COMPLEX REVERSAL-NONREVERSAL SHIFTS AND CONCEPT-LEARNING THEORY

by

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B.A., University of British Columbia, 1966

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Psychology

Accepted for the Faculty
of Graduate Studies,
[redacted]
12 November, 1970.

We accept this thesis as conforming
to the required standard

[redacted]

University of Victoria

October 1970

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Abstract

A complex stimulus situation was employed in a variation of the reversal-nonreversal paradigm. Adult human subjects were given simple and complex forms of reversal and nonreversal shifts to perform on a four-dimensional, two relevant dimension problem. It was found that a simple reversal was more readily performed than a complex reversal, and that a complex nonreversal was more readily performed than a simple nonreversal. A replication, incorporating an evaluation of experimenter bias, verified the initial findings. Explanation of the results in terms of the Kendler & Kendler (1962) two-stage mediation theory and the Zeaman & House (1963) attention theory was shown to be impossible without modification to the theories.

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1. Introduction

The influence of Spence (1936) can be seen in most approaches to problem-solving, but the contemporary study of the role of the concept and its utilization is more directly evolved from Lawrence's (1949, 1950) studies, which demonstrated that transfer between problems on the basis of stimulus dimensions which are relevant to both acquisition and test concepts could be learned regardless of the overt choice responses conditioned to the acquisition stimulus. The transfer of dimensional dominance is the basis of the single-stage component and pattern theories described by Bower (1961) and Estes (1959).

Although component and pattern theories adequately explained most simple problem-solving, they were not capable of accounting for the more complex reversal-nonreversal shift paradigm[1]. Several studies clearly indicated the need for a reconsideration of the single-process theories by pointing out that animal (Kelleher, 1956) and young human (Kendler, Kendler & Wells, 1960) subjects perform better on nonreversal shifts, and that adult human subjects perform better on reversal shifts (Buss, 1956; Harrow & Friedman, 1958; Kendler & D'Amato, 1955). As these results could not be explained in terms of extant single-process theories, since such theories predict that prior $\underline{X} - \underline{Y}$ learning will

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[1] The reversal-nonreversal paradigm involves the learning of a concept according to a set of rules involving combinations of dimensions and values along the dimensions. When the concept has been learned to some specified criterion, the experimenter changes the concept and studies the subject's ability to shift to the new concept. Reversal shifts are confined to changes within the positive dimension while nonreversal shifts involve changes of positive dimension (Wolff, 1967).

impede Y - X learning, attention turned to dual-process theories.

Largely as a result of the requirement for an explanation of the reversal-nonreversal paradigm results, two types of dual-process theories emerged. These can be summarized as mediation theories (Kendler & Kendler, 1962) and attention[2] theories (Trabasso & Bower, 1968; Zeaman & House, 1963). Within the latter classification there are several mathematical models (Estes & Hopkins, 1961), but these models differ primarily in their approaches to the analysis of the stimulus situation and not on basic theoretical tenet.

The two-stage mediation theory (Kendler & Kendler, 1962) revealed the influence of chaining processes (Kendler, 1961). Kendler & Kendler (1962), in their consideration of "horizontal" and "vertical" processes, relied on chaining to explain the apparently different processes utilized by young human (and infrahuman) subjects and adult human subjects. Specifically, they employed the construct of the "response-produced cue as a mediator" (Harper, 1964, p. 583) between the stimulus situation and the overt response. The horizontal processes, then, are constructs designed to account for the continuity of behaviour during problem-solving; the vertical processes to account for the apparently contiguous consideration of several levels of S - R units. These descriptions have been criticized by Mackintosh (1965, p. 144) for their vagueness, and interpreted by Wolff (1967) as, respectively, verbal labels for dimensions and verbal labels for within-dimension cues.

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[2] Attention is here considered simply as an orienting response by the organism to certain aspects of the stimulus situation.

Where the mediation theory reflected the influence of chaining processes, modern attention theories began with Lawrence (1949, 1950), whose ideas were incorporated into one-stage[3] attention theories (Bower, 1959; Estes, 1959). When it became evident that the single-process approach was inadequate, an amalgamation of pattern and component theories led to the formulation of the current dual-process attention theories (Trabasso & Bower, 1968; Zeaman & House, 1963). Such theories state that problem-solving is achieved by two distinct processes. The first of these consists of directing attention to the relevant stimulus dimension and adapting out attention to those dimensions which are irrelevant. The second process consists of conditioning an overt choice response to some value along the relevant dimension. Attention theory thus holds that it is this combination of response tendencies that comprises problem-solving activity.

Although Mackintosh (1965), in a review of selective attention in discrimination learning, refused to admit the validity of Kendler & Kendler's mediational approach on the grounds that the intervening "response-produced cue" is left formally undefined, it would appear that to some writers (Wolff, 1967), the two approaches are useful despite their differences. Although the foci are different (verbalization vs. attention), it would appear that, in many respects, they are compatible. The vertical processes of the mediation theory correspond to the overt choice responses of the attention theory, and the horizontal processes parallel the attention to dimension aspect of the attention theory.

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3. One-stage theories hold that discrimination learning is a single, continuous process.

It should be evident that the notion of competing response tendencies can be discovered in both attention and mediation theories. A central aim of problem-solving research, then, is to determine the method of operation of the competing response tendencies. Upon presentation of a stimulus situation, the subject sets about sampling from the population of available attributes. The attributes under consideration can be classified as dimensions (ie: size, shape) and values along the dimensions (ie: large, medium, small; round, octagonal, square) - dimensions elicit a general, covert response to a class of cues and values elicit overt choice responses to particular cues from a class. The strength attained by these responses is generally accepted to be a function of reinforcement (Estes, 1959, p. 49), and both Trabasso & Bower (1968) and Zeaman & House (1963) employ reinforcement in their mathematical models for the analysis of the strength of analysers.

If mediation and attention theories are similar in that they both postulate two types of response, they disagree on the question of the relative importance of the types of response. Although the Kendler & Kendler (1962) theory is described as "pretheoretical", it is suggested that the two types of response might be equally weighted, and that a measure of the difficulty of any shift might be the sum of the number of new associations that must be formed (p. 591). Goss (1961, p. 258) gives a theoretical justification of this assumption of equal response weights. In contrast to this point of view, Mackintosh (1965) suggests that there is no evidence that attention and choice responses obey the same laws. This approach is followed by Zeaman & House (1963). It appears that the independent manipulation of parameters would make the explanation of shift effects less difficult. It should, however, be noted that Kendler & Kendler (1962, p. 591) explain that they merely offer the notion of equal weights until experimental clarification is available. It is interesting that, on the basis of the assumption of equal weights, the finding that a reversal shift is more readily performed by adult human subjects (Kendler & D'Amato, 1955) is not explicable. If both dimensional and overt choice responses are learned and equally weighted, it is difficult to explain why the dimensional response is not extinguished at the same rate as the choice response, since neither is reinforced until the subject has extinguished his choice response. This observation would indicate that unequal weights are required, as advocated by the attention theorists.

It is concluded that both attention and mediation theories are useful in their approaches to problem-solving, and that, with the addition of the assumption of differential weights to the mediation theory, both can explain simple problem-solving of the type encountered in the reversal-nonreversal paradigm.

Unfortunately, most concept learning is not of the two-dimensional, two value per dimension type often encountered in the literature. Concept learning typically involves many dimensions and many values per dimension. To generalize from the results of two-dimensional studies to complex human concept learning would at best be precarious, and could well lead to the same type of oversimplification as that which resulted from the single-process theories and the simplistic studies they inspired. Tighe & Tighe (1968) explored the complex stimulus situation by employing three and four values per dimension, but there has been little research into the use of multiple dimensions.

The purpose of the present study was to examine a more complex stimulus situation from within the framework of the two-stage mediation and attention theories in the hope that a more useful paradigm than the simple reversal-nonreversal shift would emerge. It was anticipated that a more complex reversal-nonreversal paradigm might prove useful in evaluating existing theories of problem-solving, and that its use might facilitate generalization to complex human problem-solving.

The shift examined in the present study was a modification of the common reversal-nonreversal paradigm (Wolff, 1967) comprising two dimensions with two values per dimension. For the training sequence, one dimension and one of its two values are relevant (positive). A reversal shift requires that the same dimension remain relevant and that the choice response be shifted to the other value on the relevant dimension (ie: if colour is relevant, black positive and shape irrelevant, the shift would be from black to white). A nonreversal shift requires that the relevant dimension be changed and that one value from the new relevant dimension be chosen (ie: shape becomes relevant, square or round positive, and colour irrelevant). Thus, the reversal shift involves a change in overt choice response only, while the nonreversal shift involves changes in both dimensions and overt choice response.

The present study specified two degrees of shift difficulty as well as types (reversal/nonreversal) of shift. The stimulus situation consisted of four dimensions and two values per dimension. Two dimensions and one value from each were relevant to all solutions.

The acquisition series consisted of determining the two relevant dimensions and learning responses to the two positive values from these dimensions.

Two reversal shifts were defined. A simple reversal (SR) was a shift in which only one choice response from one relevant dimension was changed; a complex reversal (CR) was a shift in which both overt choice responses were changed. In accordance with the common definition of reversal, the relevant dimensions were not changed in either the simple or complex reversal, and the positive values for both acquisition and test sets were from the same two dimensions. Similarly, two nonreversal shifts were defined. A simple nonreversal (SN) was a shift in which one relevant dimension from the acquisition set was replaced as relevant by a previously irrelevant dimension and the second relevant dimension and its dimensional value (overt choice response) remained relevant. In the complex nonreversal (CN), both previously relevant dimensions became irrelevant. In nonreversal shifts, new overt choice responses accompanied new dimensional responses.

Table I lists all possible simple and complex reversal and nonreversal shifts which could follow Blue Square or One Small as the acquisition concept. Table II enumerates the new responses required for each shift, and the Total column gives a statement of the relative difficulty of the shifts as predicted from the Kendler & Kendler (1962) theory with the assumption of equal weights. In terms of errors to criterion, this theory predicts $SR < CR = SN < CN$, and thus that reversal shifts will be easier than nonreversal shifts (Buss, 1956). The Zeaman & House (1963) theory yields $CR < SR$ and $CN < SN$, but makes no specific prediction of the relative difficulty of reversal and nonreversal shifts.

Table I

Examples of Simple and Complex Reversal and Nonreversal Shifts From the Acquisition Concepts Blue Square and One Small

ACQUISITION	SR	CR	SN	CN
blue square	blue circle red square	red circle	one blue two blue large blue small blue one square two square large square small square	one large two large one small two small
one small	one large two small	two large	small red small blue small square small circle one red one blue one square one circle	red square red circle blue square blue circle

Table II

New Responses Required for Shifts

Shift	New Responses		
	Dimension	Choice	Total
SR	0	1	1
CR	0	2	2
SN	1	1	2
CN	2	2	4

2. Experiment 1

Method

Subjects. Forty male officers and non-commissioned officers of the Canadian Armed Forces served as volunteer subjects. Their ages ranged from 21 to 45 years, with an average of approximately 30 years.

Stimulus Materials. The stimuli for both acquisition and test phases consisted of six identical sets of sixteen 12.70 cm by 7.60 cm white index cards. Geometric figures, differing on four dimensions and two values per dimension, were drawn on the cards with red or blue ink. The dimensions were colour (red/blue), shape (square/circle), size (large/small), and number of figures (one/two). Each stimulus card displayed one value from each dimension for a total of four values per card. Large squares measured 3.50 cm, small squares 2.00 cm, large circles 3.55 cm in diameter, and small circles 2.00 cm in diameter. Figures on two-figure cards were centered on the superior bisector with 1.50 cm the minimum distance between figures. As each stimulus card displayed representative values from each dimension, there were 16 possible combinations (see Fig. 1).

Procedure. Subjects were tested individually in one of the four conditions as determined from a table of random numbers. Prior to the test session, each set of stimulus cards was shuffled, and the sets were arbitrarily ordered. Cards from different sets were never interchanged, to minimize the possibility of a subject reaching criterion by a false hypothesis coupled with a fortuitous sequence of cards. As there were 16 different cards, 13 consecutive correct responses was used as the criterion of having acquired the test concept.

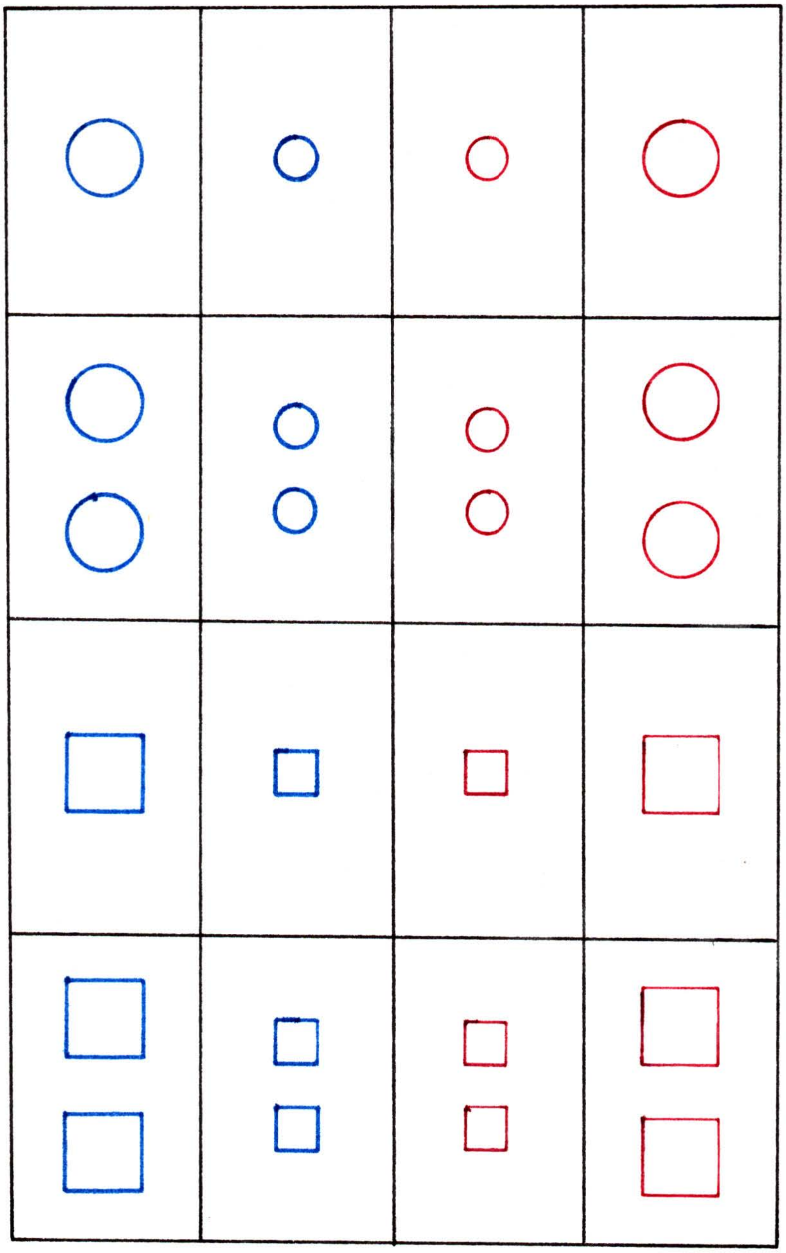

Figure 1. Stimulus cards.

Each subject was instructed that he was to solve the problem in the minimum number of stimulus exposures, and that the solution consisted of identifying a combination of two cues. He was shown representatives of all dimensions and values, and the acquisition phase was not begun until it was ascertained that the instructions were understood. Because of the complexity of the problem, it was often necessary to repeat parts of the standard explanation to ensure comprehension.

The subject was seated across a desk from the experimenter, who exposed the stimulus cards singly and sequentially by placing them in a notched holder lying on the desk. Each stimulus card was identified by the subject as an exemplar ("yes") or a nonexemplar ("no") of the concept, and the experimenter replied to each response with "correct" or "incorrect". Each stimulus was exposed for approximately 10 seconds.

The experiment consisted of two parts: the acquisition phase and the test phase. The criterion for both was 13 consecutive correct responses. On the fourteenth presentation after the first correct response of the criterion series, the experimenter changed the concept. There was no break in continuity of presentation when shifts were made, and the subject was not informed.

Four shifts were employed: simple reversal, complex reversal, simple nonreversal, and complex nonreversal. The choice of relevant dimensions and dimensional values for all conditions (acquisition and test) was determined from a table of random numbers for the problem under consideration. The measures of the concept shift were errors to criterion and trials to criterion. An error was scored when an exemplar was identified as a nonexemplar, or when a nonexemplar was identified as an exemplar, and both types of error received the same weight.

Results

The results are depicted in Figure 2. It was found that, in terms of trials to criterion, the complex reversal was more difficult than both simple reversal and complex nonreversal, and that the simple nonreversal was more difficult than both complex nonreversal and simple reversal. There was no significant difference between the simple reversal and the complex nonreversal, nor between the simple nonreversal and the complex reversal. Separate analyses were made using errors to criterion and trials to criterion, and the results for both techniques were concordant.

The $\underline{F}_{max}$ statistic for homogeneity of variance was calculated (Kirk, 1968, p. 62), and with $\underline{F}_{max}$ (errors) = 5.78 and $\underline{F}_{max}$ (trials) = 3.57 ($\underline{df} = 9$, $\underline{k} = 4$), it was concluded that the variances were homogeneous ($\underline{p} > .05$). A two (reversal/nonreversal) by two (simple/complex) factorial analysis of variance was then computed for both measures (Table III). For the error measure, there was no significant difference between reversal and nonreversal shifts, nor between simple and complex shifts. There was, however, a significant interaction effect with $\underline{F}_{\text{shift x difficulty}} = 9.29$ ($\underline{df} = 1/36$, $\underline{p} < .005$). Similar results were obtained using trials to criterion as the measure of the subject's ability to shift (see Table III).

Simple effects were computed and all but Difficulty at Nonreversal were found to be significant at the .05 level or beyond (Table III). In addition, differences between specific groups were evaluated by two-tailed _t_ tests for the difference of comparisons (_df_ = 36). Significant differences at the five percent level were obtained between simple reversal and complex reversal, simple reversal and simple nonreversal, complex reversal and complex nonreversal, and simple nonreversal and complex nonreversal. The results were consistent for both measures (Table IV).

Despite the random assignment of subjects to acquisition conditions, it was found that there were acquisition differences for treatment groups in both Experiment 1 and Experiment 2. To exercise a posteriori control of these differences (Tables IX, X), the analyses of variance were adjusted for a single covariate (acquisition errors for the errors to criterion analysis; acquisition trials for the trials to criterion analysis). The analyses of covariance, summarized in Table V, were highly concordant with the analyses of variance.

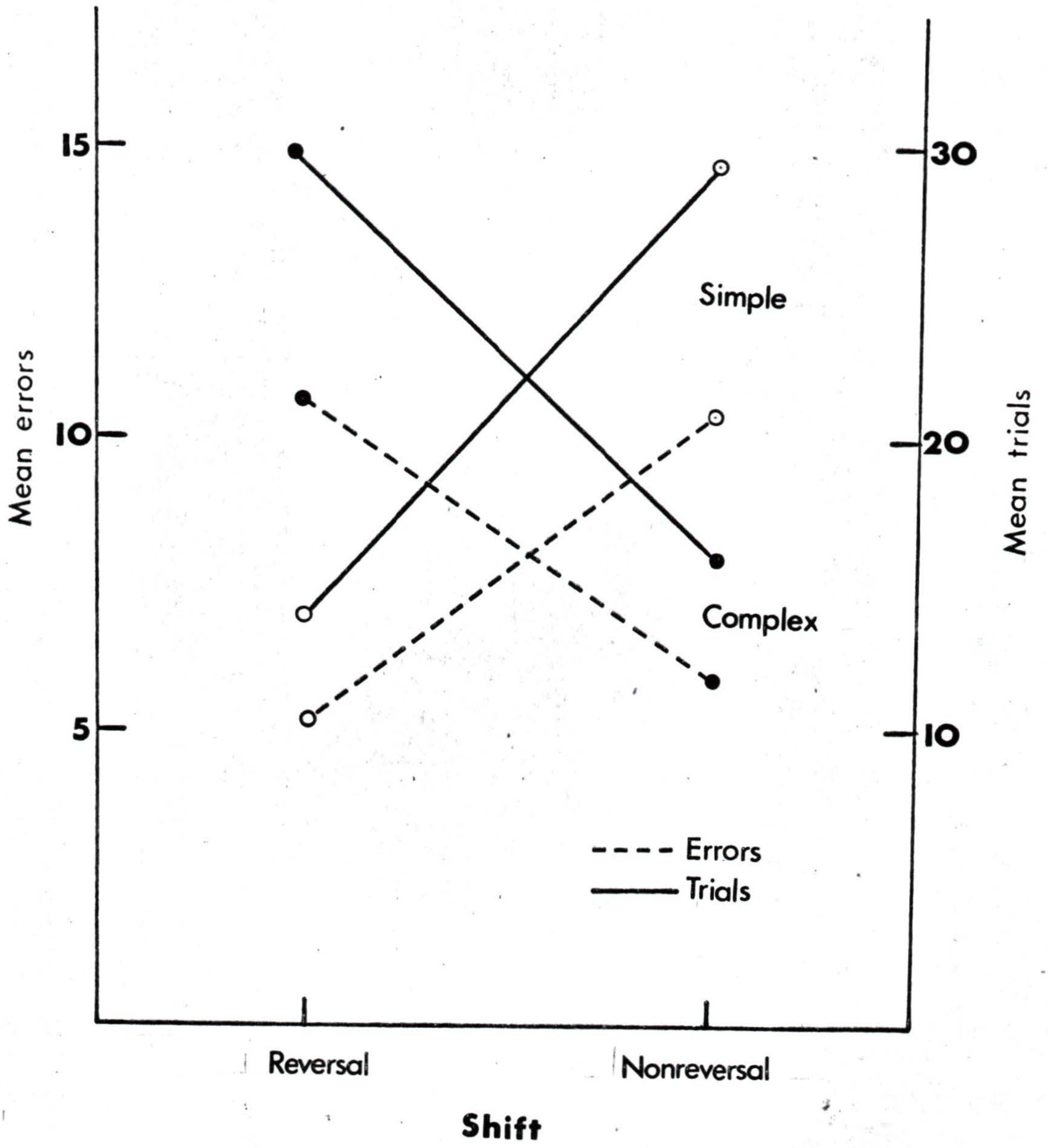

Figure 2. Experiment 1 - Shift by Difficulty Interaction (Errors and Trials)

Table III

Experiment 1 - Analysis of Variance

Summary (Errors and Trials)

Source	*df*	*MS*	*F*	*p<*
Total	39	28.328	-	-
	39	*238.400*	-	-
Shift (S)	1	.625	.03	ns
	1	*16.900*	*.08*	*ns*
S at Simple	1	125.000	5.14	.05
	1	*1232.450*	*6.18*	*.025*
S at Complex	1	101.250	4.17	.05
	1	*858.050*	*4.35*	*.05*
Difficulty (D)	1	4.225	.17	ns
	1	*22.500*	*.11*	*ns*
D at Reversal	1	145.800	6.00	.025
	1	*1264.050*	*6.33*	*.025*
D at Nonreversal	1	84.050	3.46	.10
	1	*832.050*	*4.17*	*.05*
S x D	1	225.625	9.29	.005
	1	*2073.600*	*10.33*	*.005*
Error	36	24.289	-	-
	36	*199.572*	-	-

Note.- Italics denote trials to criterion.

Table IV

Experiment 1 -

t Tests for Differences of Comparisons

(Errors and Trials)

Shift	*t*	*p*<
CR - SR	2.41	.05
	2.52	*.05*
SN - SR	2.27	.05
	2.49	*.05*
CR - CN	2.04	.05
	2.08	*.05*
SN - CN	1.86	.10
	2.05	*.05*
CN - SR	.41	ns
	.44	*ns*
CR - SN	.18	ns
	.03	*ns*

Note.- Italics denote trials to criterion.

Table V

Experiment 1 - Analysis of Covariance

Summary (Errors and Trials)

Source	*df*	*MS*	*F*	*p*
Total	38	28.594	-	-
	38	*241.824*	-	-
Shift (S)	1	4.621	.19	ns
	1	*16.723*	*.08*	*ns*
Difficulty (D)	1	.973	.04	ns
	1	*5.613*	*.03*	*ns*
S x D	1	207.188	8.30	<.01
	1	*1999.875*	*9.77*	*<.005*
Error	35	24.967	-	-
	35	*204.775*	-	-

Note.- Italics denote trials to criterion.

3. Experiment 2

As the procedure employed in Experiment 1 involved considerable interaction between the experimenter and subjects, it was felt that a control for experimenter bias should be incorporated into the replication to be described in Experiment 2.

Method

Subjects. Forty-eight male officers and non-commissioned officers of the Canadian Armed Forces served as volunteer subjects. Their ages ranged from 21 to 47 years, with an average of 38 years.

Procedure. The procedure was similar to that of Experiment 1, with the addition of an experimenter factor to the design. To examine the possibility of experimenter bias, three experimenters, two of whom were unaware of the purpose of the study, were employed. Each experimenter tested four subjects from each of the four conditions. Subjects were assigned to experimenters from a table of random numbers. All stimulus materials were identical to those of Experiment 1.

Results

The results were highly similar to those of Experiment 1 (Fig.3). In addition, there was no evidence of experimenter bias.

A two (shift) by two (complexity) by three (experimenter) factorial analysis of variance was calculated for both errors and trials to criterion. As for Experiment 1, the only significant effect (exclusive of simple effects) was the shift by difficulty interaction, with $F_{errors} = 8.58$ and $F_{trials} = 7.61$ ($df = 1/36$, $p < .01$). Simple effects (Table VI) also confirmed the results of Experiment 1, as did the analyses of covariance (Table VIII).

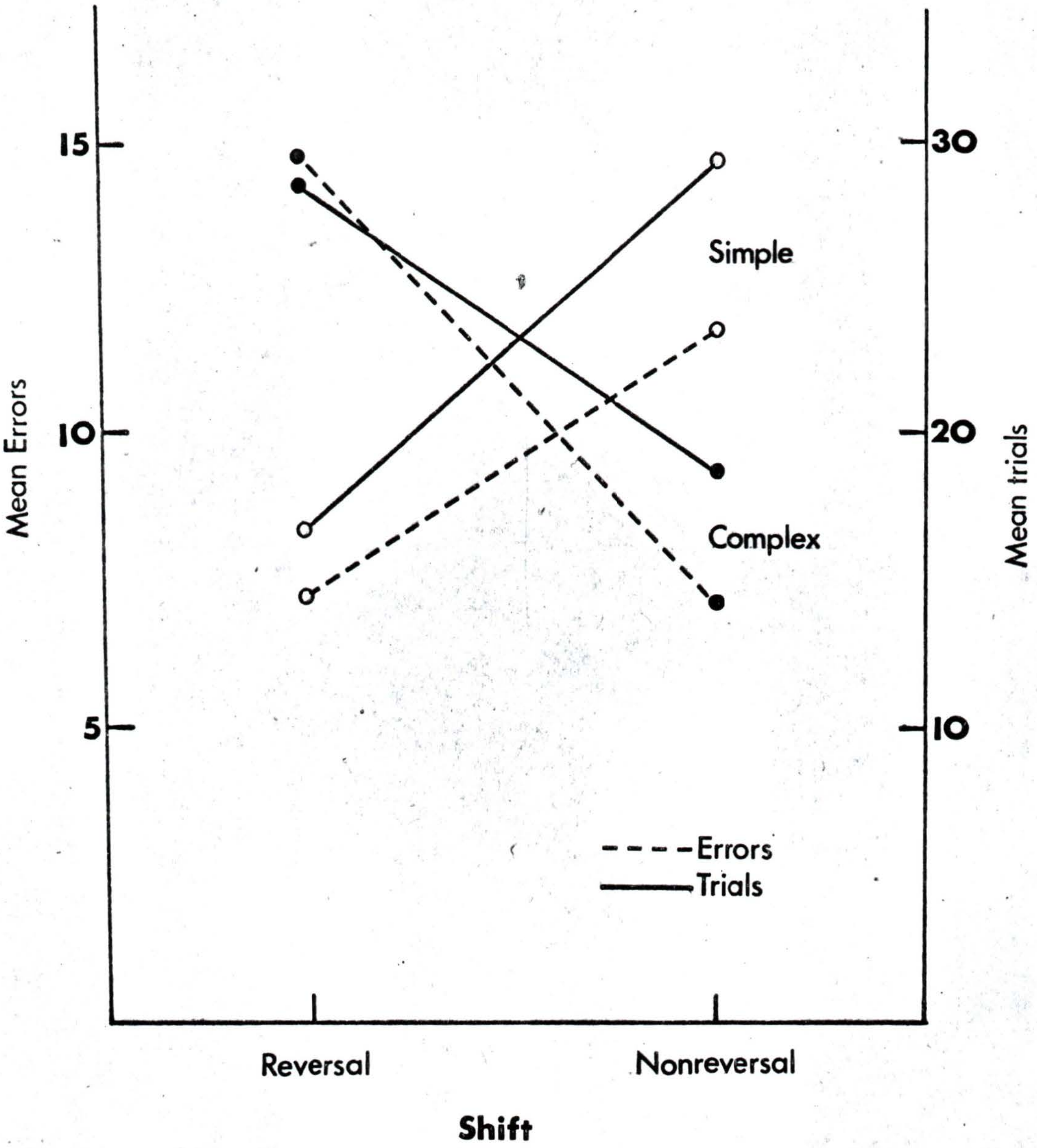

Figure 3. Experiment 2 - Shift by Difficulty Interaction (Errors and Trials)

Table VI

Experiment 2 - Analysis of Variance

Summary (Errors and Trials)

Source	*df*	*MS*	*F*	*p*<
Total	47	51.638	-	-
	47	*191.213*	-	-
Experimenter (E)	2	19.313	.39	ns
	2	*43.938*	*.22*	*ns*
Shift (S)	1	21.333	.44	ns
	1	*30.083*	*.15*	*ns*
S at Simple	1	126.042	2.57	ns
	1	*975.375*	*4.96*	*.05*
S at Complex	1	315.375	6.44	.025
	1	*551.041*	*2.80*	*ns*
Difficulty (D)	1	18.750	.38	ns
	1	*4.083*	*.02*	*ns*
D at Reversal	1	308.167	6.29	.025
	1	*828.375*	*4.21*	*.05*
D at Nonreversal	1	130.667	2.67	ns
	1	*672.041*	*3.42*	*.10*
E x S	2	1.021	.02	ns
	2	*12.271*	*.06*	*ns*
E x D	2	15.438	.32	ns
	2	*59.771*	*.30*	*ns*
S x D	1	420.083	8.58	.01
	1	*1496.334*	*7.61*	*.01*
E x S x D	2	66.147	1.35	ns
	2	*72.021*	*.37*	*ns*
Error	36	48.972	-	-
		196.681	-	-

Note.- Italics denote trials to criterion.

Table VII

Experiment 2 -

t Tests for Differences of Comparisons

(Errors and Trials)

Shift	*t*	*p*<
CR - SR	2.52	.05
	2.06	*.05*
SN - SR	1.61	ns
	2.24	*.05*
CR - CN	2.54	.05
	1.27	*ns*
SN - CN	1.65	ns
	1.84	*.10*
SR - CN	.03	ns
	.38	*ns*
SR - SN	.91	ns
	.17	*ns*

Note.- The shift listed first was the more difficult. Italics denote trials to criterion. All tests are two-tailed (*df* = 36).

Table VIII

Experiment 2 - Analysis of Covariance

Summary (Errors and Trials)

Source	df	MS	F	p
Total	46 *46*	51.186 *194.667*	- -	- -
Experimenter (E)	2 *2*	12.285 *55.213*	.25 *.28*	ns *ns*
Shift (S)	1 *1*	20.872 *27.660*	.42 *.14*	ns *ns*
Difficulty (D)	1 *1*	14.336 *7.684*	.27 *.04*	ns *ns*
E x S	2 *2*	1.295 *12.785*	.03 *.06*	ns *ns*
E x D	2 *2*	16.732 *49.053*	.33 *.25*	ns *ns*
S x D	1 *1*	393.939 *1537.727*	7.86 *7.69*	<.01 *<.01*
E x S x D	2 *2*	55.798 *73.805*	1.11 *.37*	ns *ns*
Error	35 *35*	50.091 *199.997*	- -	- -

Note.- Italics denote trials to criterion.

4. Discussion

Kendler & Kendler (1962) Theory

The finding that a simple reversal was more readily performed than a complex reversal is concordant with the Kendler & Kendler (1962) pretheoretical model with the assumption of equal weights for dimensional and overt choice responses. While the simple reversal requires one choice shift and no dimensional shifts (Table II) for a weight of one, the complex reversal requires two choice shifts for a weight of two. The results support the prediction that difficulty of shift is a function of the number of new associations to be learned. The finding that a complex nonreversal was easier than a simple nonreversal is not readily explicable in these terms. A complex nonreversal requires two choice and two dimensional shifts for a weight of four, compared to the single choice and dimensional shifts (weight of two) for the simple nonreversal. The results are not compatible with the theory, which predicts that the simple nonreversal should be more readily performed than the complex nonreversal. A final consideration is that the theory predicts that the complex reversal and simple nonreversal should be equally difficult with two shifts each. The prediction is not disconfirmed by the results, which indicate that there was no significant difference between the two groups (Tables IV, VII).

The Kendler & Kendler (1962) theory clearly predicts that a reversal shift should be easier than a nonreversal shift. The prediction is not supported by the present results, which indicate that there was no significant difference between reversal and nonreversal shifts (Tables IV, VII).

It must then be concluded that the Kendler & Kendler (1962) pretheoretical model must be modified before it can account for the present results. Such modification would probably take the form of differential weighting of dimensional and overt choice responses to the stimulus situation. This conclusion was predicted by Mackintosh (1965, p. 144).

Zeaman & House (1963) Theory

An examination of the results in terms of the Zeaman & House (1963) attention theory can best be accomplished by considering the general aspects of the theory without entering the mathematical model for the strength of analysers. In this theory, O_1 is an observing response to a dimension (covert dimensional response), R_1 an instrumental response (overt choice response) to the rewarded within-dimension value, and R_1' an instrumental response to the unrewarded within-dimension value. PO_1 and PR_1 denote the probability of occurrence of O_1 and R_1, and numerical subscripts indicate the dimension. It is assumed that all O_1s and R_1s are learned at criterion.

In this theory, a constant of proportionality is employed to give differential weighting to R_1s and O_1s. This is similar to the modification proposed for the Kendler & Kendler (1962) theory. Basically, if a nonreinforced instance follows the shift, the PR_1s and PO_1s undergo decrements proportional to their magnitudes (Zeaman & House, 1963, p. 170). Also, if O_1 and O_2 were positive for the acquisition set, PO_3 and PO_4 would gain increments equal to those lost by O_1 and O_2, and any loss in PR_1 and PR_2 would be accompanied by corresponding increases in PR_1' and PR_2' (p. 170-171), as the probabilities are complementary.

The Zeaman & House (1963) theory would appear capable of explaining a variety of results, mainly because of the flexibility supplied by the constant of proportionality. By manipulating the relative importance of the dimensional and value responses, most experimental results should be explicable.

Reversal Shifts. For the reversal shifts employed in the present study, the positive O_is remained constant across the shift; only the R_is were altered. In the case of the complex reversal, if R_1' and R_2' replaced R_1 and R_2 as positive within-dimension responses, the first instance identified as positive from the training concept (for example: O_1, O_2, R_1 and R_2) was nonreinforced, leading to decrements in PO_1, PO_2, PR_1, and PR_2, and to corresponding increments in PO_3, PO_4, PR_1' and PR_2'. Since all responses involving O_3 or O_4 were unrewarded, PO_1 and PO_2 would remain relatively high. Similarly, all acquisition concept responses would give increased PR_1' and PR_2', the complex reversal shift to be learned.

For the simple reversal, if R_1 remained positive from acquisition to test phase and R_2' replaced R_2 as positive in the new concept, the first instance identified from the acquisition concept would be unrewarded, leading to decrements in PO_1, PO_2, PR_1 and PR_2, and to corresponding increments in PO_3, PO_4, PR_1' and PR_2'. As for the complex reversal shift, PO_1 and PO_2 would remain high, but unrewarded responses R_1 and R_2 would lead to decrements in PR_1 and PR_2, and to increments in PR_1' and PR_2'. As R_2' would be rewarded and R_1' would not, considerable false reinforcement would be introduced to the new-learning task. For example, responding to R_2' (the new positive within-dimension response) could lead to either reinforcement or non-reinforcement, depending on the R_1 with which R_2' was paired.

It would thus appear that the Zeaman & House (1963) theory would predict that the complex reversal is less difficult than the simple reversal, but this prediction is not substantiated by the results, which show that the simple reversal was clearly the easier shift.

Nonreversal Shifts. The superiority of the complex nonreversal over the simple nonreversal can be explained by the attention theory. For the complex nonreversal, the acquisition responses (for example: O_1, O_2, R_1 and R_2) must be replaced by O_3, O_4, R_3 and R_4. Since all positive responses based on the acquisition concept would lead to decrements in PO_1, PO_2, PR_1 and PR_2; the probabilities of the new observing responses would overcome the increase of the choice responses. It should be noted that dominance of the O_1s over the R_1s is a necessary assumption (Zeaman & House, 1963, p. 166).

The simple nonreversal involves the learning of one O_1 and one R_1, with one O_1 and one R_1 remaining constant across the shift. If O_1 and R_1 remain positive, and O_3 and R_3 must be learned, a response on the basis of the acquisition concept (O_1, O_2, R_1 and R_2) would give an increase in PO_3, PO_4, PR_1', PR_2', PR_3, PR_4, PR_3' and PR_4', when, in fact, O_4, R_4, R_3' and R_4' are irrelevant. This response would also give a decrement in the relevant O_1 and R_1. Since the simple nonreversal permits such shift-impeding false reinforcement, it would be predicted that a complex nonreversal would be less difficult than a simple nonreversal. This prediction is in accordance with the results of the present study.

Multiple-Look Model. This interpretation is based on the One-Look Model (House & Zeaman, 1963) of the Zeaman & House (1963) attention theory. It should be noted that the Multiple-Look Model (House & Zeaman, 1963) might appear to be more directly applicable to complex concept learning because it postulates three O_is for the two relevant dimension problem - one to each relevant dimension and a third to a composite dimension composed of both relevant dimensions.

If the acquisition concept consists of O_1, O_2, R_1 and R_2, the Multiple-Look Model supposes a third O_i, to the composite dimension (1+2), designated $O_{(1+2)}$. The first negative instance following the shift causes decrements in $PO_{(1+2)}$, PO_1, PO_2, PR_1 and PR_2. For the complex nonreversal, the O_i and R_i decrements favour learning. Thus, $PO_{(3+4)}$ will increase and only the correct responses R_3 and R_4 remain to be learned. In comparison, the simple nonreversal is followed by decrements in $PO_{(1+2)}$, PO_1, PO_2 and attendant PR_is. As $PO_{(1+2)}$ decreases, $PO_{(3+4)}$ increases. This is not in accordance with the concept to be learned, and the solution of the simple nonreversal shift is impeded. It can similarly be seen that a complex reversal would be less difficult than a simple reversal.

The difficulty of reconciling the Zeaman & House (1963) and Kendler & Kendler (1962) predictions with the results of the present study arises because the theories cannot account for the finding that the simple form of one shift (reversal) and the complex form of the other shift (nonreversal) are easier. It would appear that, to explain the inconsonant results of this study, two distinct theories would be required.

Although the focus has been on the complexity of shift aspect of the problem, an examination of the adequacy of the theories to account for the finding that there was no significant difference between reversal and nonreversal shifts is useful. On the basis of the assumption of equal weights, the Kendler & Kendler (1962) theory predicts that the reversal shift will be easier than the nonreversal because, for the present study, three new associations were required for the reversal compared to six for the nonreversal (Table II). The addition of differential weighting for dimensional and overt choice responses would give a prediction consistent with the results only if no weight were assigned to the dimensional responses. This is not in accordance with a two-process approach.

The Zeaman & House (1963) theory does not predict the difficulty of reversal and nonreversal shifts, as the relative difficulty hinges on the change in probability associated with the O_1s and R_1s. It would, however, appear unlikely that the experimental results would be predicted because of the necessity of assigning a very small weight to the O_1s of the nonreversal shift.

It must be concluded that the results of the present study are not consistent with the predictions of the Kendler & Kendler (1962) and Zeaman & House (1963) theories, as to ease of shift or relative difficulty of simple and complex shifts. The problem arises not from the difficulty of predicting that a simple shift would be easier than a complex shift, but from the finding that for reversal shifts the simple form was easier than the complex, and that for nonreversal shifts the complex form was easier. As indicated by Mackintosh (1965, p. 144), the independent manipulation of response weightings can be used to account for the superiority of either complex or simple shifts; however, the present results indicate that manipulation is not sufficient to account for complex concept learning shifts.

It appears that the ineffectiveness of the Kendler & Kendler (1962) mediation theory lies in its lack of specificity. The assumption of equal weights has been shown to be inadequate, and there is no postulation to direct attempts to differentially weight the responses. In this respect, the title "pretheoretical" seems appropriate, but the model is of little use in the consideration of more complex concept learning than that encountered in the common reversal-nonreversal paradigm.

The Zeaman & House (1963) attention theory seems more suited to explaining the results of the complex shift paradigms, particularly if the Multiple-Look Model is used. This model, because of its attention to composite dimension component, would seem suited to an explanation of the complex concept learning considered in this study. Closer examination, however, reveals that it cannot account for the results obtained.

The obvious conclusion is that the lack of provision for the independent consideration of the two relevant dimensions encountered is the source of the problem. This is a natural consequence of the evolation of the theories, which resulted largely from work with simple paradigms. Before a theory can successfully account for complex paradigms, it must be made more flexible by permitting the independent consideration of relevant dimensions and overt choice responses. It does not seem unreasonable to hypothesise that a subject who has learned with some degree of certainty that O_1 and O_2 make up the concept will revert to some previous level of learning where he was certain about O_1 and uncertain about O_2 when faced with disconfirmation of his $O_1 - O_2$ hypothesis.

To be comprehensive, a theory should incorporate both hierarchical sequential and simultaneous consideration of O_is and R_is. In typical hypothesis evaluation, the subject might initially invest one O_i (for example O_1) with considerable weight, and a second O_i (O_2) with less weight. Nonreinforcement of the concept would lead to decrements in both O_is, but the decrement would be proportionally larger for O_2 than for O_1, resulting in an earlier removal from dominance of O_2 and its replacement with a new O_i (O_3 or O_4). The subject might then pair all other O_is with O_1 before O_1 was removed from dominance. Reinforcement of the concept would build PO_1 and PO_2, but the increment would be proportionally larger for O_2, and eventually the probabilities would be equal (as the probabilities approach 1). At this time, a composite component $O_{(1+2)}$ would become realistic.

A corollary to this study is that it would be unwise to base any new theory on experimental evidence derived solely from four-dimension, two relevant dimension paradigms, for such limitation could well lead to the same problems in generalization as evolved from the use of the traditional reversal-nonreversal paradigm. Tighe & Tighe (1968) have successfully employed three and four dimensional values, and the addition of multiple values to the present paradigm would probably be useful. The only limiting consideration is that cognitive strain increases geometrically with the number of cues to be considered, and that a balance of complexity and manageability must be achieved.

Table IX

Experiment 1 - Means and Variances for Acquisition and Test Phases (Errors and Trials to Criterion)

		SR	CR	SN	CN
ACQUISITION	$\bar{X}$	5.10	4.80	6.40	10.10
		16.70	*13.70*	*17.90*	*26.20*
	s^2	8.49	7.56	14.64	31.92
		64.61	*34.20*	*115.09*	*115.35*
TEST	$\bar{X}$	5.10	10.50	10.10	6.00
		13.80	*29.70*	*29.50*	*16.60*
	s^2	12.54	39.83	37.88	6.89
		99.29	*291.79*	*318.06*	*89.16*

Note.- Italics denote trials to criterion.

Table X

Experiment 2 - Means and Variances for Acquisition and Test Phases (Errors and Trials to Criterion)

		SR	CR	SN	CN
ACQUISITION	$\bar{X}$	8.67 *18.83*	11.83 *21.42*	10.00 *19.58*	10.17 *19.83*
	s^2	16.16 *36.47*	53.29 *57.23*	27.66 *70.22*	33.14 *139.29*
TEST	$\bar{X}$	7.33 *16.58*	14.50 *28.33*	11.92 *29.33*	7.25 *18.75*
	s^2	23.52 *159.72*	84.81 *159.52*	50.63 *252.24*	19.84 *106.39*

Note.- Italics denote trials to criterion.

Table XI

Experiment 1 - Raw Data

SR

S1	6	18	5	10	1S-1L
S2	13	34	10	34	2R-2B
S3	4	9	4	14	BO-BSQ
S4	5	12	3	7	RS-BS
S5	2	12	2	9	2L-2S
S6	6	22	3	6	BS-RS
S7	3	5	13	30	BSQ-BO
S8	5	25	4	6	BO-BSQ
S9	4	14	3	12	1S-1L
S10	3	16	4	10	LSQ-LO

CR

S11	2	10	6	19	RO-BSQ
S12	2	9	5	21	2L-1S
S13	5	14	4	6	SSQ-LO
S14	1	5	19	47	10-2SQ
S15	5	13	22	54	RL-BS
S16	6	25	10	30	BS-RL
S17	11	23	7	16	2SQ-10
S18	5	13	14	34	BSQ-RO
S19	7	15	5	16	2L-1S
S20	4	10	13	54	BO-RSQ

SN

S21	13	35	11	40	LR-LSQ
S22	9	21	3	18	SO-1S
S23	3	11	2	6	1B-1L
S24	1	1	6	11	2O-LO
S25	3	4	12	38	BL-BO
S26	5	18	21	43	BO-BL
S27	4	13	15	35	LO-2O
S28	10	31	10	41	1L-1B
S29	10	29	5	6	1S-SO
S30	6	16	16	57	SO-1S

CN

S31	8	28	3	3	1R-LSQ
S32	9	11	4	14	2B-LSQ
S33	5	13	11	20	RSQ-1L
S34	8	32	5	10	1R-SSQ
S35	6	23	2	3	1SQ-BS
S36	6	31	7	17	BS-1SQ
S37	23	50	7	27	SSQ-1R
S38	18	33	6	21	1L-RSQ
S39	12	21	7	19	LSQ-2B
S40	6	20	8	32	LSQ-1R

Note.- From left to right: training errors to criterion, training trials to criterion, test errors to criterion, test trials to criterion, training-test stimuli (R = red, B = blue, SQ = square, O = circle).

Table XII

Experiment 2 - Raw Data

SR

E1	S1	7	17	9	17	1L-1S
	S2	9	20	3	6	BSQ-BO
	S3	3	9	8	14	2SQ-2O
	S4	10	14	17	40	BO-BSQ
E2	S5	14	29	6	12	2R-2B
	S6	16	25	15	35	1SQ-1O
	S7	7	12	2	6	2L-2S
	S8	4	12	5	11	1S-1L
E3	S9	12	27	3	6	2B-2R
	S10	4	20	4	7	LR-LB
	S11	12	19	11	35	SR-SB
	S12	6	22	5	10	RSQ-RO

CR

E1	S13	8	19	20	41	2B-1R
	S14	6	14	4	12	SO-LSQ
	S15	12	29	9	23	RSQ-BO
	S16	9	22	7	20	1L-2S
E2	S17	4	13	10	20	1R-2B
	S18	5	16	27	47	SR-LB
	S19	16	26	6	18	BO-RSQ
	S20	22	29	18	40	2SQ-1O
E3	S21	9	14	26	42	1O-2SQ
	S22	30	39	30	41	2S-1L
	S23	8	17	9	20	LB-SR
	S24	13	19	8	16	LSQ-SO

SN

E1	S25	3	11	18	47	2L-2R
	S26	9	14	4	13	1S-1SQ
	S27	5	13	10	19	2R-2SQ
	S28	5	22	7	26	1B-1S
E2	S29	11	30	8	29	1O-1R
	S30	9	14	26	56	1SQ-1B
	S31	18	24	6	13	LR-LO
	S32	7	12	9	16	SB-SSQ
E3	S33	12	23	19	43	LO-2L
	S34	21	40	8	17	RO-1R
	S35	6	13	21	52	BO-2B
	S36	14	19	7	21	1L-1R

CN

E1	S37	23	49	4	8	1L-BSQ
	S38	2	4	3	9	2S-BSQ
	S39	11	20	16	34	1R-LO
	S40	4	8	5	14	1B-LSQ
E2	S41	9	13	2	9	10-SB
	S42	6	10	9	34	1SQ-LB
	S43	7	20	8	16	SR-10
	S44	14	28	14	33	SB-10
E3	S45	18	26	8	16	SO-2R
	S46	8	30	3	10	LSQ-2R
	S47	7	11	10	27	BO-1L
	S48	13	19	5	15	BSQ-1L

Note.- From left to right: training errors to criterion, training trials to criterion, test errors to criterion, test trials to criterion, training-test stimuli (R = red, B = blue, SQ = square, O = circle).

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