*STIMULUS-RESPONSE COMPATIBILITY AND STRESS EFFECTS IN A ONE-DIMENSIONAL COMPENSATORY TRACKING TASK

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The concept of S-R compatibility as applied to perceptual-motor systems refers to the phenomenon that the rate at which such a system can process information is a "function, not so much of the characteristics of a particular stimulus or of a particular set of responses, but rather of the degree to which the sets of stimuli and responses form a congruent match" (5). Under this concept can be subsumed the various studies of problems of control-display relations. Such aspects of the problem like axis of movement of the control and the line of movement of the display, directions of movements of the display and the control, etc., have been found to be important with respect to errors and time taken for performance of the task (1, 9, 10). In other words, control display relationship that is more "natural" or "realistic", such as, for example, both moving in the same direction, have been found to be advantageous (2). Further, working under stress has not only been found to impair perceptual-motor performance, but psychologists have also felt that under stress situations, operators are likely to revert to more "primitive" reaction patterns or to the "old or natural set", i.e. to a situation having a higher S-R compatibility (1, 3, 7, 8).

The object of the present experiment was to determine if stress effects interact with stimulus-response compatibility in a simple perceptual-motor task. The stimulus-response compatibility had reference to the directions of movements of the display indicator and control knob in a one-dimensional compensatory tracking task. More specifically, it was hypothesized that:—

(a) there will be impairment of performance under the opposite (i.e. incompatible) directions of movements of the display and the control, and

(b) stress will have more adverse effect on performance under the incompatible, than the compatible set-up.

Method

A one-dimensional continuous electronic compensatory apparatus was used for the study. The problem generator consisted of a cam, driven by a constant-speed motor. A potentiometer activated by a cam-follower translated the cam motion into voltage changes, which in turn deflected the S's tracking display indicator from the zero (upright) position. The wave form of the cam-generated tracking input combined the frequencies of two sinusoidal waves: a fundamental of 6 cpm frequency and the second harmonic of 12 cpm. The

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equation for this input was:

$$\theta = 12 \sin wt + 7.5 \cos 2\, wt$$

where θ is needle deflection in degrees, w is 0.6288 radians/sec. (6 cpm fundamental), and t is time in seconds.

The tracking display was a zero-center voltmeter with a range of ± 5v. The display was mounted on a rectangular face and had a maximum needle deflection of 90 deg. of arc on the upper portion of the display and a scale length of 3-29/32 in. *Ss* operated a control knob of 1-in. diameter for positional control of the needle excursion. The axis of movement of the control knob was perpendicular to the plane of the display pointer movement.

Two control-display relationships were employed in this study. For treatment I, i.e. the compatible S-R condition, the display needle would move clockwise when the knob was turned clockwise and conversely. For the incompatible S-R condition, treatment II, when the knob was turned clockwise, the display would move counterclockwise and conversely.

A secondary task was used in certain trials for experimentally inducing stress. A board, 3 in. high from the table top, was constructed which had a row of five toggle switches, 2 in. apart and serially numbered 1 to 5. During the 1 min. trial period, *S* would be pressing the switches at the rate of one in every 5 sec. A random sequence of numbers 1 through 5 were recorded on a phonograph and played back to *Ss* over a pair of earphones at the rate of one every 5 secs. *Ss* were required to operate the appropriate one of the switches whenever they heard one of these numbers. The switches were connected with a set of five lights at *E's* station so that E could record the errors. The errors in this have been so infrequent that the data have been ignored.

The tracking apparatus was placed on the table at an eye distance of about 12 inches. The board containing the switches was placed on *S's* left, adjacent to the tracking apparatus. *S* operated it by his left hand while performing the tracking task with the right. The *S* was told before each trial started if he was to do one or two tasks. The instructions for the secondary task were to press the appropriate switch as soon as the number was heard. A ready signal 2 sec. before the trial started was given.

Thirty undergraduate psychology students at the Ohio State University volunteered as subjects for the experiment. All were right handed. Half of the group served under each of the two conditions. The primary and secondary tasks were combined under the two experimental conditions as below:—

	Trials 1-3, 7-9, 13-15, 19-21	Trials 4-6, 10-12, 16-18	N
Treatment I (compatible)	Tracking	Tracking and Switch Pressing	15
Treatment II (incompatible)	Tracking	Tracking and Switch Pressing.	15

Each trial lasted for 1 min. Between trials, *Ss* were given 1 min. rest, and between Trials 12 and 13, 2 min. rest was introduced. The performance score for each trial was the absolute integrated error which represented the deviation of the display indicator from the null point as a resultant of the problem input and *S's* control manipulations. The problem voltage and *S's* response signal were fed into a set of three computer amplifers, the third one giving the integrated absolute error score. The error score was in terms of voltage, one volt representing 9 deg. of needle deflection, and was read out by the experimenter from a voltmeter.

Results

The basic data consisted of 630 error scores (30 subjects for 21 trials each). The mean error scores for each trial for the two experimental groups are summarized below in Fig. 1. Figure 2 represents the difference in performance for the two groups expressed as a percentage of score for the compatible group.

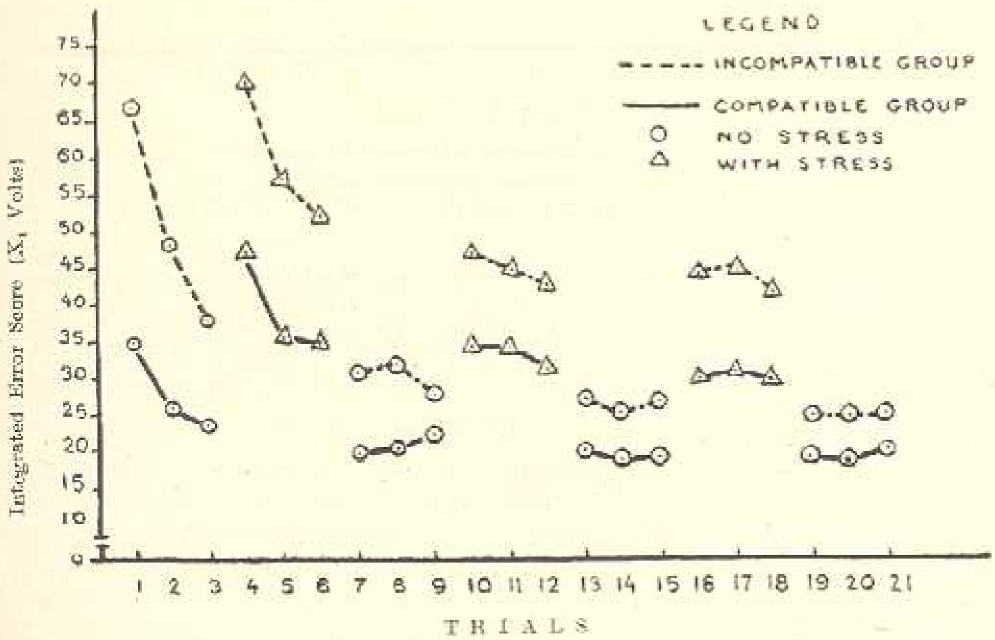

Figure 1 Mean Performance of Two Groups ($n_1 = n_2 = 15$)

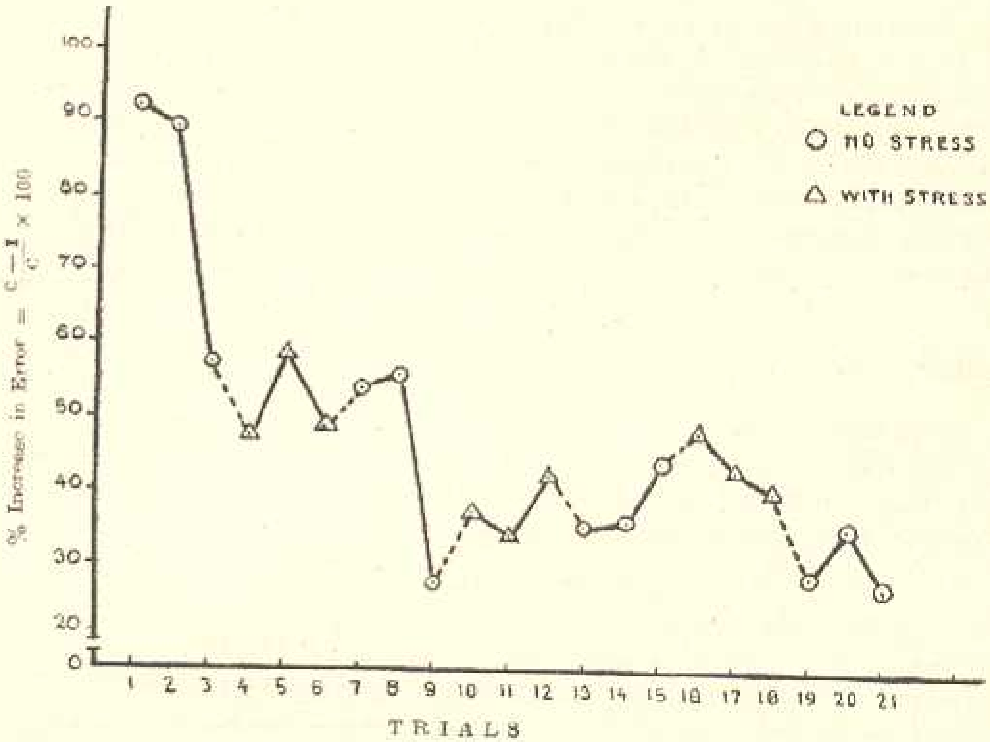

Figure 2, Difference in Performance Between Compatible (c) and Incompatible (I) Conditions, Expressed as % of Performance in Compatible Condition

In order to determine whether the direction of movement between control and display was affecting performance, and also whether effect of the experimentally induced stress varied with this relationship. the data were analysed by means of an analysis of variance. The analysis of variance design, together with the mean error scores in each cell, is given in Table 1.

Table 1

Mean Error Score per Trial (in ¼volts) Under Two Conditions of Compatibility. Two Conditions of Stress and Three levels of Practice.

Control Display Relation Trials.	Practice I No Stress 1–3	Practice I Stress 4–6	Practice II No Stress	Practice II Stress	Practice III. No Stress 13–15	Practice III. Stress 16–18
Compatible	27.8	39.4	20.7	32.7	18.9	30.4
Incompatible	50.6	59.4	29.8	44.5	25.8	43.1

The results of the analysis is given in Table 2. It will be noted that F values for effects of control-display relation, stress condition and practice effects are all significant at the $p < .01$ level. The only interaction effect that is significant is between practice and control-display relation.

TABLE 2.

Analysis of Variance of Error Scores under Two Conditions of Control-Display Movement Relations, Two Conditions of Stress, and Three Conditions of Practice.

Source of Variance	df	Mean Square	F	Sig.
1. S-R Compatibility (C)	1	78166.66	30.79	0.01
2. Subjects (SU)	28	2538.50	—	—
3. Stress (St)	1	65018.01	81.01	0.01
4. (St. x C.)	1	349.88	0.44	NS
5. (St x Su)	28	802.60	—	—
6. Practice Periods (P)	2	33797.52	49.14	0.01
7. (P x C)	2	5769.52	8.39	0.01
8. (P x Su)	56	687.79	—	—
9. (P x St)	2	671.51	0.64	NS
10. (P x St x C)	2	642.41	0.62	NS
11. (P x St x Su)	56	1041.33	—	—

Note: 2 was error term for 1, 5 for 3 and 4, 8 for 6 and 7, and 11 for 9 & 10.

Discussion

The result of the analysis of variance indicates that performance under the reversed direction of motion relation was significantly worse than under the direct relation, as predicted. It also appears that practice effect is smaller under the compatible than under the incompatible condition. This is supported by the significant interaction between practice periods and the two compatibility conditions. It is not possible to predict from the present study if difference in error measures between the two S-R conditions will hold up after prolonged training although Fig. 2 does indicate a decrease in performance difference under the two conditions. However, reference can be made to a study reported by Fitts and Seeger (6), wherein a 32 day practice period under three different S-R compatibility conditions was not enough to remove differences in measures like reaction time, movement time, and frequency of errors.

The addition of the secondary (stressing) task had a significant effect on performance under both S-R conditions. Tracking was poorer. In terms of absolute error units, deterioration was greater in the incompatible groups than in the compatible group. But relative deterioration of the two groups is about the same. This is seen in Fig. 2 where after trial 9 differences between compatible and incompatible groups expressed as a percentage of the compatible group score do not show systematic variation for trials with and without the secondary task.

It is felt that the effect of induced stress on more complex tasks performed unde compatible and incompatible S-R conditions should be examined. If interaction is not seen as is the case here at least the reasons for its absence may be better understood.

Summary

Performance in a one-dimentional compensatory tracking task under two condi tions of control and display relation of movements was studied under normal and experi mentally induced stress conditions. It was found that performance in terms of error value was consistently superior when the movement of the control knob displaced the display indicator in the same direction than when the two moved in opposite directions. Addition of the secondary task led to a significant deterioration in performance under both S-R condit ions. However, there was no significant differential effect of the stressing task on the compatible and incompatible groups.

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