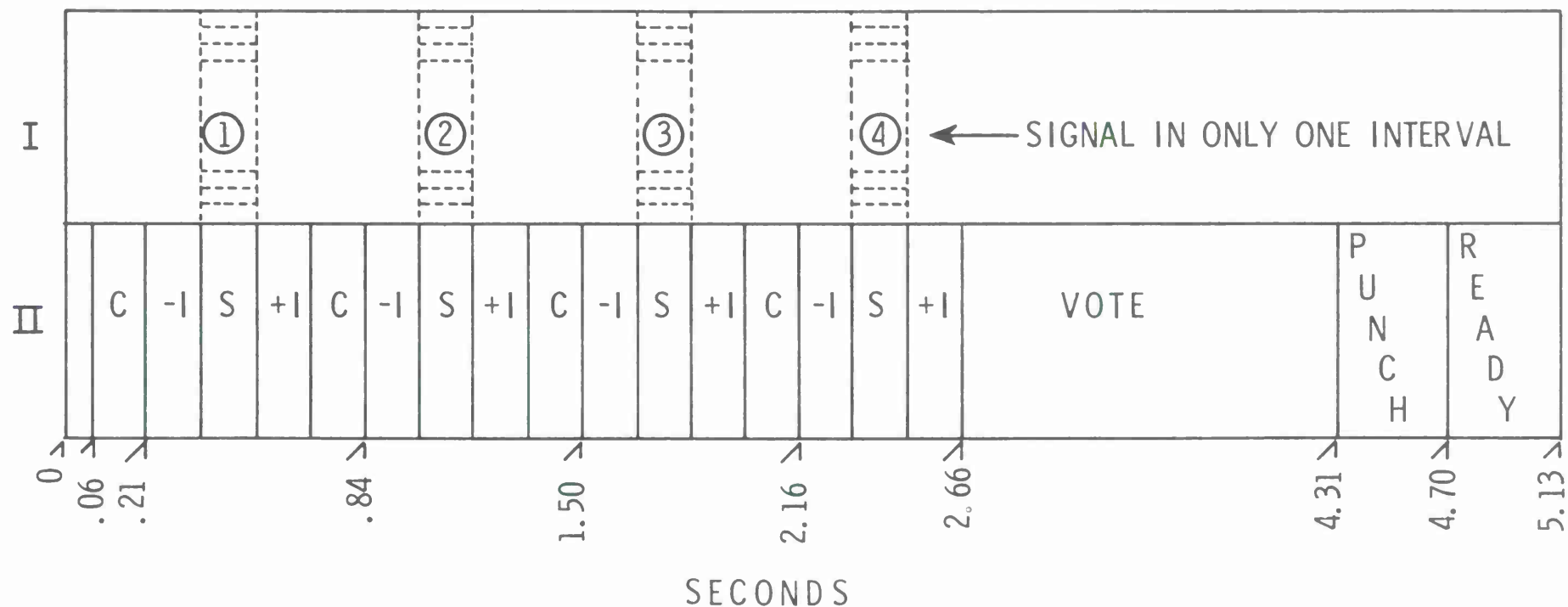


Figure 1. Standard time configuration of trials. I: four possible signal intervals. II: Basic time periods. The segment between the .06 and 2.66 sec. points consisted of 16 equal intervals of approximately 165 msec.

Events occurring during the periods labeled Vote, Punch and Ready are as implied by those titles.

Signals were evenly divided among the four OI's according to the following rules: Four independent blocks of 12 trials comprised a run of 48 successive trials. The sequence within each block included three occurrences of each OI, randomly sampled without replacement. For any O, a given run sequence was used only once.

Recording - As a run progressed, the signal interval and the interval voted were automatically recorded on punched-paper tape, i.e., the data tapes. Additionally, digital counters accumulated the numbers of correct and incorrect trials for every run.

Signals - A signal consisted of an increase, on the order of .1 to 1.5 ft. Lambert, in the brightness of a fixation spot located in the center of the display panel. It was produced by raising the current flow through a projector lamp by a given amount (determined by signal strength needs) for a period of 165 milliseconds.

EXPERIMENT I²

This experiment tested visual detection where the only photic aids to OI time-certainty were the "Ready" and "Vote" lamps. Acoustic specification of OI's was complete under two of the three conditions.

Observers - Five university students, two female, three male, and three other men served as observers. The group was diversified as to amount of experience in similar experiments.

²

The following description of Experiment I is, in substance, the text of a paper scheduled to be read at a meeting of the Eastern Psychological Association in April 1965.

Method.

Conditions and sets - There were three acoustic conditions:

1. Continuous binaural noise of 70 db SPL overall amplitude (CN).
2. The same noise continuous except for 165 millisecond interruptions coincident with all OI's. (INTRPNS).
3. Quiet except for noise as specified above, presented in the form of bursts of 165 milliseconds, coincident with the OI's. (BURSTS)

The noise had a frequency range of 100 - 6800 cps. It was maintained at 50 db SPL overall as the "off" or quiet state. The noise was produced by a random noise generator (Crayson-Stadler Model 456).

A set of runs consisted of one run under each acoustic condition, i.e., three runs interspersed with rest periods.

Procedure - After a minimum of practice, each O performed four sets. All possible orders of conditions occurred at least twice, and different "orders of orders" were used.

Results.

The means for INTRPNS and BURSTS were above those of CN. The superiority of BURSTS over INTRPNS was significant. Means and comparison data are shown in Table 2.

Discussion.

This experiment supported a position holding that time specification alone fails to explain acoustic facilitation in forced-choice visual detection. INTRPNS and BURSTS were acoustic reciprocals and contained identical time information. INTRPNS proved inferior to BURSTS, however, and additional facilitatory mechanisms are inferred to have been operating under BURSTS.

TABLE 2
SUMMARY OF DATA COMPARISONS
(8 OBSERVERS)

<u>Condition</u>	<u>Compared to</u>	<u>Outcome</u>
Bursts (Mean = 61.34)	Remaining 2 Conditions	Superior; $F=9.9$ with 2.14 df (3X8 Analysis) $p < .01$
Bursts (Mean = 61.34)	Interruptions (Mean = 53.46)	Superior; $F=7.3$ with 1.7 df $p < .05$
Interruptions (Mean = 53.46)	Contin. Noise (Mean = 44.59)	Higher, but differences not statistically significant

EXPERIMENT II

This experiment tested visual detection where the photic aids to OI time-certainty were the "Ready" and "Vote" lamps and, in addition, a small, auxiliary panel, illuminated shortly before each OI. This panel has been mentioned in the explanation of observation intervals, and is discussed in Watkins et al. (1964, pp. 4-6).

Observers.

Six Os, selected on the basis of never having participated in any similar experiments, were used.

Method.

Sound Conditions - The same three used for Experiment I.

Procedure - In alphabetic order, the Os were separated into three pairs. The first pair performed 30 runs (the entire experiment) under CN. The two other pairs were assigned two different sequences of accomplishing 30 runs, with the first ten and the last four runs always under CN. For one of these pairs, the middle 16 runs consisted of eight under BURSTS, followed by eight under INTRPNS. The remaining pair performed its middle 16 runs in the reverse order, i.e., eight INTRPNS runs, then eight BURSTS runs.

Runs 1 through 6 were excluded from all computations. These were considered practice runs, needed for establishment of suitable signal strengths, which in turn were held invariant for each O through the remainder of the experiment.

Results.

The results are best understood from Figure 2. The reader should first note the shape and shading key, in the upper right corner of the figure, where a single symbol is shown as conveying pair identification and noise condition information. With the key in mind, and a caution to avoid making comparisons across pairs (signal strengths were not equated, either in physical intensities or on any detectability basis) the reader should observe the record of events as graphed on the left side of the figure. Table 3 lists the means plotted in the summary graph at lower right in Figure 2.

EXPERIMENT III

This experiment tested the effectiveness of bursts preceding, during, or following OI's. The bursts used were of three durations. Photic aids to time-certainty were the same as in Experiment II.

Observers.

Four male laboratory personnel served for this experiment.

Method.

Conditions and sets - There were eight acoustic conditions:

1. Continuous noise. (CN)
2. Bursts at -1 segments; i.e., four bursts of noise per trial, presented at the four "-1" times shown in Figure 1. (-1).
3. Bursts coincident with the four OI's. (S).
4. Bursts at the four "+1" times. (+1)

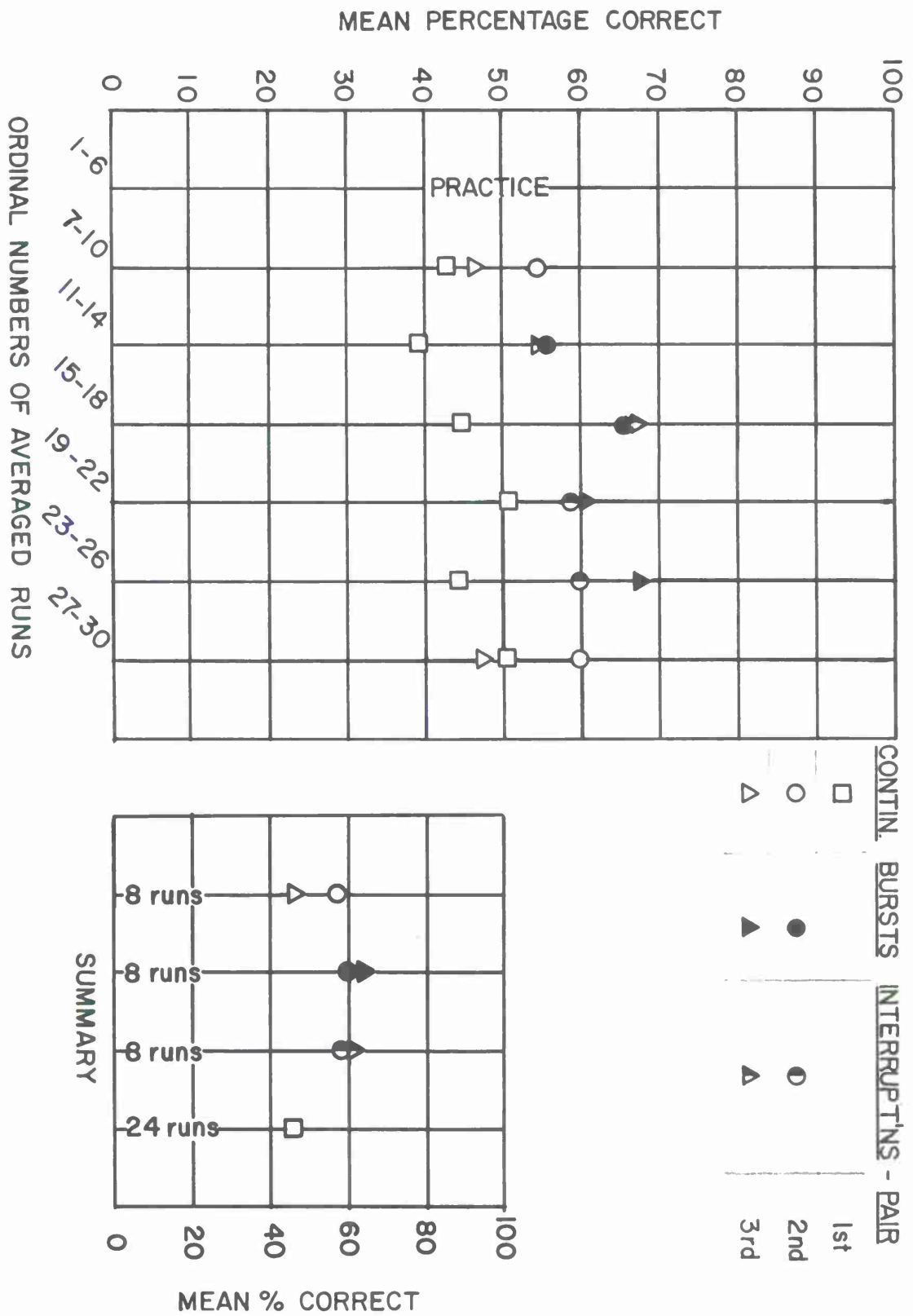


Figure 2. Detection performance of pairs of observers in Experiment II.

TABLE 3

Summary Means - Experiment II

Condition	Pair	No. runs Averaged	Mean % Corr.	Pairs 2 & 3 Combined
CN	1	24	45.5	52.0
	2	8	57.0	
	3	8	46.9	
BURSTS	2	8	60.8	62.4
	3	8	63.9	
INTRPNS	2	8	59.0	60.0
	3	8	60.9	

Note. Unequal signal strengths preclude across - pairs comparisons.

5. Bursts of two times the duration of those listed above, presented through the four pairs of adjacent -1 and S segments. (-1S)
6. Bursts similar to those of -1S condition, but covering the S and +1 segments. (S+1)
7. Bursts at all -1 and +1 times; i.e., eight bursts of 165 milliseconds, interspersed with silent periods of equal duration. (-1, +1)
8. Bursts three segments long covering -1, S, and +1. (-1S+1)

Noise was either presented binaurally at 70 db SPL overall, or not presented. The frequency range was 100 - 6800 cps.

A set consisted of eight runs - one per condition.

Procedure - Each O performed four sets, usually accomplishing a full set on one day. The sequence within sets was varied.

Results

The mean scores for the extremes of the acoustic conditions, viz., S (best) and +1 (lowest) differed to the extent of 15 percentage points. A significant ($p < .05$) F ratio was obtained when the between - conditions mean square was tested. Figure 3 displays group means for all acoustic conditions. Although no significant difference between any pair of conditions was apparent, the following may be noted. Condition 3 (S) was rivalled but not bettered. Burst duration appeared less important than temporal position. Just one condition, +1, was inferior to continuous noise. Condition 4 (+1) was poorest for three of the Os and superior only to CN for the fourth O.³

³ Selected conditions (#1, 3, 4&5) were tested again in a small scale follow-up to the main experiment, with 3 college women as Os. The results were much like those reported for the laboratory males, particularly in the consistently low standing of +1 bursts.

EXPERIMENT III

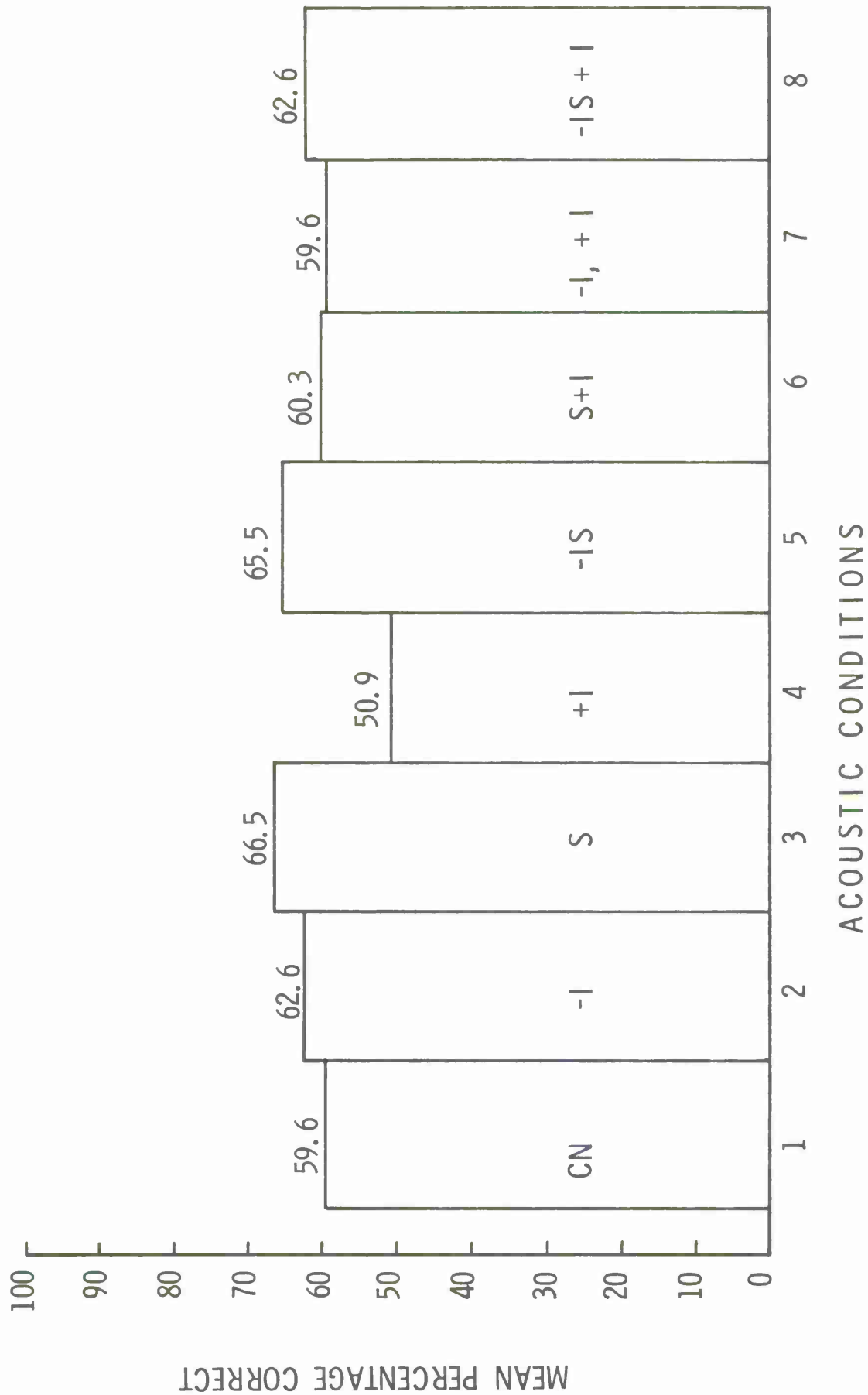


Figure 3. Detection performance under 8 sound conditions by a group of 4 observers.

EXPERIMENT IV⁴

An entirely new element, a timing spot, was introduced in the testing situation for this experiment. It allowed investigation of acoustic effects under a condition of presumably high time-certainty. The acoustic conditions which had looked interesting on the basis of data from previous experiments were chosen.

Observers.

Five university students served as Os, two women, three men.

Method.

Visual events - As stated earlier, the site of the signal in these experiments was the center of the display panel. There, a circular spot which remained somewhat brighter than the surround, served as a fixation "point." As in the prior experiments, an increase in the intensity of that spot constituted the visual signal. In addition, a concentric spot was introduced: the timing spot. No part of the 1.3 in. diameter fixation/signal spot extended beyond the perimeter of the 1.4 in. timing spot. The timing spot brightened for the periods identified in Figure 1 as "S" and was invisible at all other times. The "L Cue" panel was not used.

The consequence of these photic arrangements was that each trial began with the "Ready" lamp on; it continued with the occurrence of four OI's, each involving an intensification of the display center (one of which was slightly greater than the other three); it ended at the termination of the Vote period, indicated by the usual "Vote" lamp operation.

⁴ The idea of improving time-specification through the visual means described was proposed by Charles R. Brown.

Auditory events - Five sound conditions were used, in sets consisting of one run per condition. They were:

1. Continuous noise. (CN)
2. Bursts coincident with OI's. (S)
3. Bursts at +1 times. (+1)
4. Interruptions at OI's. (RS)
5. Interruptions at +1 times. (R+1)

Noise was binaural and random within the 100 - 6800 cps. band; the On amplitude was 70 db SPL overall and the Off (i. e. , quiet) amplitude was 50 db.

Procedure - The Os were given approximately 1 1/2 hours of practice, distributed equally among the sound conditions. They then accomplished ten sets, usually at the rate of one set per day. The order of conditions was the same for all Os for a given set. A quasi-random arrangement of conditions among sets was followed.

Findings.

The conditions did not differ significantly. However, condition 2 (S) held its primacy from the first set through the last, standing finally at 56.70 per cent. Next was condition 5 (R+1) at 55.98. Third was +1 at 54.94, followed by RS, 54.54. Poorest at practically all stages was CN, 53.32 in the final tabulation.

The data were analyzed for practice effects (experimental run signal strengths were constant for each O) with the following interesting outcome: There occurred a highly significant improvement through the course of this experiment, in spite of the uncommonly long pre-experimental training

period provided. This phenomenon was not seen in any of the other experiments of this series, and may be associated with use of a timing spot.

DISCUSSION

The facilitation effect.

Earlier experiments (Watkins, 1964; Watkins & Feehrer, in press) have shown that bursts of noise sounded in coincidence with the times of its possible occurrence rendered a light signal substantially more detectable than the same signal was when other sound conditions prevailed. This finding is confirmed in the experiments described in the present paper.

Substitution of a reciprocal sound condition, having the identical information content with respect to time specification, has shown that bursts (at OI's) aid detection in a manner not adequately explained by consideration of time specification. There is a further benefit which we are inclined to regard as a phenomenon of "heightened attentiveness." The latter term is meant to imply a modification in the sensitivity of observers to signal stimuli. Consideration will now be given to pertinent aspects of the concept of attention.

Attention.

Several recent formulations dealing with attention phenomena (Deutsch and Deutsch, 1963; Magoun, 1963, pp. 103-113; Pribram, 1962, pp. 123-127; Sokolov, 1963) have leaned heavily upon the electrophysiological evidence gained within the past few years. Older theoretical treatments of

the subject have frequently included objective behavioral data as well as the classical introspective observations. (See Woodworth and Schlosberg, 1954, pp. 72-106). Theorists certainly are not in total agreement about the form of the ideal model of attention, but it seems that a characterization of "attending," as summarized by Pribram (1962), would evoke few objections. The following account represents our interpretation of implications derived from a considerable amount of electrophysiological and neuropsychological evidence (ibid. p. 135):

A sensitive organism is exposed to a "novel event," i.e., one or more receptor organs responds to energy impingements, to which the organism has not become "habituated" (see below). In this first stage, there occurs a behavioral consequence termed a "reflex" orientation movement and an electrophysiologically observable modification in brain activity. If there is some persistence or repetitiveness of the novel event, the second stage begins, (the resulting behavior is called an orienting reaction, or a searching response) and electrical activities of certain regions of the brain exhibit characteristic changes. In this second stage, the subject is "attending" to something in the usual sense of the term. What is being attended may or may not be discernable by an observer. Importantly, this "attentive" state involves other sensory systems besides that which conveyed information concerning the "novel event." (See also, Magoun, 1963, p. 90; Hernandez-Peón, 1961, p. 511).

Habituation - describes the final results of persistent, or repetitious stimulation. The responses formerly elicited diminish to the vanishing

point. A classic experiment by Sharpless and Jasper (1956) demonstrated the habituation phenomenon. They employed intra-cranial sensing electrodes to observe the electrical activity of a region of the cerebral cortex of cats when tones of several frequencies were sounded repeatedly. The discharge pattern which occurred at the first presentation of any of the tones was clearly distinct from the quiet (tone-free) situation. When a particular tone was repeated over many presentations, the electrical response became more brief, then ceased to occur altogether. When a new frequency was then presented the response was maximal. Data of this sort are associated with disagreement among theorists as to whether "input filtering" is done at peripheral, intermediate, or "very high" levels in the nervous system - or at plural stages.

The foregoing sketch of some current concepts in attention theory relates to the present experimental findings in the following way: behavior in the form of visual detection performance should be expected to show little or no effect via "attention," based upon an easily habituated sound stimulus such as continuous, moderate-amplitude, random noise. Indeed, none were seen. The observers could have been aroused to greater attentiveness by changes in their acoustic environment, as bursts of noise (or breaks in otherwise-continuing noise) interrupted the habituated state at observation intervals, including actual signal times. Contemporary attention theory and the present results have been consistent to this point, but can the superiority of noise bursts over their acoustic reciprocals be said to show such consistency? Apparently not, insofar as the state of relevant formulations in the field of attention is perceived by the present authors. Nevertheless, it is from

this domain that an eventual clarification of the phenomenon of intersensory facilitation, as we have observed it, is expected to come.

The significance of Experiment IV

When a timing spot was employed, converting the observer's task from one of detecting a brightening to that of detecting the greatest among four physical brightenings, the acoustic effect diminished. As has been mentioned, time-certainty differences between sound conditions should have been minimal and negligible in that experiment. Indeed, no significant differences were found, suggesting on its face that time-specification was an all-important factor in this whole line of investigation. That appears improbable, however, in view of the outcomes of the experiments previously discussed. Also, because the differences in Experiment IV, even though statistically non-significant, were in the direction favoring bursts at OI's and therefore, consistent with all other data.

If it be supposed that sound-induced elevation of "attention level" had something to do with signal detectabilities in other experiments, why should it not have operated to a significant extent in Experiment IV? Perhaps the lesson is no more complex than recognizing that intra-sensory stimuli can operate to alter level of attention, and thus, sensitivity, sufficiently to pre-empt most of the potential for increased attentiveness.

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