AN EXPERIMENTAL ANALYSIS OF A CODING RESPONSE THEORY OF DISCRIMINATION LEARNING

by

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Thesis submitted to the Graduate Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Psychology

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May, 1975

Blacksburg, Virginia

ACKNOWLEDGMENTS

I wish to express my deepest appreciation to for his invaluable cooperation and guidance in the production of this thesis. In addition, I wish to thank for their support and advisory assistance.

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For many years the theory of Kenneth Spence (1936, 1937) and Clark Hull (1943) guided most of the research on discrimination learning. In that view, a stimulus gained associative strength with a response according simply to the number of reinforcements delivered to the response occurring in the presence of the stimulus; any part of that stimulus gained as much associative strength as any other part.

However, Lashley (1938a, b) and recently, Reynolds (1961) observed that organisms reinforced in the presence of some multi-dimensional compound stimulus would later respond differentially to one part of the stimulus and not the others. This observation suggested the operation of some attentional process in the form of a stimulus selector mechanism in addition to the associative strength mechanism of Hull and Spence.

Several current discrimination learning theories, e.g., Zeaman and House (1963), Lovejoy (1968), and Sutherland and Mackintosh (1971) have elaborated specifically on the basis of an existing stimulus selection or attention process. The theory of N. Sutherland and N. Mackintosh (1971) is probably the most influential of these. It uses, although more restrictively, both the associative strength mechanism of Hull and Spence and a set of stimulus selection mechanisms which they call stimulus analyzer mechanisms. These stimulus analyzer mechanisms select some specific aspect of a stimulus situation. One analyzer mechanism gains an increased tendency of being selected by an analyzer selection center as a function of that analyzer's correlation with some consistently occurring outcome. A response selector center affects the selection of some response that will subsequently be hooked up with the selected analyzers. Stimulus analyzer mechanisms are seen as most probably being neural centers. However, the observation or measurement and subsequent explication of these neural centers is yet to come.

Sutherland and Mackintosh (1971) list a large body of data that can be explained by their stimulus analyzing theory. These data include such phenomena as intra- and extra-dimensional transfer effects, blocking and overshadowing, transfer along a continuum, the overtraining reversal effect, and probability learning. In the past such data have produced difficulties for theories which ignored attentional processes. However, since stimulus analyzers are not sufficiently specified to permit their direct observation, there are regions of indeterminacy in the Sutherland and Mackintosh theory. These regions of indeterminacy severely limit the derivation of testable research hypotheses and practical applications from the theory.

D. H. Lawrence (1963) has proposed an additional stimulus selection theory of discrimination learning. The theory takes into account Lawrence's early demonstration that stimulus dimensions take on an "acquired distinctiveness" as a function of being correlated with some reinforcing consequence (Lawrence, 1949, 1950). Lawrence's model includes a mechanism which he calls a "coding response", which serves many theoretical functions similar to those of Sutherland and Mackintosh stimulus analyzing mechanisms. That is, the coding response can affect the selection of a specific stimulus element and a subsequent response linkage to that element.

Coding as a general process is present whenever a constant operation or transformation is made on a set of quantities. When applied to discrimination learning, such a transformation takes the form of the substitution of some response and its stimulus consequences for some particular stimulus situation. A coding response might take any topographical form. The stimulus consequences of the coding response, then, represent code items, which are subsequently linked to some terminal response.

Several writers have described phenomena which suggest that coding may occur. Kendler and Kendler (1962) have noted that human children frequently mediate their problem solving behaviors with vocal responses. Kling (1971) has suggested that human subjects, when faced with an extremely difficult learning task, will convert the entire problem into verbal form, and do the actual problem solving manipulations verbally.

In the verbal learning literature, many observations have led to explanations that employ a coding process. Glaze (1928) has noted that certain nonsense syllables which remind subjects of real English words are encoded by the subjects as if they were the real words (e.g., LUV as love and BEL as bell). Lindley (1960) found that nonsense syllables that could be encoded as real words were learned at a more rapid rate than were nonsense syllables that could not be so encoded. Underwood (1963) has noted that subjects will often select some aspect of the experimentally-provided stimulus (nominal stimulus) to serve as the actual or functional stimulus. Underwood thus suggests that an active stimulus transformation process is typical of human subjects in a learning situation.

Miller (1956a, b) has proposed that one effective way of retaining information sets during verbal learning studies is to transform these sets into a single higher-order verbal code. Such an operation consists of substituting some aspect of the original sets for the whole, thus yielding a smaller "chunk" with which to work. N. F. Johnson (1972) has suggested that such coding occurs within an organizational scheme, with each element fitting somewhere on a particular dimension, with such elements of the dimension representing the actual coded information.

It appears that there are many suggestions that coding occurs in human verbal learning situations. However, the mechanisms of the coding process as generally used by the verbal learning writers is nearly exclusively associated with the processing and organization of events in memory. While there may be the future prospect of locating and handling a memory in real time, the temporal distance between memorial events and current events forces a different analysis than that permitted when direct observation of ongoing processes is required. As such, theories of coding as proposed in the verbal learning literature are somewhat different than that proposed by Lawrence (1963).

While a memory notion of coding appears adequate in explaining many verbal learning phenomena, it encounters some difficulty when applied to certain other types of discriminations. Kling (1971), for example, points out that extremely rapid and accurate discrimination learning often occurs in situations that preclude verbal behavior. If coding responses occur in these situations, then they must consist of topographies other than verbal topographies.

Carter (1971) has observed stereotyped mediating behaviors in pigeons, which, he suggests are under the stimulus control of experimental stimuli and appear to serve a coding function in the solving of a matching to sample problem by these birds. He further notes that Wright and Cumming (1971) have determined what could be interpreted as color-naming functions for pigeons. That is, they observed that pigeons tended to respond differentially to three different color hues in much the same manner that human subjects name three primary hues (e.g., Beare, 1961, 1963). These color-naming behaviors represent a transformation of a set of wavelength values into a set of three specific responses, which serve to affect subsequent response hook-ups with the wavelength values. Such a set of operations strongly suggests the presence of a defined coding system.

The implications of the observations of Carter (1971) and of Wright and Cumming (1971) are supportive of the notion that coding might occur in situations that preclude verbal responding. Given these implications, a coding response theory should allow for the presence of coding in non-verbal as well as verbal response forms. The general theory of Lawrence (1963) permits coding to take the form of any response topography. A coding theory should further allow for the direct observation and measurement of its components, as well as specification of its operations and functional relations to other systems. Developing on the character of Lawrence's general theory, it seems reasonable to suggest the following set of functional definitions of the coding process:

I. Coding responses are operants.

II. Coding responses produce, as consequences of their occurrence, discriminative stimuli for subsequent responding. The specifications of coding response-produced discriminative stimuli differ in some way from specifications of the experimenter provided stimuli,

III. Coding is a function of stimulus dimensions, and code items refer to values on those dimensions.

IV. Coding occurs in every discrimination.

While these rules are not exhaustive of the possible characteristics of coding, they do provide for certain testable assertions. The present study, then, was designed to test several notions of the coding function, as defined by these rules.

For this purpose, the conditions of Rules II and III will be assumed by the experimental procedures. Holding these conditions constant, we will then test the assertions of Rules I and IV. Given these two rules, we might state the following hypotheses: 1) Learning rates should be equal for any arbitrary set of coding behaviors, and 2) Learning should be severely impeded or prevented in situations where coding behaviors do not occur.

In testing these hypotheses, however, certain extra-experimental conditions must be controlled for. If, for example, coding occurs in every discrimination, then subjects that possess a well-established, naturally developed set of coding responses due to their history of discrimination problem exposure would be expected to reflect such exposure upon being introduced to any new discrimination problem. Such a condition suggests the need to choose a population of subjects with limited experience in solving complex discriminations. Such a population was located through previous experimentation. Johnson, Hoenigmann, and Pauly (1970) exposed children of various ages to conditional discrimination problems. On these problems, children from the third grade and higher grades acquired the conditional discriminations readily, indicating previous conditional discrimination experience. However, subjects below the third grade level, acquired the conditional discrimination only with large numbers of trials, indicating little or no previous conditional discrimination experience. The present study, then, employed both college level and first grade subjects in order to examine the effects of introducing arbitrary coding systems in situations where conditional discrimination behaviors are well-established, and in situations where these behaviors are not well established.

The effectiveness of conditional rule strategies that apparently are employed by human subjects is probably due largely to the use of verbal coding responses that are a part of these strategies. In order to demonstrate the effectiveness of some non-verbal coding system, it will be necessary to find a set of standard stimuli that limit ready verbalizations to their presence. Such a set of stimuli was located in some preliminary work. Adult subjects were shown a large series of 7-dot patterns imposed on a 4 X 4 position matrix. Three patterns were selected because the subjects consistently did not name them. Using these dot patterns as standard stimuli in a conditional discrimination, it would then be expected that the conditional discrimination based on them would be as likely to occur with some arbitrary, non-verbal form of coding or with a selected verbal code, as with a naturally developed form of coding.

Because coding responses are functionally defined and Lawrence's assertion that any of several response topographies may serve as coding responses, it seems possible to establish coding relations with responses of arbitrary topography and stimulus consequences of arbitrary dimension. Indeed, response topographies and stimulus dimensions might be selected to permit convenient observation. However, to insure that some arbitrary response topography might serve as a coding response, it will be necessary to pretrain this response to occur in the presence of a standard stimulus. The present study proposes to establish two sets of response topographies, one verbal, and one mechanical or non-verbal, as coding responses to be used in a conditional discrimination problem. If, in fact, any response topography might serve as a coding response, then one might expect both the verbal and the non-verbal response system to produce equally facilitated discrimination performance.

With the further assertion that coding is a necessary part of discrimination learning, there exists the possibility of tautology. As such, it will be necessary to test a group that has no ready coding system available to it. By the assertion of Rule IV, such a group should not readily learn a discrimination problem.

The present study, then, will employ three specified coding groups, including a verbal coding group, a manual coding group and a control or no coding group. The effects of the three coding strategies will be tested for both a first grade and a college level population.

Methods

Subjects

Eighty-three subjects were drawn from two different populations. Eighteen subjects were first grade students obtained from the Blacksburg, Virginia, elementary schools. The remaining 65 subjects were college level students, obtained through pre-experimental sign-up from the Introductory Psychology subject pool at Virginia Polytechnic Institute and State University.

Apparatus

A specially constructed conditional discrimination apparatus, measuring 51 cm X 30 cm X 30 cm was used (Figure 1). The front 51 cm X 30 cm panel was used as the problem or subject contact panel, while the rear panel was used as a control panel for the experimenter.

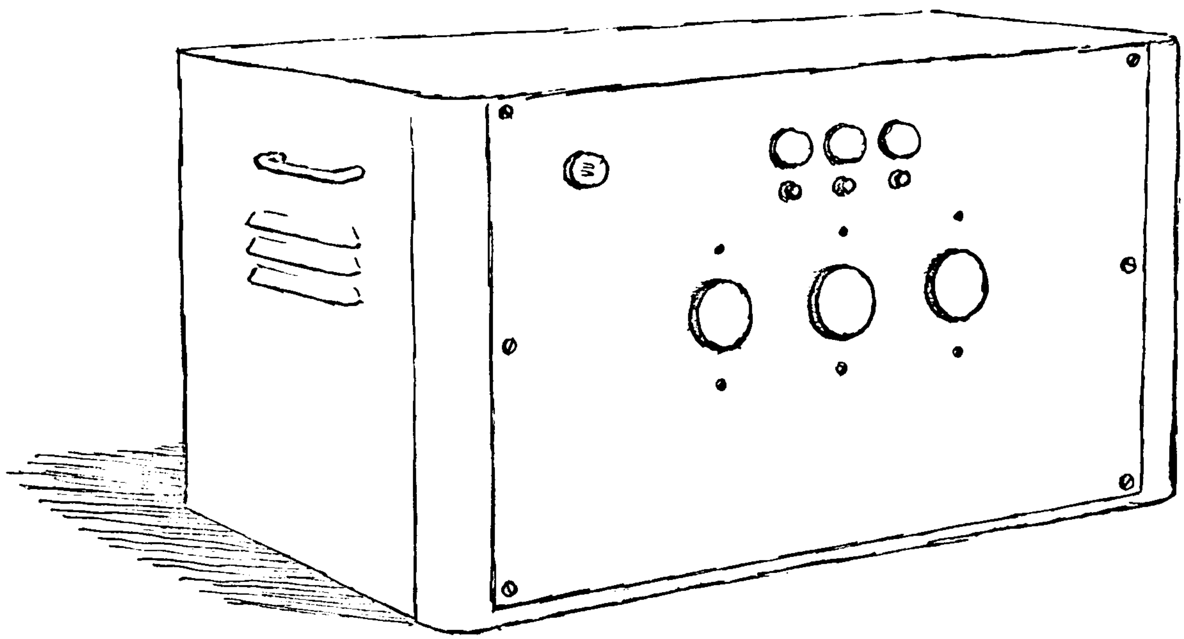
Three translucent keys, (Grason-Stadler E8670A), measuring 3cm in diameter were aligned horizontally, at the center of the subject contact panel. Behind each key was an Industrial Electronics Engineers In-line display unit which could transilluminate the key with any of five different stimulus patterns. The center unit projected three different dot patterns on the center key. These patterns consisted of seven dots randomly imposed on a 4 X 4 matrix. The dot patterns were used as standard (ST) stimuli. The two side units were used to project three different comparison (CO) stimuli. These stimuli included a vertical line, a horizontal line, and a 45-degree

Figure Captions

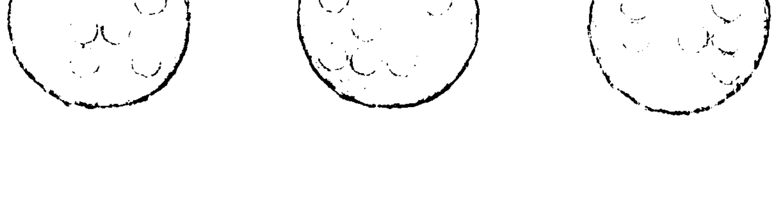
Figure 1a. Conditional discrimination apparatus viewed from the front, subject's contact position.

Figure 1b. Respective standard (ST) dot patterns as they appeared on the center key of the conditional discrimination apparatus. The left most pattern matches with an "X", the center pattern matches with a horizontal line and the right most pattern matches with a vertical line.

a.



b.



oriented cross. All CO stimuli were constructed from diameters 20 mm wide, and were white on a dark achromatic background.

Located 6 cm above the three keys were three small push button switches, each just below one of three differently colored pilot lights (white, amber, and red). These buttons, which were used only for coding by the explicit manual coding group, were inoperable except during the manual coding condition.

A 6 volt buzzer and a neon light were located in the upper left-hand corner of the contact panel, and was operated for 1.0 sec immediately following a correct CO choice, as indicators of pending reinforcement.

Presentation of the various ST and CO stimuli as well as correct coding button and correct CO (left or right) could be controlled manually by the experimenter, via a series of selector switches located on the control panel.

White, Great Northern beans were used as reinforcement markers, with penny-value vending machine charms and experimental credits for Introductory Psychology class as reinforcers for first graders and college students, respectively.

Procedure

The subject was seated facing the subject panel of the conditional discrimination apparatus. On three successive trials, the subject was shown each of the 3 different ST stimuli and told, "These are three different dot patterns that will appear throughout this experiment." Following this, each subject was randomly assigned to an experimental condition, and began the pre-training for that condition.

Explicit manual pretraining. The subject was shown each of the three ST stimuli along with one of the coding buttons and was told, "Whenever this dot pattern appears, you should press this coding button." Then he was given random presentations of each ST and was required to make the correct button-pushing (coding) response. After each correct code, the experimenter indicated to the subject that he had coded correctly, by saying, "Good". Following a 10 sec inter-trial interval, another trial was presented. If the subject during any trial pressed the incorrect coding key, the trial was cancelled, all lights were immediately extinguished, and no key press had any effect. The experimenter at this point would say, "That was not the right button to push. Please try it again." Following a 10 sec intertrial interval, he would represent the same ST. Explicit manual pretraining continued until the subject had coded correctly on each of 15 consecutive trials.

Explicit verbal pretraining. The subject was shown each of the 3 ST stimuli and given a different name, either HOUSE, CAR, or SCHOOL, for each. He was then told, "Whenever a dot pattern appears, you should say the name for it." Following this, he was given random presentations of each ST and required to correctly name (code) each. After each correct code, the experimenter indicated to the subject that he had coded correctly by saying, "Good". Following a 10 sec intertrial interval, another trial was presented. If the subject coded incorrectly during any trial, the trial was cancelled, and no key press had any effect. The experimenter said "That was not the right name. Please try it again." Following a 20 sec intertrial interval, the same ST was represented. Explicit verbal pretraining continued until the subject had coded correctly on each of 15 consecutive trials.

Non-explicit pretraining. Previous pilot work showed an average of 21 trials was required in order for explicit coding subjects to attain correct coding discriminations. Because of this, each Non-explicit subject was shown each of the 3 ST stimuli in random order and told, "I will now let you look at each of the dot patterns several times." In this condition, no means of coding was provided to the subject and no response was required of the subject. Non-explicit pretraining continued until each ST had been presented seven times.

Instructional trials. Every subject received six instructional trials at the beginning of the conditional discrimination session. The subject was shown an ST, required to make the appropriate coding response, and then told, "Now press the key with the dots on it." When this key was pressed the two CO keys were lighted with red lights. The subject was then told, "Now press the button on the right." When he pressed the button the reinforcement light would flash and a buzzer would sound for 1.0 sec. The subject was then told, "Each time that the light flashes and the buzzer sounds, you should take one bean out of the box on top of the apparatus." First grade subjects were told, "Whenever you get three beans, you may trade them for any one of the toys in the bag next to the box of beans." College subjects were told, "You must get 12 beans to complete this experiment. You get one bean each time that you make a correct choice, and the buzzer and the light operate. However, each time you make an incorrect choice, not only do you not get a bean, but you must give back all the beans that you have earned up to this point. This means in order to get 12 beans to complete the experiment, you must be correct 12 times in a row." Each ST was presented twice during the 6 instructional trials. For every trial, the subject was told to press the CO key for which reinforcement consequences were programmed, so that he could practice bean count and exchange rules.

Conditional discrimination. Following the six instructional trials, the subject was exposed to conditional discrimination trials. These conditional discrimination problems, called "symbolic matching" (Cumming & Berryman, 1965) because each CO is assigned arbitrarily by the experimenter to "match" a different ST. On successive presentations matching an ST with a CO on any trial, there were 12 possible stimulus combinations, assuring that each ST appeared equally often on the center key and each CO appeared equally often and on both left and right side keys. The sequence of twelve trial types was drawn from a table of random permutations (Cochran & Cox, 1950). Trials were presented until 12 successive, correct CO choices were made or until 300 trials had been presented, whichever came first.

A matching trial was started by presenting an ST on the center key. This set the occasion for coding in the case of the explicit coding conditions. At this point explicit verbal subjects had to name the dot pattern, while explicit manual subjects had to made a coding button press. Incorrect codes were met with the same correction procedures that were present during pretraining, while a correct code followed by a press to the center key immediately produced a simultaneous presentation of CO stimuli on the side keys. At this time additional presses to the center key had no further effect, but a press to the matching CO produced a buzzer and a neon light flash followed by the presentation of one bean to the subject. The beans could be exchanged for a vending machine toy or experimental credit, depending on the grade of the subject. A press to a non-matching CO produced a 10 sec blackout of all keys. Any press between the blackout or reinforcement period and the start of the next trial (10 sec in duration) had no effect.

Following each experimental session, each subject was asked the following two questions:

1. "How did you know which was the right button to press in order to make the buzzer sound?"

2. "Did you try any particular system or strategy other than the correct one before you reached the 12 bean criterion?"

Following this questioning, all subjects were told a brief explanation of both the apparatus and the experimental procedure, along with a statement of the rationale of the study. They were then allowed to ask any questions or make any comments about the study that they had.

In all, data was collected for 65 college level subjects (including 24 explicit manual, 21 explicit verbal and 20 non-explicit subjects) and 18 first grade subjects (6 subjects per group).

RESULTS

Table 1 shows the mean number of trials to the learning criterion under each coding condition for both 18 first grade and 65 college level subjects. No first grade, non-explicit subject reached the twelve-in-a-row-correct learning criterion. The mean of 300 trials for this group represents zero variation from the 300 trial limit. All other subjects at the first grade level, as well as all college level subjects, did reach the twelve-in-a-row-correct learning criterion.

Table 2 shows the mean number of errors to the learning criterion under each coding condition for both first grade and college level subjects. These data are normally distributed and have homogeneity of variances. Since the errors to learning criterion data meet these two assumptions, and the trials to learning criterion data do not, it was decided to use the errors to criterion as the principal index of learning, and to analyze the differences between the respective means of the groups using a parametric analysis of variance.

Both the experimental coding conditions and the grade level made a difference in learning rates. The statistical analysis revealed significant differences due to different coding type, $\underline{F}$ (2, 77) = 26.489, $\underline{p} < .01$, and between grade levels, $\underline{F}$ (1, 77) = 297.962, $\underline{p} < .01$. On the average, college level subjects acquired the conditional discrimination with about one-fourth the errors that were made by first grade subjects. But the effects of coding type were apparently different for the grade levels, since the Coding Type X

Table 1

Mean Trials to Criterion Across

Three Coding Conditions

	First grade	College students
Explicit Manual	120.0	30.88
Explicit Verbal	144.0	44.67
Non-Explicit	300.0*	60.03

*Represents 300 trial maximum trial allotment; criterion was not met, for both grade levels.

Table 2

Mean Errors to Criterion Across Three Coding Conditions, for Both Grade Levels

	First grade	College students
Explicit Manual	51.0	14.21
Explicit Verbal	68.16	15.38
Non-Explicit	162.16	20.45

Grade Level interaction also met statistical significance, F (2, 77) = 47.83, $p < .01$. For this reason it was decided to examine the simple effects of both coding and grade level upon learning rate.

The mean errors to criterion for the three coding groups from the first grade group were compared with their counterparts from the college level group. These individual comparisons revealed that not only were college level non-explicit subjects faster learners, than first grade non-explicit subjects, t (24) = 15.09, $p < .01$, but college level explicit verbal subjects were faster learners than first grade explicit verbal subjects t (25) = 5.96, $p < .01$, and college level explicit manual subjects were faster learners than first grade explicit manual subjects t (28) = 7.712, $p < .01$. Overall, it appears that college level subjects were indeed superior performers on conditional discrimination tasks, as had been suggested by the previous work by Johnson, Hoenigman, and Pauly (1970).

First Grade Subjects

An analysis of variance comparing the mean error scores of the three first grade coding groups indicated that a significant effect of coding type on errors to criterion was present, F (2, 15) = 58.0, $p < .01$. A further partition between the three coding groups used a Duncan's Multiple Range Test to control for the inflated alpha-level probability due to repeated analyses. The difference between the explicit manual group and the explicit verbal group (D = 17) was not significant, but both the difference between the explicit manual and the non-explicit groups (D = 111) and the difference between the explicit verbal and the non-explicit groups (D = 94) were significant (R = 93, $p < .05$).

The same comparisons can be made with respect to the number of trials to criterion. Since no non-explicit subject reached the learning criterion, only the scores from explicit manual and explicit verbal groups may be compared. A Mann-Whitney U-Test showed no reliable difference between the trials to criterion scores from these two conditions ($U = 18$, $p > .50$). However, the trial scores from the explicit manual and explicit verbal conditions were significantly different from a value of 300 trials, the number allotted to non-explicit subjects ($U = 0$, $p < .01$).

College Level Subjects

The effects of coding type on the mean number of errors to the learning criterion for the three college level groups, as shown in Table 2, were analyzed. While the college level subjects learned with fewer trials and fewer errors than the first grade subjects, there is a similar pattern in their mean error scores. That is, college level subjects used about the same average number of errors in the explicit manual and explicit verbal conditions and a greater number of errors in the non-explicit condition. However, the differences in mean errors to criterion for these subjects are not statistically reliable, F (2, 62) = .09, $p > .05$).

An analysis of variance of the mean trials to learning criterion for the college level subjects (Table 1) was precluded by non-homogeneity of variances for the respective coding groups. However, a Kruskal-Wallis one-way analysis of variance revealed that these data were congruent with the errors to criterion data reported above, showing no differences between coding groups, $\underline{H} = 3.58$, $\underline{p} > .10$.

Verbal Report Analysis

All subjects were questioned about any solution strategy that they may have employed during the conditional discrimination procedure. Interestingly, not one first grade subject reported a solution strategy, although first graders in the two explicit coding groups did develop a solution strategy, as revealed by their learning. In contrast, not one college level subject failed to report a solution strategy.

All of the solution strategy reports consisted of descriptions of the ST stimuli and their relation to CO choices and consequences. They differed with respect to descriptions of, or ways of coding, the ST stimuli. Table 3 presents the various coding systems reported by the college level subjects. Beside reports of the two explicit, manual and verbal systems, which were provided by respective pre-training trials, there were also reports of other coding systems. These reports of non-explicated coding were categorized into four types as follows:

3-Dot. A system whereby one particular set of 3 dots in each ST dot pattern was selected. The position of these dots was used to define the ST. Every report containing the "three-dot" phrase pointed to the same set of three dots in each ST pattern.

Visual Imagery. A system whereby "design" or "picture" words or phrases were used to define the ST dot patterns. For example, one report described a dot pattern as "backwards P", another as "a 2", and another as "a face". Any report categorized as a visual image report described all three ST dot patterns in such terms; it was never the

Table 3

Number of College Level Subjects from each Experimental Group Who Reported Forms of Coding, With the Mean Errors to Criterion for Each Form

Code type	Experimental Conditions: Explicit manual	Explicit verbal	Non-explicit	Total	Mean errors
Explicit Manual	12	..	..	12	$\bar{X}$ = 20.0
Explicit Verbal	..	20	..	20	$\bar{X}$ = 15.5
Non-Explicit	12	1	20	33	$\bar{X}$ = 15.38
3-Dot	9	1	13	23	$\bar{X}$ = 12.9
Imagery	1	..	4		
Quadrant	2	..	2	10	$\bar{X}$ = 21.5*
2-Dot	..	..	1		

*Represents combined mean for Imagery, Quadrant, and 2-Dot coding forms.

case that one dot pattern was noted by an image and a second pattern by three dots.

Quadrant. A system whereby one of four quadrant areas, in each pattern, which contained numerous dots defined each ST. As it happened, all quadrant reports referred to the same portions in each ST dot pattern.

2-Dot. A system similar to the 3-dot system, but where a particular pair of dots in each pattern defined each ST dot pattern. Only one, 2-dot report was observed.

Note that all the non-explicated forms of coding were verbal in nature. That is, all consisted of verbal descriptions of ST stimulus properties.

Experimental conditions appear to have exercised some control over verbal reports. Twelve of the twenty-four explicit manual subjects reported the explicit manual coding system. The explicit verbal condition was quite specific in its effect, as 20 of 21 explicit verbal subjects reported the explicit verbal coding system. Of course, since the explicit systems were not available to them, all the reports by the 20 non-explicit subjects were non-explicated coding systems.

In all, 33 subjects reported using a non-explicated form of coding. Twenty-three of these subjects reported using the 3-dot system. Of the remaining ten subjects, four reported a system utilizing visual imagery, four reported a quadrant system, and one subject reported a 2-dot system.

In order to determine if a particular reported strategy was associated with a higher or lower rate of learning than the others, an analysis of the respective learning rates for subjects reporting each of the different coding systems was done. Due to the relatively low frequency of occurrance of the Quadrant, Visual Imagery, and 2-Dot coding systems, a single category composed of all three of these coding categories plus the 3-Dot category was employed in the analysis. The mean errors to learning criterion for this combined group (15.38) and for the explicit verbal group (15.5) were compared using an analysis of variance. The comparison revealed that the self-initiated verbal coding systems reported by 33 subjects were not associated with a reliably different number of errors to criterion than was the experimenter-explicated verbal coding system, $F(1, 52) = .06$, $p > .05$. A further analysis comparing the mean of these two groups to the mean (20.0) of the group that reported using the explicated manual coding system revealed no differences, (Z approximation to the Mann-Whitney $U = .397$, $p > .34$).

DISCUSSION

Four functional rules for the operation of a coding system have been proposed. Briefly, these rules provide that 1) the coding events are operant responses of arbitrary topography (Rule I), 2) such a coding process occurs in all discriminations (Rule IV), 3) coding responses produce discriminative stimuli (Rule II), and 4) these discriminative stimuli vary along different dimensions than experimentally specified dimensions (Rule II). Experimental procedures assumed conditions 3 and 4. That is, the explicated coding responses produced stimuli, either lighted pilot lamps or vocalizations, which differed from the ST dot patterns. With these assumptions we may examine the assertions of conditions 1 and 2.

From assertion 1, if the coding events may be any arbitrary response topography, one should expect to observe a functional equivalence between the effects of the explicit manual and explicit verbal coding conditions. Indeed, there were no differences in learning rate, between explicit manual and explicit verbal conditions for either first grade or college level subjects, as indicated by both errors to criterion and trials to criterion measures.

If coding is necessary to discrimination learning, as assertion 2 from Rule IV states, then conditions under which no coding occurs should yield no discrimination learning. Similarly, conditions under which coding does occur should yield discrimination learning. These logical consequences are quite clear in the data from the first grade subjects. No first grade subject who was not provided with explicit coding behaviors acquired the conditional discrimination. At the same time, all subjects that were provided with an explicit set of coding behaviors did learn the conditional discrimination.

College level subjects who were not provided explicit coding responses nonetheless managed to learn the discrimination. Recall, however, that every college level subject reported a solution strategy and, further, that these reports were reports of coding systems. While a coding system report in no way substitutes for observations that the coding system was used (i.e., that the code items from such a system controlled CO choices), one may reasonably assume that a subject is more likely subsequently to report a particular coding system when he has used it. Given the understanding that a frequently occurring report suggests specific behaviors that may be observed in future experiments, the verbal reports of the present experiment may indicate that a coding system was in use. Thus, the fact that all the verbal reports described coding systems is consistent with the assertion that coding is necessary to discrimination learning.

A further assertion can be derived from the confluence of assertions 1 and 2 above. Assume that the difference in grade level represents, among other things, an extensive difference in histories of solving discrimination problems. If coding occurs in every discrimination and if coding consists of operant relations, then college level subjects noted for their extensive discrimination experience should exhibit strong, precurrent coding behaviors. Not only should one expect rapid learning by the college level subjects, which was indeed observed, but one may also expect to observe coding patterns which reflect their learning histories.

The explicit manual and explicit verbal pretraining procedures established sets of observable precurrent behaviors that could serve coding functions in the conditional discrimination. However, other, naturally-developed precurrent behaviors could also serve coding functions. The data obtained from the verbal reports of the college level subjects suggests that the pretrained behaviors were used in coding systems since subjects frequently reported them as such. One might also infer that naturally-developed verbal behaviors served coding functions in several instances since those subjects who reported a self-initiated coding system learned as rapidly as those who reported the explicit systems.

It would appear that no first grade subject brought precurrent coding behaviors to the experiment since there were no such reports. This should be expected, according to Silverman and Craig (1969) who observed that children in the kindergarten to second grade range did not verbally mediate their discriminative behaviors.

GENERAL DISCUSSION

The present paper has proposed a theory of discrimination learning and subjected this theory to experimental scrutiny. Using a functional definition of coding responses, the experiment has demonstrated that responses whose topographies are arbitrarily specified may serve the defined coding function. In addition, certain findings indicate that coding is necessary for discrimination learning. Finally, it appears that various coding systems ordinarily draw from historically established elements of behavior repertoires. Taken together, these conclusions generally support the plausibility of coding response accounts of discriminative stimulus control phenomena, and they suggest that stimulus control relations may be managed by managing explicit coding functions through current conditions.

The prospect of managing stimulus control in this manner invites a consideration of practical applications of coding response theory. Several investigators have devoted much research effort to problems of discrimination learning by severely retarded children. A common thread in these words concerns the difficulty in establishing stimulus control by relevant aspects of problem stimuli. Several authors have reported either failure to obtain stimulus control or instances in which incidental, irrelevant aspects of the environment control responding (e.g., Barrett, 1965, Ellis, Girandeau, and Pryer, 1962; House & Zeaman, 1958, 1960). While such adventitious relationships occur and are transient in normal children (Krechevsky, 1932; Harlow, 1959), they tend to perseverate and interfere, or completely block subsequent learning in retardates (Sidman & Stoddard, 1967; Touchette, 1968, 1971).

Zeaman and House (1963) have suggested that failures to establish stimulus control of responding in retardates are due to attentional mechanisms. Specifically, they have argued that the failure lies in the lack of attentional behaviors in the retardates. More recently, Touchette (1968) has further elaborated on the notion of attentional deficits. In commenting on the failure of stimulus control in retardates, Touchette has suggested that while appropriate reporting responses might be differentially reinforced, the possibility exists that inappropriate observing responses are occurring, thus producing superstitious controlling relations.

An alternative explanation of impaired discrimination learning in retardates might be suggested from coding response theory. One might expect that since relatively little, if any discrimination problem experience has occurred during the history of the retardate, that very few precurrent coding response patterns have been formed. If this is the case then one could not expect any but the simplest of discriminations to be managed by these individuals. A tenable solution to this problem would be to provide the subject with some set of responses which might be used as a means of coding. This might be accomplished by pretraining some extremely easy discrimination, using highly differentiated stimuli (e.g., colors with widely differing wavelengths). When the subject has reached a reasonably high level of proficiency on the simple task, the discriminative stimuli from the more difficult task might be introduced together with the stimuli from the easy discrimination, in order to transfer the control from the initial stimuli to the other stimuli. In this manner, the same coding response serves to mark some complex of stimuli with a single stimulus dimension.

Such a procedure has been demonstrated to be highly effective in training complex discriminations in severely retarded children (Touchette, 1968). In this study, subjects were trained initially to differentially select one marker stimulus over another. When they had reached a high degree of proficiency at this task, a set of relatively complex geometric patterns were presented, with the marker stimulus superimposed on them. Over successive trials the marker stimuli were faded out, leaving only the geometric patterns controlling the behavior. Control subjects who did not receive marker stimulus pretraining did not master the discrimination using the geometric patterns.

Such explanations of retardate learning as are offered by coding theory are certainly subject to further empirical verification, and subsequent modifications of the above proposed applications will almost certainly be made. However, it appears that coding theory does offer reasonable accounts of discrimination learning phenomena. While in many cases these accounts with their present details do not predict differently than do other theories (e.g., Sutherland and Mackintosh, 1971; Zeaman and House, 1963), they do afford direct observation and quantification of their crucial mechanisms, thus allowing for comprehension of discrimination learning phenomena in more naturalistic terms.

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An analysis of verbal reports taken at the end of training for the non-explicit college subjects revealed that all of these subjects reported using some form of self-initiated coding. This finding adds support to the assertion that coding is a necessary part of discrimination learning.

The results of the study support the plausibility of an objectively based coding response theory of discrimination learning. Such an account readily lends itself to further research and to practical applications.

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AN EXPERIMENTAL ANALYSIS OF A CODING RESPONSE

THEORY OF DISCRIMINATION LEARNING

by

Michael Stephen Cook

(ABSTRACT)

The present study has proposed four functional rules for a coding response theory of discrimination learning. Two of these rules, 1) coding responses occur in the presence of experimental stimuli and produce discriminative stimulus consequences, and 2) code items are values or a particular stimulus dimension, were assumed by the experimental conditions. The other two rules, 1) coding responses might be any artibrary response topography, and 2) coding is necessary for discrimination learning, are tested by the experiment.

Eighteen first grade and 65 college level subjects were exposed to conditional discrimination problems under one of three coding conditions, an explicated manual code, an explicated verbal code or a no explicated code condition. Subjects using either the verbal or the manual coding forms learned at approximately the same rate, supporting the rule stating that coding response topographies may be arbitrary. No first grade non-explicit subject ever learned the conditional discrimination. This finding supports the rule asserting necessity of coding. However, all college level non-explicit subjects learned, and at a rate equal to that of the two explicit coding groups.

An analysis of verbal reports taken at the end of training for the non-explicit college subjects revealed that all of these subjects reported using some form of self-initiated coding. This finding adds support to the assertion that coding is a necessary part of discrimination learning.

The results of the study support the plausibility of an objectively based coding response theory of discrimination learning. Such an account readily lends itself to further research and to practical applications.