JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1978, 29, 527-533 NUMBER 3 (MAY)

ATTENTIONAL CHANGES DURING DISCRIMINATION LEARNING BY RETARDED CHILDREN[1]

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Eight moderately retarded children were trained on a simultaneous two-choice discrimination problem and a series of discrimination-shift problems. The procedure required the subjects to perform overt observing responses to produce elements of the discriminative stimuli, making it possible to measure directly changes in attention to different aspects of stimuli during learning. The patterns of change in observing responses were generally in line with descriptions of attentional changes derived from two-process theories of discrimination learning; for example, the frequency of irrelevant observing responses was high during the presolution period during extradimensional shifts but was low during intradimensional shifts. Contrary to current theories, extradimensional shifts caused an immediate increase in irrelevant observing responses, and intradimensional shifts usually caused an increase in relevant observing responses. Subjects responded to later shift problems by initially increasing both relevant and irrelevant observing responses, then withholding irrelevant observing responses.

Key words: discrimination learning, compound stimuli, attention, observing responses, discrimination shifts, button pressing, retarded children

A child may be trained to choose one stimulus in preference to another by use of a discrimination training procedure that reinforces choice of one stimulus only. Discrimination training procedures are basically divisible into two categories, those permitting two or more alternative responses (concurrent schedules) and those permitting only one response to be emitted or withheld (multiple schedules). Studies of discrimination learning by retarded children have typically used procedures in the first category, with the result that theoretical accounts of retardate discrimination learning are mainly concerned with the process of learning to choose between concurrently available responses. Two-process discrimination-learning models, such as that of Zeaman and House (1963), regard the choice between available external responses as a sequel to a covert choice between available attentional responses. According to Zeaman and House's theory, the subject learning a discrimination problem must first learn to attend to the relevant stimulus dimension (*e.g.*, color, form, or position), then learn to make the correct overt response. Zeaman and House maintained that retarded children did worse than normals on discrimination problems only because they were less likely to attend to the relevant stimulus dimension. Other theories, too, have posited attentional deficiencies as the cause of slow discrimination learning by retardates, although the conceptualization of the attentional deficit has taken a variety of forms characterized by terms such as "distractibility" (Hagan and Huntsman, 1971) and "narrowness of attention" (Fisher and Zeaman, 1973).

Given such interest in the role of attention in discrimination learning by retardates, it is unfortunate that there have been few attempts to provide an accurate description of attentional processes during such learning. What little is known about the nature and function of attention responses has been gleaned by inference from the variation in the pattern of overt responses accompanying variation in stimulus parameters, as for example in the voluminous literature on discrimination-shift paradigms (Esposito, 1975).

[1]This research was supported by equipment grants from the Golden Kiwi Medical Research Distribution Committee, and the University of Auckland Research Committee. N.N.S.'s contribution was supported by a Postgraduate Scholarship from the Medical Research Council of New Zealand. Reprints may be obtained from I. L. Beale, Department of Psychology, University of Auckland, Private Bag, Auckland, New Zealand. We wish to acknowledge the cooperation of the staff of Mangere Hospital and Training School.

Only a few studies have attempted direct measurement of attentional responses during discrimination learning. One report (Touchette, 1971), describes a temporal fading procedure that allows direct measurement of the point of transfer of control from one dimension of a compound stimulus to another, but does not permit the monitoring of other changes in attention. Another more generally useful technique described by Eimas (1969) involves making available covert "observing responses", which must be emitted to disclose the discriminative stimuli on each trial. Eimas used this technique to study attentional changes during overtraining and reversal of a successive discrimination in which only one stimulus was presented on each trial.

The present experiment extends the technique used by Eimas to a two-choice, simultaneous discrimination in an attempt to obtain a direct description of attentional changes during the solution of discrimination problems of the type most often encountered in the literature on retardate learning, and about which there has been considerable theorizing. Following Zeaman and House (1963), we have taken Wyckoff's (1952) concept of an "observing response" as a measurable, overt equivalent of a response of "attending to" a stimulus. While recognizing that there may be more to attention than can be seen from overt responses that disclose discriminative stimuli, we note that this is at least an essential and significant part of the process.

METHOD

Subjects

Residents of the Mangere Hospital and Training School, a state institution for the mentally retarded in Auckland, New Zealand, were randomly selected from the segment of the population that attended the training school; they had no gross motor or sensory defects, or severe emotional disturbance. Of the 12 children initially selected, four were discontinued as subjects during the experiment because they failed to learn the original problem within 360 trials; the remaining eight were randomly divided into two experimental groups. Table 1 presents the subject characteristics. None had previous experimental history with discrimination learning of the type employed in this experiment.

Table 1

Characteristics of the Subjects

Subject	*Sex*	*CA*	*MA*	*IQ*	*Length of Institutionalization*
		(years-months)			(years-months)
JM	M	11-2	3-1	33-43	10-0
RM	M	17-0	4-9	33-43	3-0
AE	F	13-3	3-3	29-39	12-0
NB	M	15-1	3-11	34-44	5-6
CW	M	10-9	5-0	40-50	4-6
DS	M	12-2	3-6	31-41	2-0
DW	F	13-2	3-5	25-35	3-0
GS	M	15-8	4-5	40-50	0-8

Apparatus

The equipment was a Series 520 Modular Human Test System (Lehigh Valley Electronics) composed of (1) a subject's console on which stimuli and reinforcers were presented and keys on which the subject made responses, (2) automatic scheduling and recording equipment located 3 m from the console and separated from it by movable screens. The subject's console sat on a desk at a convenient height for clear viewing of stimuli and easy access to response keys. The face of the console measured 70 cm wide by 80 cm high. The console contained three standard modules. One was a choice-response module containing three rectangular transparent Plexiglas keys 8.3 cm high and 4.8 cm wide. These keys were backed by a translucent panel, which served as a screen for three multiple-stimulus projectors. Only the left and right keys and their projectors were used in this experiment, the centre key being inoperative and serving only to provide a 5-cm separation between the two effective keys. A light touch on either key (minimum force 0.3 N) closed a microswitch behind the key, which fired a 20-msec pulseformer on the control rack.

Immediately to the left of the choice-response module was an observing-response module containing four rows of three buttons 1.9 cm square. Only two of these, in the centre column, were used in this experiment. These could be illuminated and when pressed with a minimum force of 0.5 N, closed a circuit operating a 20-msec pulseformer.

Below the choice-response module and the observing-response module was a coin-dispenser module that had been modified to dispense small sugar-coated candies. When the dispenser operated there was an accompanying noise from a solenoid and a red light shone for 5 sec on the dispenser panel.

Stimuli

The projectors behind the choice-response keys could project onto the screen behind each key either a colored shape 2.8-cm square in red, green, yellow, or blue, or a white letter (bold-face capital) approximately 2.3 cm high and 1.1 cm wide, either P, T, K, or W.

Procedure

General. In the first session, subjects were trained to sit at the console and to press either choice-response key to operate the candy dispenser. They were also taught to press the illuminated observing-response buttons to produce brief stimuli (0.1 sec duration) behind the choice-response keys. The upper button produced letter stimuli and the lower button produced colors. With the equipment programmed for the initial training problem, the experimenter held the subject's hands and guided them through an appropriate response sequence on several trials, until the child could use the observing-response buttons and a choice-response key on each trial, and could collect candy from the dispenser without assistance. The trial sequence was then reset to the beginning and recording commenced.

The training procedure was a two-choice simultaneous discrimination. Each problem used two stimulus dimensions, one of which was relevant, and the other irrelevant, to solution of the problem. Two elements from each dimension were used. For the relevant dimension, one element (positive) was correlated with reinforcement, the other (negative) with nonreinforcement. For example, in the initial training problem given all subjects, color was the relevant dimension, and red was positive and green negative. Each irrelevant element was paired equally often with each relevant element, so that each was correlated with reinforcement on only half the trials. In the initial training problem, each of the letters T and P (irrelevant) was paired equally often with red and green colors (relevant).

Subjects were trained on the initial problem for nine daily sessions, 40 trials per session. Each trial commenced with illumination of the observing-response buttons. Each touch on these buttons produced a 0.1-sec presentation of letters (upper button) or colors (lower button). If both buttons were pressed simultaneously, no stimuli resulted. There was no restriction on the number of observing responses that could be made on any trial. With or without having made an observing response the subject could at any time during the trial press either the left or right choice key on which stimuli were displayed. If the subject pressed the key on which the positive element could be displayed in that trial, the candy dispenser operated and all keys became dark and was ineffective for 6 sec. This was designated a correct response. If the other key was pressed, all keys became dark and ineffective for 20 sec (timeout). This was designated an incorrect response. The maximum trial duration was 10 sec; if there was no response on the choice keys within this interval, all keys were darkened and ineffective for 6 sec. Simultaneous responses on both choice-response keys were treated as an incorrect response.

Trial sequence. In each session of 40 trials, each stimulus element occurred equally often on left and right keys. Irrelevant elements were paired equally often with each relevant element. No element appeared on both keys during any one trial. Hence, there were only four stimulus configurations for each problem, and each block of eight trials contained two of each configuration. Trial succession in each block of eight was arranged each day by shuffling a pack of eight cards. This was repeated five times, giving five independent sequences of eight trials for the day's session. For the initial problem, the four stimulus combinations for left and right keys were (1) red, P; green, T (2) red, T; green, P (3) green, T; red, P (4) green P; red, T.

Design

The succession of problems presented to the two groups of subjects is shown in Table 2. Both groups received four transfer problems, two being intradimensional (I.D.) shifts and two extradimensional (E.D.) shifts. An I.D. shift involved introducing two new relevant elements from the dimension relevant in the previous problem. An E.D. shift involved introducing relevant elements from the dimension previously irrelevant. Both types of transfer problem have been used extensively in former studies of attentional factors in discrimination learning (see Esposito (1975) for a recent review). Group 1 received transfer problems in the order E.D., I.D., E.D., I.D.; Group 2 received them in the reverse order.

Unlike the original training problem, which was given for nine sessions, each transfer problem was continued until subjects individually reached a three-part criterion of discriminative performance as follows:

(1) choice criterion: 80% correct choice responses in two consecutive daily sessions.
(2) observing-response criterion: no irrelevant observing responses in two consecutive daily sessions.
(3) observing efficiency criterion: a maximum of one relevant observing response per trial in two consecutive daily sessions.

RESULTS

Performance on each session is summarized for three typical subjects in Figure 1. Observing-response data are shown in the lower panels, using two different indices of performance. The proportion of relevant observing responses is obtained by dividing the number of relevant observing responses by the total number. An indication of the absolute numbers of both types of observing response is also given, values shown being the logarithm of the mean number of observing responses per trial. Values of minus infinity (corresponding to zero observing responses per session) are not shown. This index is regarded as reflecting efficiency of observing.

The proportion of correct choice responses in each session is shown in the upper panels. Also shown in the upper panels, in some cases, is the proportion of responses on the right key. This is shown only for those problems in which values outside the range 0.4 to 0.6 were obtained, *i.e.,* where a subject appeared to be favoring the left or right key.

Initial Problem

The number of sessions required before subjects were choosing the correct stimulus on every trial varied from five to eight, but six subjects achieved this performance by the sixth session. In most cases, the transition from chance to criterion performance was achieved in a single session, the exception being D.W. who showed proportion-correct values between 0.6 and 0.7 for two sessions before reaching criterion in the following session. Three subjects (R.M., G.S., D.W.) favored either the right or left key during the presolution period. All except two subjects (N.B., R.M.) emitted relevant and irrelevant observing responses with comparable frequency during the presolution period. In the two exceptional cases, relevant observing responses were more frequent than irrelevant responses. In every subject, irrelevant observing responses ceased soon after the correct-choice criterion was met. Five subjects showed a progressive reduction in the frequency of relevant observing responses after the choice criterion was met.

Table 2

Stimulus Arrangements for the Original Training and Discrimination Shifts[a]

Group	*Stimulus Type*	*Stage 1*	*Stage 2*	*Stage 3*	*Stage 4*	*Stage 5*
1. DW AE GS JM		Original training	ED shift	ID shift of stage 2	ED shift of stage 3	ID shift of stage 4
	relevant	red + green −	P + T −	K + W −	yellow + blue −	red + green −
	irrelevant	T P	red green	red green	T P	T P
2. CW NB DS RM		Original training	ID shift	ED shift of stage 2	ID shift of stage 3	ED shift of stage 4
	relevant	red + green −	yellow + blue −	P + T −	K + W −	red + green −
	irrelevant	T P	T P	red green	red green	T P

[a]ED = extradimensional shift; ID = intradimensional shift; + = positive stimulus (reinforced); − = negative stimulus (timeout). See text for details of stimulus positions and reinforcement contingencies.

Shift Problems

Considering first the number of sessions required to reach the choice criterion, in all except two subjects (D.W., D.S.), I.D. shifts were more rapidly mastered than E.D. shifts. In the two exceptional cases, the second E.D. shift was mastered in Session 1, and the second I.D. shift in Session 2. The first two shifts followed the same pattern as in the other subjects, however.

The difference between E.D. and I.D. performance can be related to the pattern of observing responses during the presolution period. During E.D. shifts, there were many irrelevant observing responses, which tended to be sustained over several sessions. On I.D. shifts, irrelevant observing responses were comparatively few and were largely confined to the first session. Interestingly, this occurred more in the second than in the first I.D. shift, suggesting that the subjects may have learned to observe both dimensions when choice responses were unreinforced at the beginning of a shift. Such a strategy was required for solution of the E.D. shift that intervened between the two I.D. shifts.

At the beginning of an E.D. shift, particularly the first, there was an increase in the occurrence of observing responses to the previously relevant, now irrelevant, dimension. In the first E.D. shift, this was accompanied by a complete absence of relevant observing responses during at least the first session.

In three subjects, position habits (favoring left or right key) appeared during the presolution period of some (but not all) shift problems. In two cases, both E.D. and I.D. shifts were involved (D.W., R.M.) but in the other case, only the first E.D. shift was involved (G.S.). In most cases these temporary position preferences occurred before irrelevant observing responses stopped, but there was one instance that did not fit this pattern (D.W., first I.D. shift, Session 1).

The transition from chance performance to criterion was usually abrupt (one or two sessions), but the first E.D. shifts of R.M. and D.W. showed some evidence of a more gradual transition. In both cases, it is noteworthy that irrelevant observing responses decreased, but that in R.M.'s case a position habit seemed to prevent improvement.

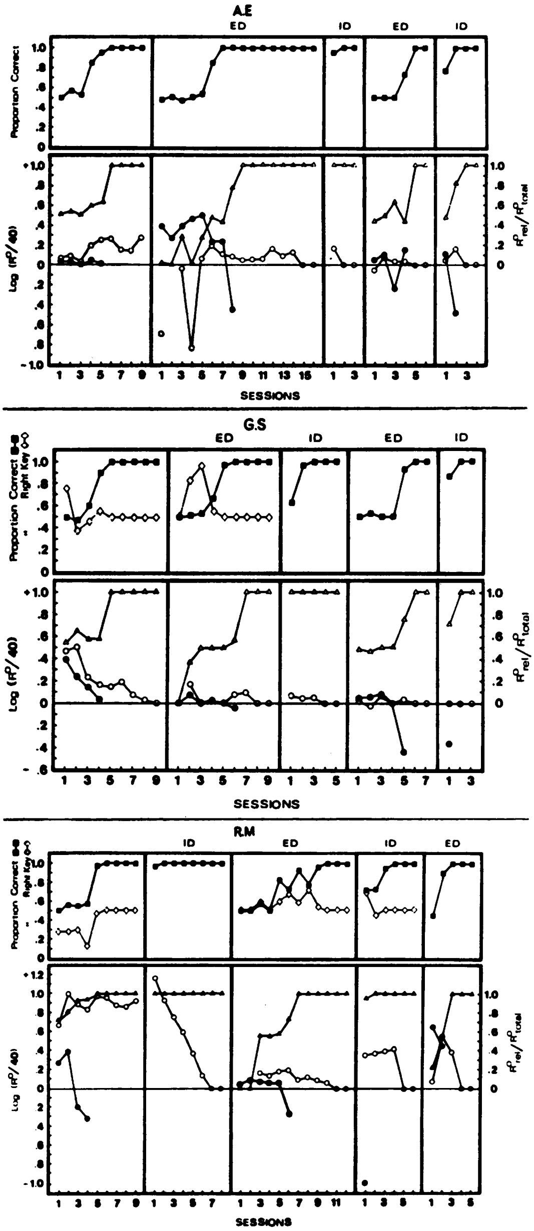

Fig. 1. The performance of three subjects is summarized for the original problem and successive ED and ID shifts. Data plotted are the proportion of correct responses (squares), the proportion of right-key responses (diamonds), the proportion of total observing responses to the relevant dimension (triangles), and the logarithm of the mean observing responses per trial to the relevant (open circles) and irrelevant (closed circles) dimensions.

DISCUSSION

The results show that as a general rule, subjects make the transition from near-50%

correct to near-perfect performance in a single session, a style of performance that has been characterized as evidence of learning by "insight" or "hypothesis testing" (Zeaman and House, 1963). The results replicate two other effects reported in the literature: the relative difficulty of E.D., compared to I.D., shifts and the progressive reduction of this difference in difficulty with continued experience with both types of shift (Zeaman and House, 1963). This relative difficulty of E.D. shifts has been regarded by two-process learning theorists as evidence that subjects learn to attend to specific dimensions of stimuli, and that these attentional responses transfer to new problems, where their effect might be facilitative or inhibitive according to whether the dimension attended to is still relevant for solution of the problem. The present results confirm this view, showing a high frequency of irrelevant observing responses during the presolution period of E.D. shifts, and their relative infrequency during I.D. shifts. In fact, introduction of an E.D. shift often resulted in an increase in observing responses to the now-irrelevant dimension. This result is not consistent with the suggestion of some attention theorists (Zeaman and House, 1963; Mackintosh, 1965) that nonreinforcement at the beginning of a discrimination shift causes progressive extinction of the previously relevant attentional response. Similarly, the onset of an I.D. shift usually increased, not reduced, relevant observing responses. A similar effect at the onset of discrimination reversal has been described by Premack and Collier (1966) with college students and by D'Amato, Etkin, and Fazzarro (1968) with monkeys. Of course, the increase in rate of an instrumental response at the onset of extinction is well known (Keller and Schoenfeld, 1950, p. 11), and the present case may well have a similar origin. We are inclined to think, however, that the increase in observing is an indirect effect of unreinforced choice responses; nonreinforcement leads the subjects to look more closely at the stimuli before making their choice response. It is reasonable to suppose that this would facilitate the solution of the discrimination-shift problem, resulting in an increase in the probability of reinforcement of instrumental choice responses. This interpretation is borne out by the observation that in later shift problems, subjects acquired the strategy of responding to nonreinforcement by increasing observing responses to both stimulus dimensions. When the problem was solved, observing responses to the irrelevant dimension were then withheld. This strategy was probably a major contributor to the decrease in the relative difficulty of E.D. shifts in Phases 4 and 5 of training.

Our results bear on the question of whether subjects learn something about only one dimension of the discriminative stimuli on any trial (single-look model; *e.g.*, Zeaman and House, 1963) or whether learning may take place with respect to more than one dimension on any trial (multiple-look model; *e.g.*, Fisher and Zeaman, 1973). In the present experiment, subjects frequently made observing responses to color and form on the same trial, a fact reflected in the session summaries in Figure 1. This is not to say that they tested hypotheses about more than one dimension on any trial, of course, although their spontaneous verbal comments suggested that this might be the case. Two subjects showed a systematic bias to the right or left key while still making irrelevant observing responses.

The present results have relevance to claims of certain two-process theories of discrimination learning (Zeaman and House, 1963; Mackintosh, 1965) that overtraining of a mastered discrimination involves further differentation of the probabilities of attending to relevant and irrelevant stimulus dimensions. We found that, in general, after the instrumental-choice criterion was reached, further training reduced irrelevant observing responses to one per trial. On later shift problems, however, some subjects reached all three criteria in the same session; in these cases, further training would not have resulted in any change in the observing responses measured in this experiment. We would suggest, therefore, that the effects of overtraining should be regarded as conditional on the experience of the subject with discrimination problems of a similar type.

Finally, some observations can be made about the capabilities shown by the retarded children in this experiment. It has been argued that retarded children have difficulty on discrimination problems because of a restricted breadth of attention (Ullman, 1974), or because they are unable to inhibit attention to irrelevant stimuli (Heal and Johnson, 1970).

In the present study, we might take these factors to be measured respectively by the ability to make observing responses to the newly relevant dimension at the onset of an E.D. shift, and the rate of decrease in the number of irrelevant observing responses during an E.D. shift. Performance on these variables during the first E.D. shift left considerable room for improvement, and normal children matched for mental age might well have done much better. However, all subjects showed considerable improvement in the second E.D. shift. The rates of improvement and the level of performance achieved is in some ways more impressive than the slowness shown by some subjects in the first E.D. shift, both because it suggests that a very high level of performance might be achieved after experience on a few discrimination shift problems, and because it is common to all subjects, however bad their initial performance.

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Received 13 August 1977.
(Final acceptance 8 December 1977.)