WADC TECHNICAL REPORT 54-364

THE CONCEPT OF RESPONSE RESTRICTION APPLIED TO DIAL READING

The Eighth of a Series of Reports on
"SET" As a Determiner of Perceptual Responses

WILLIAM A. LEE
MELVIN FREITAG

UNIVERSITY OF VIRGINIA

APRIL 1955

WRIGHT AIR DEVELOPMENT CENTER

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AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
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FOREWORD

This report is the eighth of a series relating to laboratory experiments designed to explore the operation of perceptual "set" and its application to human operator efficiency in the process of the intake of information. The investigation covered in the present report was conducted by Mr. W. A. Lee and Mr. Melvin Freitag, under the general supervision of Dr. R. H. Henneman. These studies were carried on at the University of Virginia under Contract No. W33(038)-ac-21269. This contract was initiated under Project No. 7192, Task No. 71603, "Visual Message Presentation." The contract was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, with James E. Smithson acting as Project Engineer.

ABSTRACT

In many practical situations involving data presentation the human operator is called upon merely to check-read or "monitor" instrument dials. Such monitoring involves relatively simple perceptual responses to specific aspects of rapidly changing stimuli. Previous studies of perceptual set in the present series have been concerned with more complex perceptual responses (identification) in relatively static situations. Furthermore these earlier studies had not included multiple task conditions, such as frequently characterize operational situations. Accordingly, an experiment was designed to learn the effectiveness of setting cues as an aid to accuracy of dial-checking when subjects were simultaneously performing a competing visual-motor task. Degree of setting and sense channel of cuing were the experimental variables.

The results indicate that dial-checking accuracy was significantly improved by the introduction of the setting cues. Performance on the competing task was unaffected by the setting operations. Sense channel of cuing was not a significant factor, a surprising finding in view of the "crowded" visual channel resulting from the employment of the two simultaneously visually controlled tasks.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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INTRODUCTION

Previous laboratory experiments on perceptual "set" at the University of Virginia have demonstrated the facilitating effects of setting cues (conceived of as response-restricting information) on the identification of ambiguous stimuli (2, 3, 4, 5, 6, 7, 8). Stimulus materials have included distorted geometrical figures, letters of the alphabet, and words. Both location and identification response uncertainty (resulting from stimulus distortion or background clutter) were shown to be significantly reduced by the setting cues. Experimental cuing has taken several forms (e.g., areal restriction, lists of response alternatives, and specific categories). The effectiveness of setting was shown to apply to both visually and aurally presented stimuli, and either of these sense channels appears to be suited to the presentation of the setting cues.

The earlier experiments have investigated relatively complex perceptual responses, i.e., location and identification, in relatively static situations, i.e., where stimulus patterns were changing at a slow rate (only between trials). In the interests of extending the generalization of the effects of set in facilitating the perception of ambiguous stimuli, it was judged advisable to add research on situations calling for simple responses (e.g., only detection) to specific aspects of rapidly changing stimuli. The check-reading or monitoring of such instruments as temperature and pressure gauges, or fuel indicaters, in aircraft involve this type of perceptual response. Since this kind of monitoring demands only occasional periodic scanning of instruments, it usually occurs in conjunction with other competing tasks. Indeed, the aircraft pilot is seldom free to concentrate full attention upon his check instruments, being simultaneously occupied with other more demanding tasks such as the execution of maneuvers or exchanging messages on the radio telephone. The importance of the multiple task situation in air operations has been stressed in other technical reports from the University of Virginia (1, 9).

None of the previous investigations of set had included the condition of simultaneous performance of a distracting task, hence the question of the effectiveness of setting cues when persons are simultaneously distracted remained to be answered. If occupation with simultaneous multiple task performance is a frequent condition encountered in air operations, then it is obviously important to verify the hypothetical advantage of perceptual setting under such conditions. It was therefore decided to investigate the effect of setting cues on the accuracy of check-reading of multiple dials when the subjects were simultaneously engaged in performing a perceptual-motor task. To obtain wider generality, the visual and auditory presentation of setting cues was to be compared. Since both the check-reading task and the distracting task required the visual input of information for their performance, it was logical to suppose that auditory cuing might be more effective in this kind of situation than visual cuing. In accordance with this rationale an experiment was designed to answer the following questions:

1. Can the accuracy of monitoring of multiple dials, performed simultaneously with a distracting task, be facilitated through cuing?

2. Will level of performance on the distracting task be influenced by the simultaneous cuing of the check-reading task?

3. If certain setting operations are found to influence either the check-reading or distracting task, will their effects be all-or-none, or will they vary in degree in accordance with the presumed degree of response limitation? In other words, is either check-reading accuracy or task performance changed systematically by progressive increases in the degree of response restriction imposed by the setting cues?

4. Will the sense channel by which the setting cues are presented influence the setting effects?

In order to answer these questions the following experiment was designed. The variables that were conceptually manipulated were (1) degree of restriction achieved by the setting cues, and (2) modality or sense channel of cuing. Operationally, these variables were employed in conjunction with two tasks to be performed simultaneously. The first task required the subject to check-read simultaneously four dials corresponding to which was a row of four keys. The subject had to indicate the detection of a needle's having entered a "critical" zone on a particular dial by pressing with his left hand the key which corresponded to that dial. The second task (a semi-tracking task) entailed the subject's pressing a set of four keys with the fingers of his right hand -- the keys corresponding to a set of four lights which flashed on and off individually in random order. Setting information (cuing)was varied in four ways: (1) by giving no cues; (2) by giving a signal every time any dial needle moved (a signal every 1.8 seconds); (3) by giving a signal that a needle on one of the four dials had entered a critical zone; and (4) by giving a signal that a needle in one of two dials (the pair on the left or the pair on the right) had entered a critical zone. Sense channel of cuing was varied by employing either a light or a buzzer. Under the fourth setting condition the appropriate pair of dials (that is, left vs. right) was indicated visually by the use of lights of two different colors. Aurally, left was indicated by a buzzer; right, by a bell. The variables -- degree of setting and sense channel of cuing -- were organized into a 4 x 2 factorial design. Table 1 depicts all combinations of the two variables.

TABLE 1

Experimental Design

Sense Channel of Setting	Degree of Setting I No Setting	II Any Dial Change	III Four-Dial Critical	IV Two-Dial Critical
Visual	N = 5	N = 5	N = 5	N = 5
Auditory	N = 5	N = 5	N = 5	N = 5

PROCEDURE

Subjects

Forty subjects (male college undergraduates) were randomly assigned to the eight cells (5 per cell) representing all combinations of experimental conditions.

The Distracting Task

The semi-tracking task employed in this experiment was similar to a visual-motor task used in the multiple-task performance research reported earlier (9). Four green lights arranged in a horizontal line flashed on and off individually at a rate of two per second. The sequence of lights was random within a series of 44. Thus, there was no pattern for the subject to learn. Rather, he was compelled to respond directly to the lights by pressing the appropriate one of a set of four keys corresponding to the four lights. The correct key had to be pressed during the half-second interval in which the light remained on in order to constitute a correct response. The subject operated this task with his right hand.

The Dial-Monitoring Task

The subject operated with his left hand a similar bank of four keys which corresponded to the four dials. The dials were spatially arranged in

the form of a square and were situated two feet in front of the subject at eye-level. The type of dial used and the spatial arrangement of the four dials are indicated schematically in Figure 1. All the dials were calibrated from 0 to 100. From 0 to 20, and from 80 to 100, the calibration marks on all four dials were covered by black masking paper, thus indicating "critical" zones. The pointers could assume any one of seven positions on the dial faces---one position well within the blackened areas at each end, and five intermediate positions in the undarkened middle ranges of the dial. The subjects' task was to press the appropriate key in the left-hand bank whenever any dial pointer entered a critical zone. All of the pointers moved simultaneously every 1.8 seconds, and one of them entered a black zone on the average of once every nine seconds. The time intervals between zone entries were varied randomly, and only one pointer was actually inside of a critical zone at any one time.

Manipulation of Setting Cues

The differential cuing of the dial-monitoring task was manipulated by employing seven combinations of sense channel and degree of cuing. The subjects of Group I received no setting cues. Those of Group II received a signal whenever the dial pointers moved to a new position (i.e., once every 1.8 seconds). This signal was a flashing red light for the visual group and a buzzer for the auditory group. The subjects of Group III received a signal whenever one of the pointers on any of the four dials entered a critical zone. This signal continued as long as the pointer remained in the black zone. Again the signal for the auditory group was a buzzer, while for the visual group it was a red light. The Group IV subjects also received a signal whenever a pointer entered a critical zone, but in addition they received information as to which pair of dials was involved. Thus the subjects in visual Group IV saw a red light when one of the two dials on the left side had a pointer in a black zone, and a white light when one of the two dials on the right side had a pointer in a black zone. Auditory Group IV subjects received a similar cuing to spatially differentiate between the two pairs of dials. In this case a buzzer was sounded when the "critical" dial was one of the two on the left, and a bell was rung if it was on the right side.

Experimental Procedure

Each subject was given two practice trials, each of 150 sec. duration. At the end of this time the actual experimental session was begun. During this period each subject received 15 trials of 75 sec. duration, these trials being separated by inter-trial intervals of 45 sec. Total time for both practice and experimentation required approximately 40 min.

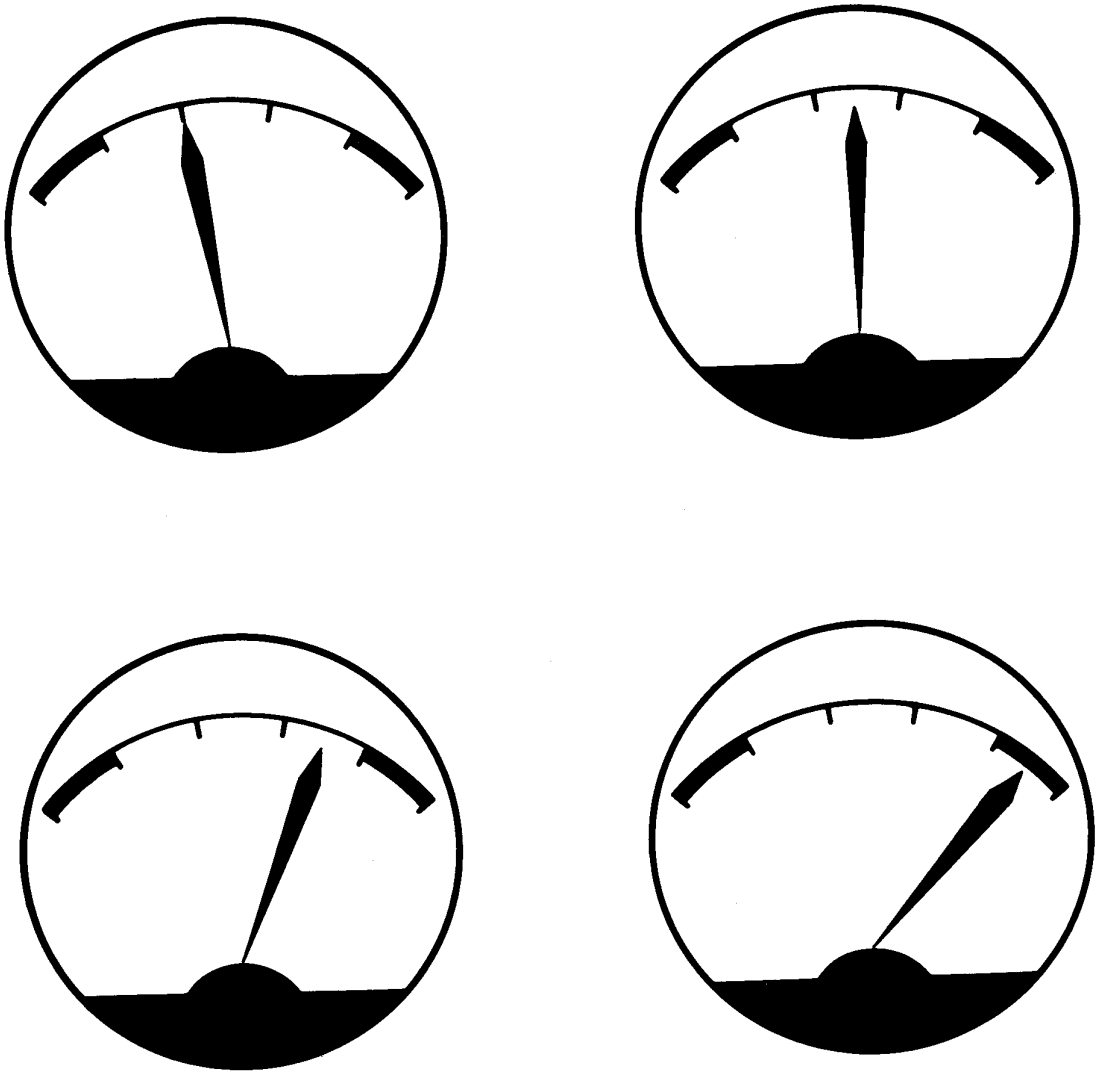

Figure 1. Schematic Representation of the Four Dials, Showing Their Spatial Arrangement. The Schematic Dials Are the Same Size as Those Actually Used.

RESULTS

Percents of correct detections in the dial-monitoring task and the combinations of conditions under which they were obtained are presented in Table 2. An analysis of variance (see Table 3) performed on these data indicates that these scores were significantly influenced by the variation in setting conditions. The signal for general change in needle position (Condition II) did not significantly improve accuracy of monitoring. The signal for actual needle entry into a critical zone (Condition III), however, did bring about significant score increases, and the signal for needle entry into a critical zone for a particular pair of dials (Condition IV) brought about a further significant increase. Variation in sense channel of cuing (audition vs. vision) did not significantly influence detection scores independently, nor did it interact significantly with setting conditions.

Percents of correct response in the secondary task are presented in Table 4. An analysis of variance (see Table 5) performed on these data indicates that quality of performance was not significantly influenced by either of the experimental variables.

DISCUSSION

The four previously raised questions may now be answered on the basis of the results of the foregoing analysis.

(1) The accuracy of monitoring of multiple dials, performed simultaneously with a competing visual-motor task, can be increased through setting. This was clearly indicated by the fact that the variations in cuing conditions significantly influenced percents of correct responses in the dial-checking task.

(2) In the present experiment secondary task performance was uninfluenced by the setting conditions. This suggests that the beneficial effects of the presently employed cuing conditions were limited to the dial-checking task, and did not aid the second task by reducing the difficulty of checking the dials. The fact that motor task performance did not change further indicates that improvement in the monitoring task performance was not achieved at the expense of the semi-tracking task. This is an important additional finding with regard to the operation of set. Since the multiple task situation is common in air operations, it would obviously be unwise to introduce setting cues designed to increase proficiency of one task component if level of performance of other essential task components suffered as a result. The present results thus afford evidence that the beneficial effects of setting extend to complex task situations.

TABLE 2

Dial-Checking Scores

(Per Cent Correct)

		Setting Condition				
		I No Setting	II Any Dial Change	III Four-Dial Critical	IV Two-Dial Critical	Total
Visual		10.3	9.3	65.5	81.7	
		9.4	32.9	25.0	78.0	
		35.7	33.1	40.8	82.6	
		52.1	48.3	56.3	76.6	
		23.2	24.8	74.1	92.0	
	T.	130.7	148.4	261.7	410.9	951.7
Auditory		26.6	48.2	43.5	79.1	
		10.0	24.6	67.4	80.3	
		13.1	37.0	37.6	81.8	
		13.7	1.5	64.3	85.3	
		22.3	48.9	57.2	79.0	
	T.	85.7	160.2	270.0	405.5	921.4
Total		216.4	308.6	531.7	816.4	1,873.1

TABLE 3

Analysis of Variance of Dial Scores

(Per Cent Correct)

Source of Variation	Sum of Squares	df	Mean Square	F	p
A. Setting Conditions	21,415.09	3	7,138.36	36.51	.001
I vs II ≠ III ≠ IV	8,458.80	1	8,458.80	43.26	.001
(I vs II)	425.04	1	425.04	2.17	.200
II vs III ≠ IV	8,903.58	1	8,903.58	45.54	.001
(II vs III)	2,488.68	1	2,488.68	12.73	.005
III vs IV	4,051.28	1	4,051.28	20.72	.001
B. Audio-Visual	22.95	1	22.95		
A x B	203.28	3	67.76		
Error	6,257.06	32	195.53		
Total	27,898.38	39			

(3) For the most part the facilitating effects of the cuing operations were not all-or-none, but were in proportion to the presumed degree of response limitation. This was certainly true for Conditions I, III and IV. Condition II which was designed to reduce temporal search uncertainty produced a performance improvement but not a significant one. It should be noted that it is not possible to state with certainty where these various setting conditions lie on an uncertainty-reducing scale. Only Conditions III and IV can be located with respect to one another, Condition III containing one "bit" more of uncertainty than Condition IV. It seems reasonable to assume that Condition II contains more uncertainty than Condition III, but less than Condition I. Why it did not result in a significant improvement over Condition I is not entirely clear. It is possible of course that Condition II did not actually bring about any increased response restriction. It obviously did not restrict spatial location uncertainty. It is also possible that Condition II did produce an increment in response restriction, but the insensitivety of the experiment did not allow such effect to manifest itself. Further research would be required to clarify this point.

TABLE 4

Distracting Task Scores

(Per Cent Correct)

		Setting Condition				
		I	II	III	IV	
		No Setting	Any Dial Change	Four-Dial Critical	Two-Dial Critical	Total
Visual		65.8	30.3	49.6	58.1	
		51.2	46.2	44.1	54.0	
		24.4	60.2	53.6	34.0	
		46.8	54.8	61.7	61.1	
		50.1	50.9	70.9	47.0	
	T.	238.3	242.4	279.9	254.2	1,014.8
Auditory		52.4	66.0	70.4	41.2	
		48.4	43.2	22.3	46.3	
		63.0	56.5	72.6	53.9	
		44.2	59.6	47.8	25.1	
		61.8	47.7	73.8	24.8	
	T.	269.8	273.0	286.9	191.3	1,021.0
Total		508.1	515.4	566.8	445.5	2,035.8

TABLE 5

Analysis of Variance of Distracting Scores

(Per Cent Correct)

Source of Variation	Sum of Squares	df	Mean Square	F	p
A. Setting Conditions	741.49	3	247.16	1.41	.20
B. Audio-Visual	.96	1	.96		
A x B	592.44	3	197.48	1.13	.20
Error	5,590.65	32	174.71		
Total	6,925.54	39			

(4) The sense modality by which the cues were presented did not influence the setting effects. This finding has important practical implications. It indicates that even though the visual sense channel is already "occupied" or encumbered with two separate flows of information (those controlling the semi-tracking and the dial-monitoring tasks), uncertainty may be further reduced by the introduction of additional visual stimuli. Moreover, these reductions of uncertainty are no less than those brought about by the use of a "free" sense channel, in this instance, audition. It is obvious that this equivalence of uncertainty reduction would not have occurred if the visual cuing stimuli had not been in the same visual field as the task-controlling stimuli, thereby eliminating the need for head and eye movements. This points to the importance of the spatial location or integration of various displays when they all fall within the visual domain. The present results point again to the generalization that either the visual or auditory sense channel may be employed for presentation of cuing information. They also serve as further evidence that there is no significant tie-up between sense channel employed for cuing and that used for presentation of the stimuli to be discriminated. Both of these conclusions were suggested by the findings of an earlier experiment on set (4).

The results of the present study may be considered as extending the generalization of the previous findings on perceptual set in two practical directions. The first of these is the application of setting to the type of perception involved in check-reading instrument dials. The second and more important is the demonstration that the employment of setting cues to facilitate one component of a complex task situation does not interfere with the performance of another component.

SUMMARY AND CONCLUSIONS

Previous investigations of perceptual set at the University of Virginia have been concerned with relatively complex perceptual responses (location and identification) in relatively static situations, i.e., where stimulus patterns were changing very slowly (only between trials). In order to broaden the generalization of earlier findings on set, it was sought to determine the influence of setting cues on the check-reading of dials, a relatively simple perceptual response to specific aspects of rapidly changing stimuli. It was decided further that the influence of setting should be studied in a competing task situation to ascertain whether or not the introduction of setting cues would be effective when the operator was distracted by performing a simultaneous task, and if so, whether such cuing as an aid to one task component in the overall situation would interfere with performance on other task components. Accordingly an experiment was decided to answer the following questions:

1. Can the accuracy of monitoring of multiple dials, performed simultaneously with a distracting task, be facilitated through cuing?

2. Will level of performance on the distracting task be influenced by the simultaneous cuing of the check-reading task?

3. Is either check-reading accuracy or secondary task performance changed systematically by progressive increases in the degree of response restriction imposed by the setting cues?

4. Will the sense channel by which the setting cues are presented influence the setting effects?

The experimental design called for the manipulation of two variables, (1) degree of "setting", i.e., degree of response restriction effected by the cuing information, and (2) sense channel of cuing. Subjects were required to check-read simultaneously four dials, indicating by pressing appropriate keys with fingers of the left hand whenever a needle on one of the dials entered a "critical" zone. Simultaneously the subjects were engaged in a semi-tracking task which required pressing with the fingers of the right hand four keys corresponding spatially to four lights. These lights flashed on individually and in random sequence at a rate of two per second. Four levels of cuing were used: I. no cuing; II. presenting a signal every time any dial needle moved, whether or not it entered a critical zone; III. giving a signal that a needle in one of the four dials had entered a critical zone; and IV. giving a signal that a needle in one of two dials had entered a critical zone. Sense channel of cuing was varied by employing light (white or red) and sound (buzzer or bell) signals. Performance of the secondary task was constant for all experimental conditions.

The results obtained by these operations provided the following answers to the four questions above.

1. Accuracy of monitoring of multiple dials, performed simultaneously with a semi-tracking task, was significantly increased by the use of setting cues.

2. Semi-tracking (distracting) task performance was uninfluenced by the various setting conditions. This indicates that improvement in monitoring task performance was not brought about at the expense of proficiency on the secondary task.

3. For the most part the beneficial effects of the cuing operations were not all-or-none, but were in proportion to the presumed degree of response limitation. This was clearly true for Conditions I, III, and IV. Condition II, designed to reduce temporal search uncertainty, produced a performance improvement but not a significant one.

4. The sense channel by which the cues were presented did not influence the setting effects. This finding was seen to have important practical implications, in that it indicates that even though the visual sense channel is already "occupied" with two separate flows of information (those entailed in the semi-tracking and the dial-monitoring tasks), accuracy of dial-checking could be further improved by the introduction of additional visual cues. Moreover, this improvement was no less than that brought about by the use of a "free" sense channel, i.e., audition. This last result was in part due to the fact that all visual signals (i.e., for directing both tasks and as cues) were presented in the same visual field. However, it is surprising that auditory cuing was not found to be superior under this condition of a "crowded" visual channel.

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