cl

"ERRORLESS" DISCRIMINATION OF REVERSED LETTERS BY CHILDREN

by

MURIEL KATHLEEN GROVES

B.A., University of British Columbia, 1963

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in the Department

of

Psychology

We accept this thesis as conforming to the

required standard

THE UNIVERSITY OF BRITISH COLUMBIA

October, 1972

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Psychology

The University of British Columbia
Vancouver 8, Canada

Date September 29, 1972.

ABSTRACT

"Errorless" Discrimination of Reversed Letters by Children

by

Muriel K. Groves

The purpose of this project was to devise a method to teach preschool children to discriminate between the letters b and d quickly and with a minimum of errors. In the two pilot studies a simultaneous discrimination task was employed with one letter serving as S+ and one as S-. Children who did not reach criterion during a pretest matching-to-sample task involving the letters b and d served as _S_s. During training trials the children were reinforced with candy after each correct response. In both studies control _S_s received the final form of the letter stimuli throughout the training trials. For the progressive _S_s in the first experiment, the circular part of the negative letter was initially absent and then was introduced gradually over trials. None of the progressive or control _S_s acquired the b-d discrimination in this experiment. In the second study three-dimensional letters were used. For the progressive _S_s the upright negative letter initially

was set so that the circular part of the letter was perpendicular to the front of the body of the S, who was seated facing the letters. The circular part of the letter pointed toward the S. Then, over trials, the negative letter was rotated gradually around its vertical axis until the circular part of the letter was parallel to the body of the S. The circular part of the positive letter always was parallel to the front of the S. Thus in the final step of fading the circular parts of the positive and negative letters were parallel to the S and were facing in an opposite left-right direction. In the second study one of the eight control Ss and four of the seven progressive Ss reached criterion. The majority of the progressive Ss who reached criterion made a number of errors. It was suggested that one possible reason for the lack of the success of the pilot studies was that the fading of the S- letter was not done in a manner which was very "relevant" to the final left-right discrimination. In other words, the steps in the fading sequence did not, through a kind of successive approximations approach, ensure that the behaviour of the child would come gradually under the control of the directionality of the letters.

In the principal experiment an attempt was made to devise a fading sequence which would be more "relevant" to the final left-right discrimination. This fading sequence was compared with a control procedure in which the final forms of the letters were used throughout the trials. Subjects who did not reach criterion on the baseline matching-to-sample trials with the letters b-d were assigned to the progressive or control groups. The progressive Ss first received a series of matching-to-sample trials involving arrows pointing either to the left or right. Those who reached criterion on the arrow stimuli received a fading program involving a gradual progression from arrows to final letter-forms. The Ss who did not reach criterion on the arrow series received matching trials involving simultaneously moving arrows. The arrows were moved vertically and then horizontally. The distance of the horizontal movement was reduced gradually until the arrows were stationary. The Ss then received the fading sequence from stationary arrows to final letter-forms. Eight of the nine progressive Ss reached criterion on the b-d discrimination. Seven of the progressive Ss who reached criterion responded correctly on more than 90 percent of the trials while the eighth S was correct on 77 percent of the trials. Only one of the nine control Ss reached criterion. All Ss reaching criterion on the b-d discrimination successfully transferred to a p-q discrimination.

The results of these experiments indicate that many preschool children do not learn to discriminate between the reversed letters b and d under a differential reinforcement procedure. However, the majority of such children learn to make this discrimination with no or few errors when they receive a fading sequence which is "relevant" to the final discrimination.

TABLE OF CONTENTS

Chapter		Page
I	INTRODUCTION	1
	1. Stimulus Control and the Left-Right Discrimination	1
	2. Normative Studies on Left-Right Discrimination in Children	4
	3. Experimental Attempts to Teach Left-Right Discriminations	10
	4. Purpose of Present Research	25
II	PRELIMINARY STUDIES	26
	1. Preliminary Experiment I	26
	Method	26
	Subjects	26
	Materials and Apparatus	26
	Design and Procedure	27
	Results and Discussion	30
	2. Preliminary Experiment II	31
	Method	31
	Subjects	32
	Materials and Apparatus	32
	Procedure	32
	Results and Discussion	35
	3. Summary	40
III	MAIN EXPERIMENT	42
	1. Introduction	42
	2. Method	44
	Subjects	44

Chapter Page

Materials and Apparatus 46
Procedure 48

3. Results 57

4. Discussion 65
General Summary and Comment 65
Reasons for the Success of the Program and Possible Modifications 70
Comparison of the Program with Other Training Methods 73
Theoretical Implications 77

5. Summary 80

REFERENCES 83

LIST OF TABLES

Table Page

1. Age and Sex of Subjects in the Different Conditions 45

LIST OF ILLUSTRATIONS

Figure | Page

1. Positive stimulus d and steps 2, 3, 14, and 20 of the progressive modification of b 28

2. Positive stimulus d and steps 1, 3, 7, 14, and 19 of the progressive rotation of b 34

3. Summary and illustrations of the phases in the progression of the stimuli from thick stationary arrows to final letter-forms 47

4. Summary of experimental procedure 50

5. Illustration of how the arrows were moved 54

6. The percentage of trials on which Control and Progressive Ss responded correctly 59

7. Cumulative correct responses of Ss in the Control condition, in the Progressive condition, and in the Baseline-Only group 64

ACKNOWLEDGEMENTS

I wish to thank my advisors, Dr. D. M. Wilkie and Dr. G. J. Johnson for their assistance and comments. I especially would like to thank my chief advisor, Dr. D. M. Wilkie, for all his help and encouragement. I also would like to thank my husband, Alan, for his support. A special thanks to my parents, Flora and Arthur Croker, for their very great help and encouragement, and to my little son John for being such a good boy and making it possible for me to do this project. I also would like to thank Mrs. H. I. Jacobson for looking after John so well and Mrs. M. J. Finlay for typing the manuscript with such care.

CHAPTER I INTRODUCTION

1. Stimulus Control and the Left-Right Discrimination

In his 1966 article Terrace defined stimulus control[1] as follows:

> Stimulus control refers to the extent to which the value of an antecedent stimulus determines the probability of the occurrence of a conditioned response. It is measured as a change in response probability that results from a change in stimulus values. The greater the change in response probability the greater the degree of stimulus control with respect to the continuum being studied. (p. 271)

As an example of stimulus control, suppose that a pigeon is reinforced for pecking a key illuminated by monochromatic light. To determine if pecking is under the control of wavelength, the wavelength projected on the key is varied and pecking during these various test wavelengths is not reinforced. The pecking response is said to be under the control of wavelength if the probability of

---

[1] The concept of stimulus control is similar to the concepts of discrimination and generalization (cf., Terrace, 1966). However, the latter terms have connotations not implied by the term stimulus control. While both stimulus control and discrimination-generalization will be used interchangeably in the present paper, only the meaning of the former is intended.

pecking covaries with wavelength - the steeper the gradient relating response probabilities to stimulus values, the greater the degree of stimulus control. If pecking and wavelength do not covary during the test, pecking is not under the control of wavelength.

Terrace (1966), after reviewing the literature, concluded that the establishment of control by a particular stimulus continuum requires a differential reinforcement procedure; that is, one or more values along the continuum must be associated with reinforcement while one or more values must be correlated with non-reinforcement or a different schedule of reinforcement. As support for this conclusion, Terrace cited a number of studies (e.g., Jenkins and Harrison, 1960). In the study of Jenkins and Harrison one group of pigeons was reinforced for pecking in the presence of a tone of a certain frequency (S+ or positive stimulus). A second group of birds was reinforced for pecking in the presence of the same tone (S+) and was not reinforced for pecking during its absence (S- or negative stimulus). During a subsequent test for stimulus control, tones of different frequencies were presented. The *S*s who received non-differential training produced flat gradients, while the *S*s who received differential training produced gradients which peaked at the frequency correlated with reinforcement. Thus stimulus control was established only when a differential reinforcement procedure was used.

In most experiments on stimulus control the stimuli selected for study lie on a definable continuum. In some cases, however, the stimuli do not appear to lie along any easily definable continuum. For example, the stimuli of the present study, which differ only in whether they face to the left or to the right, do not seem to fall along a continuum of left-right directionality. There appear to be only two values on the left-right dimension; in relation to the organism, stimuli may face to the left or to the right. In the case of such stimuli, stimulus control cannot be assessed by measuring response probabilities during several test values from the continuum as is commonly done with stimuli falling along definable continua. Instead stimulus control is estimated with reference to the two values. For example, in a left-right discrimination task (ie., one stimulus is pointing to the right; the other, to the left) stimulus control can be assessed by comparing the probability of responding to the positive stimulus and the probability of responding to the negative stimulus. If the organism responds differentially during presentation of the left and right stimuli, it may be said that he is under the control of the left-right dimension.

Both psychologists and educators have been interested in determining how children's behaviour comes under the control of the left-right aspect of objects. The concern of educators with this problem results from the observation that the left-right aspect of printed letters and words does not control the behaviour of many children who are learning to read. Such children may incorrectly identify the letters b-d and p-q and may read for example, "bog" instead of "dog". In addition, these children may not read across the page in a consistent left-right direction. For example, "was" may be read as "saw" and "scared" may become "sacred". Some children persist in making these reversals long after the majority of children have learned to attend to the directional component of letters and words. Some educators (e.g., Teegarden, 1932; Wolfe, 1939) have suggested that the persistence of reversals in reading is one of the major symptoms of reading retardation and may be even the primary factor.

2. Normative Studies on Left-Right Discrimination in Children

Several studies have shown that the behaviour of many preschool and kindergarten children is not under the control of the left-right aspect of objects. Newhall (1937), for example, showed pictures including those of a chair, boat, rabbit, and horse to three- to five-year-old children. The children were instructed to select from the tray before them a cut-out block figure identical to the picture being presented. The figures were arranged on the tray so that they were rotated in either a left-right or an up-down direction from the sample. After the S identified the matching cut-out by handing it to the E, the E then handed back the form rotated in either an up-down or left-right direction from the sample. The S was asked to place it the "same" as the picture on the chart. While the children matched blocks to chart pictures almost without error, they did not always correctly place the objects handed back by the E, particularly when the objects were reversed in the left-right direction. When the blocks were rotated in the up-down direction, approximately 80 percent of the blocks were correctly placed. When the blocks were reversed in the left-right direction, correct placements ranged from 17 percent to 27 percent over Ss.

Gibson, Gibson, Pick, and Osser (1962) studied four- to eight-year-old children. Their Ss were required to choose from twelve stimuli, the stimulus which was the "same" as the sample. Among the comparison stimuli were several rotated transformations of the sample stimulus including a 45-degree rotation, a 90-degree rotation, a 180-degree rotation, and a left-right reversal. Approximately 45 percent of the left-right reversals were selected by the four-year-olds; 15 percent by the six-year olds; and 5 percent by the eight-year-olds.

In another study, Wechsler and Hagin (1964) evaluated the extent to which children in the first grade and the third grade of school discriminated between objects having different orientations. A six-choice matching-to-sample task was used. The stimuli were asymmetrical figures roughly shaped like lamb chops. The five incorrect comparisons included a 90-degree rotation, a left-right reversal, an up-down reversal, a 180-degree reversal, and one of either the combined 90-degree - left-right reversal or the 90-degree - up-down reversal. It was found that first grade *S*s incorrectly selected the left-right reversal of the sample on 13 percent of the trials, while the third-grade *S*s selected the left-right reversal on 3 percent of the trials.

Another study by Rudel and Teuber (1963) employed simultaneous discrimination tasks involving up-down rotations and left-right reversals of a U-shaped figure. The *S*s were four- to eight-year-old children. The *S*s were told after every trial whether their choice had been correct or incorrect. Criterion for each task was 10 successive correct responses in 10 trials. It was found that nearly all the three- to eight-year-old children reached criterion when they were required to discriminate between "⊓" and "⊔". However, approximately 85 percent of the three-, four-, and five-year-olds did not learn to discriminate between the left-right reversals, "⊏" and "⊐". After schooling began there was a considerable improvement in the acquisition of the left-right discrimination; approximately 33 percent of the six-year-olds and 85 percent of the eight-year-olds reached criterion on the task.

Swanson and Benton (1955) attempted to determine the extent to which children of ages five to nine years correctly identified the right-left parts of their own body and the body of a picture of a front view of a male child. Such commands as "Show me your right hand." and "Show me the left leg of the boy." were given. It was found that some children were fairly consistent in labelling left as right and vice versa. Thus, over *S*s, the correct verbal labelling scores were less than the "discrimination" scores which included credit for consistent incorrect labelling. Consideration of the "discrimination" scores indicated that for children of all ages the identification of the body parts of the boy in the picture was more difficult than the identification of the parts of their own body. The percentage of correct responses for the self-identification and the other-identification tasks were, respectively, 71.5 percent and 52.0 percent for the six-year-olds, 86.8 percent and 56.0 percent for the seven-year-olds, 89.7 percent and 69.0 percent for the eight-year-olds, and 93.6 percent and 80.8 percent for the nine-year-olds.

In studies in which alphabet-letters have been used as stimuli, it generally has been found that preschool children, and to a lesser extent school children, have difficulty in discriminating between the letter-pairs b-d and p-q. In a study by Davidson (1935), one of the sample letters d,e,p,q, or b was printed on the left side of each sheet of paper. To the right of the sample letter were four rows of ten letters, including five identical forms, five rotated forms, several letters similar in shape to the sample, and a number of other letters. Subjects were required to cross out letters which were the "same" as the sample. Davidson found that approximately 90 percent of the kindergarten children incorrectly crossed out one or more of the reversed comparison letters when the sample letters were d,p,b, and q. A smaller, but substantially large percentage (approximately 60 percent) of first-grade children made identical errors.

Popp (1964) reported similar findings with five- and six-year-old kindergarten children. In a two-choice matching-to-sample task, each letter of the alphabet served as the sample with one of each of the other 25 letters as the incorrect comparison. It was found that the children made the most errors with the pairs b-d and p-q. Approximately 35 percent of the children made incorrect matches when b or d were the samples and d and b were the comparison stimuli. Approximately 38 percent of the children made similar errors when p or q were the samples and p and q were the comparison stimuli.

A number of studies have indicated that difficulties with these letter-pairs still occur, but to a lesser extent, after several months of reading instruction (Hill, 1936) and even in higher grades (Kennedy, 1954; Wilson and Flemming, 1938). For example, Kennedy used a matching-to-sample task with single letter samples such as p, d, and t and 12 comparison stimuli including 3 correct ones and 3 of each of the inverted, reversed, and inverted-reversed rotations. It was found that Ss in the first grade of school incorrectly selected 30 percent of the reversed comparison stimuli. At the end of grade two, the Ss chose 3.3 percent of these incorrect items.

3. Experimental Attempts to Teach Right-Left Discriminations

The preceding studies show that the behaviour of young children often is not under the control of the left-right aspect of stimuli. Since it is necessary that children learn to discriminate between left and right in order to perform adequately such tasks as reading and following directions, considerable attention has been paid to devising methods to teach children this discrimination. The previously mentioned study of Rudel and Teuber (1963) clearly indicated that in a simultaneous discrimination task, simply telling the S after each trial if he was correct or incorrect does not ensure that the S's behaviour will come under the control of the left-right aspect of the stimuli. A number of other researchers have devised and tested somewhat more elaborate methods to teach this discrimination.

In a study by Jeffrey (1958), two methods of teaching a left-right discrimination to preschool children were compared. The Ss were shown on each trial a stick figure with one of its arms at its side and the other arm pointing either to the left or to the right. For the first teaching method Ss were instructed to label the stick figures according to which way the arm pointed. They were told to call the figure with the arm pointing "in this way, Jill", and the figure with the arm pointing "this way, Jack". These instructions were repeated at intervals from 10 to 20 trials. Only 3 of 14 Ss reached the criterion of 10 successive correct labelling responses; they required 30 to 40 trials. A second group had 20 trials identical to the trials received by the previous group throughout the task. The Ss not reaching criterion on this labelling phase received trials on which they were required to push a button in the direction in which the stick figure was pointing. After a criterion of 10 successful correct responses the Ss then returned to the labelling task. Five Ss reached criterion on the initial labelling phase. Seven of the eight Ss who did not reach criterion on the initial labelling reached criterion on the labelling after they had received the button-pressing trials. The number of trials (including the initial labelling and the button-pressing trials) required by these seven Ss to reach criterion ranged from approximately 40 to 80 trials. Consideration of the data suggests that the Ss made a lower percentage of errors on the button-pressing trials than on the labelling trials which followed.

Jeffrey suggested that the superior performance of the second group resulted from the labelling task being preceded by a "simpler" task, in this case differential pressing. According to Jeffrey, success in learning to respond differentially to stimuli differing in orientation depends upon the nature of the discriminatory response to be learned. Certain discriminatory responses such as differential pressing are easier to learn than are others such as differential labelling. Having the Ss initially learn a "simpler" discriminatory response (in this case differential pressing) facilitates later learning of more "difficult" discriminatory responses such as labelling. Jeffrey does not clearly explain the mechanisms of this facilitation. However, it has been suggested (e.g., Fellows, 1966) that button pressing facilitated the later labelling by making the stimuli more "distinctive". According to this view, considerably different kinesthetic cues resulting from reaching to the left or to the right were associated with each stimulus. Thus each stimulus became more "distinctive" and the later attaching of labels to the stimuli was facilitated. In the case of Ss who had the verbal labelling task throughout, this task was not learned by many Ss because there was no initial differential pressing which would make the stimuli "distinctive" enough for correct labelling.

A later study by Hendrickson and Muehl (1962), however, casts doubt upon the interpretation that the benefits of Jeffrey's pressing method resulted from different kinesthetic cues being associated with each stimulus. In this study kindergarten children served as Ss. There were two main experimental groups. The stimuli for the first group consisted of the letters b and d, below which were printed arrows always pointing outward (ie., $\underset{\leftarrow\rightarrow}{b}$, $\underset{\leftarrow\rightarrow}{d}$). In the case of the stimuli for the second group, half of the letters shown had the arrows below them pointing outward (i.e., $\underset{\leftarrow\rightarrow}{b}$, $\underset{\leftarrow\rightarrow}{d}$) while the other half of the letters had the arrows pointing inward (i.e., $\underset{\rightarrow\leftarrow}{b}$, $\underset{\rightarrow\leftarrow}{d}$). In the training phase the letters were presented successively. The Ss were required to indicate which arrow below the letter pointed the same way as the letter by pushing the right handle if the correct arrow was on the right side and the left handle if the correct arrow was on the left side. For the first group correct responding involved a consistent left arm response to the letter d and a consistent right arm motor response to the letter b. For the second group the correct arm responses to the letters were inconsistent; for example, the left arm response was required on half the presentations of d; the right arm response on the other half. After 30 training trials a paired associate transfer task was administered. The anticipation method was used. The child was required to learn which picture, a pumpkin or a snowman, was associated with each letter.

If the benefits of the handle pushing method, and thus presumably Jeffrey's button pressing method, resulted from different kinesthetic cues being associated with each stimulus, it would be expected that the first group would perform better on the transfer task than would the second group. Presumably, in the case of the former group the complex of kinesthetic cues resulting from reaching to the left would be associated with one stimulus while the complex of cues resulting from reaching to the right would be associated with the other stimulus. In the case of the latter group, the kinesthetic stimuli produced by reaching both to the left and to the right would be associated with both stimuli. The results, however, indicated that there was no significant difference between the performance of the groups. In both groups 12 of 16 Ss learned to select the correct picture (ie., pumpkin or snowman) for each letter. As might be expected, the first group made a significantly lower percentage of errors in the training tasks than did the second group. However, in the transfer tasks there was no significant difference between the groups in the percentage of errors. Hendrickson and Muehl concluded that methods which require the Ss to indicate the directional aspect of letters and arrows by pushing a handle or button with the hand toward which the stimuli are facing are effective because they ensure that the Ss attend to the directional aspect of the stimuli. Methods which require the Ss to indicate the directional aspect of the stimuli in other ways including inconsistent hand movements similarly ensure that the Ss attend to the direction in which the stimuli are facing.

It would seem that the experimental techniques of Hendrickson and Muehl and particularly Jeffrey were effective in ensuring that a high percentage of Ss learned the left-right discrimination. However, it is possible that at least some of the Ss who reached criterion in these studies did not perform without a number of errors. While it is not clear from Jeffrey's data how many errors were made by the various Ss who were given the button pressing task, consideration of the number of trials required by the Ss to reach criterion would suggest that in the button-pressing stage and particularly in the labelling task which followed, at least some Ss may have made a number of errors. In the case of the study of Hendrickson and Muehl it is even more difficult to estimate from the data provided how many errors were made by the Ss who reached criterion. Results from all the Ss in both groups indicated that in the transfer trials, the group who made the movement consistent with the direction of the letter were correct on 83 percent of the trials, while the other group, who made the inconsistent movement, were correct on 76 percent of the trials. The standard deviation for both groups was approximately 19 percent. Consideration of these means and standard deviations would suggest that it is possible that some of the *S*s who reached criterion may have made a number of errors.

A number of studies have attempted to devise techniques which, in addition to enabling a high percentage of *S*s to learn the left-right discrimination, would ensure that the *S*s performed with a minimum of errors. In these studies the differences between the stimuli were initially exaggerated and then gradually reduced until the final forms were reached. The methods of these studies are based on the techniques of Lawrence (1952) and Terrace (1963a, 1963b). Lawrence showed that the most efficient way of establishing a discrimination was to devote the early training trials to "easier" discriminations on the same continuum of stimuli as the final discrimination. Rats which received simultaneous discrimination training in four stages, from a dark gray-light gray discrimination to the final discrimination between two slightly different shades of gray, were able to achieve criterion on the final discrimination in fewer trials (trials on the earlier discriminations were counted) than rats who received their practice solely on the final discrimination. Lawrence's transfer on a continuum method has yielded similarly successful results in a variety of studies. For example, Baker and Osgood (1954) found that the most efficient way to establish a pitch discrimination was to approach the task in steps of increasing difficulty. Similarly House and Zeaman (1960) showed that discrimination training on three dimensional stimuli prior to training on two dimensional patterns produced faster learning of the two dimensional discrimination than did training on the two dimensional patterns alone.

Terrace showed that a difficult successive discrimination could be acquired with no or few errors if the difference between the positive and negative stimuli was initially large and was reduced very gradually. Terrace further observed that the reduction in errors produced by a very gradual fading sequence eliminated the occurrence of a number of possibly undesirable effects. In one experiment (Terrace, 1963a) pigeons learned a difficult discrimination without making errors (ie., responses during the non-reinforced negative stimuli) when the negative stimulus was introduced just after responding during the positive stimulus was conditioned. In this study the negative stimulus, in addition to differing in wavelength, was dimmer and shorter in duration than the positive stimulus. The brightness and duration of the negative stimulus was progressively increased until the brightness and duration of the positive stimulus were reached. The Ss who received the fading sequence after they were exposed to the positive stimulus for a period of time did not exhibit "errorless" performance. Similarly, the Ss who received the final value of the stimuli throughout training performed with errors. Terrace observed that some of the Ss who performed with errors showed bursts of incorrect responding even after a stable near perfect rate of responding had been reached. The Ss who learned essentially without errors did not exhibit these disruptions in performance. In another experiment Terrace (1963b) demonstrated that the difficult discrimination of the orientation of two white lines could be learned by pigeons without errors when the backgrounds of the two different orientations were of different colours which gradually faded to black. The control Ss who received the final discrimination throughout the trials made many errors. In both the preceding studies it was observed that pigeons who had learned the discrimination with errors often exhibited "emotional" behaviour such as wing flapping in the presence of the negative stimulus. Following "errorless" learning no such emotional responses were observed. Terrace (1966) further noted that when the training technique permits the Ss to make errors, it is possible that responding might come under the control of stimuli other than those which are experimentally manipulated. Under certain conditions permanent faulty performance might result due to an intermittent reinforcement effect. This control of responding by factors beyond the E's control would not occur under an effective progressive procedure.

Terrace's fading method has been applied in a number of teaching programs for children to ensure that discriminations not only are learned, but are learned with a minimum of errors. For example, Sidman and Stoddard (1967) devised a teaching program involving a number of discriminations between circles and ellipses. Over trials the ratio of the vertical and horizontal axis of the ellipses was made to approach one. Using this program retarded Ss learned to discriminate between a circle and an ellipse which were very similar. In another study (Moore and Goldiamond, 1964) involving a matching-to-sample task, children were taught to select from three comparison triangles, the triangle having the same orientation as the sample triangle. The incorrect comparison stimuli, which varied slightly in orientation from the sample, initially were of low light intensity. The light intensity of the incorrect matches was gradually increased to that of the correct match.

While fading methods have been effective in teaching a number of difficult discriminations, attempts to produce a fading sequence which would ensure that children would acquire the left-right discrimination have not been particularly successful. In one of these attempts, Karraker (1968) investigated both the progressive-constant variable and the early-late introduction of the negative stimulus. Both the progressive and constant groups received two sessions, each involving two phases.

The first phase of each session was identical for the constant and progressive groups. A set of seven slides was shown at each session. There was a different set for each session and only one letter was shown in each set. The first slide of the set showed either an orange b or green d accompanied by a drawing of a bat and ball in the case of b or a dog in the case of d. An arrow pointed either to the drawing or to the letter. In the case of the letter b when the arrow pointed to the drawing, _S_s were to say "bat and ball", and when it pointed to the letter, "b, as in bat and ball". Over the series of slides the letter which was being shown in the series and its associated drawing decreased in size and faded to black. By slide seven the drawing had been faded out, and there remained a black, lower-case letter.

The second phase of each session involved successive presentations of the letters b and d. In one session one letter was defined as the positive stimulus; in the next session the other letter was positive. The negative letter was introduced after either 1 trial or 23 trials of the positive letter. In the constant groups, black lower-case letters were presented throughout the trials. In the progressive groups the positive letter was in the black lower-case form. The negative letter was faded in along four dimensions (size, duration of exposure, colour, presence of drawings). It initially was larger than the positive letter and had a shorter duration of exposure. Depending upon whether the letter was a "b" or "d" it was coloured orange or green and was accompanied by drawings of either a bat and ball or a dog.

After both phases had been completed in both sessions, there was a criterion session of 14 simultaneous b-d discriminations followed by 62 randomly alternated presentations of the black lower-case letters. In the 14 slides of the simultaneous phase, an arrow pointed to the positive stimulus, the one the child had to identify. The letters differed in colour, with the d coloured green and the b, red. In addition, the positive letter also was larger than the negative one. The positive stimulus gradually was reduced in size while the colour of both stimuli faded to black. In the successive phase of the criterion session the Ss were required to name the letters which were in black lower-case form.

Consideration of the mean errors on criterion trials of the four groups showed that the time variable was significant, whereas the progressive-constant variable was not significant. The number of Ss emitting fewer than 10 percent errors was for each group: Early-Progressive 13/16, Early-Constant 11/16, Late-Progressive 6/16, Late-Constant 4/16. Due to the design of the study it is not possible to estimate whether many Ss who learned the discrimination under the progressive procedure might have required fewer trials to acquire the discrimination under a simple differential reinforcement procedure. This possibility is great in that the Ss ranged in age from 5.5 years to 6.6 years with a mean age of 5.9 years. According to the previously mentioned study of Rudel and Teuber (1963) the percentage of Ss who learned quickly to make a left-right discrimination increased greatly from ages five to six. Thus it is possible that a number of

Ss would have acquired the discrimination after very few trials. It would seem that a better test for a fading procedure would employ Ss in both control and fading groups who did not discriminate between reversed forms during some kind of baseline procedure.

Schutz (cited by Karraker, 1968) was unsuccessful in teaching the b-d discrimination with both light and colour fading, but was somewhat more successful with structural fading when the negative letter initially was filled in (b) and gradually was modified to achieve the normal form (b).

Bijou (1963) also reported an experiment involving structural fading. Both normal and retarded children were used as Ss. In a matching-to-sample task involving five choices, a deformed version of the mirror-image of the sample nonsense shape was introduced as one of the choices and was altered gradually over trials to achieve a final mirror-image form. For example the incorrect "mirror" comparison stimulus for the sample stimulus was progressively modified from to the final reversed form by gradually moving the lower bar upward.

Although Bijou's study often is cited as an example of successful teaching of the left-right discrimination, the program was not effective for all Ss; Ss varied considerably in the extent of their progression through the program. In fact, it is not too clear from the study what percentage of the Ss were successful. While a short pretest involving no reinforcement was given, there was no control group or any form of reinforced baseline procedure. These omissions question any claim for the success of the fading method, as there is no way of estimating how many of the Ss would have learned the left-right discrimination under a simple differential reinforcement procedure - perhaps in fewer trials than were required with the progressive procedure. This possibility is great in that many of the normal Ss were five or six years of age and came from a medium-high socioeconomic level. In addition, many of the retarded Ss had mental ages of greater than six years. Furthermore, a matching-to-sample task may be easier than the simultaneous or successive discrimination tasks which were used in the previously mentioned fading experiments.

In summary, the previously mentioned training methods have not been effective in ensuring both that a high percentage of Ss learn the left-right discrimination and that the performance of these Ss is essentially "errorless". Rudel and Teuber (1963) showed that simply telling the S after each trial if he was correct or incorrect was ineffective in teaching the majority of preschool children to make the discrimination. In the case of the methods involving arm movement (ie., Jeffrey, 1958; Hendrickson and Muehl, 1962), it was found that these techniques, particularly the method of Jeffrey, taught a high percentage of Ss to make the left-right discrimination. However, as mentioned previously, it would seem possible that the performance of at least some of these Ss was not without a number of errors. With regard to the fading techniques of Bijou (1963), Karraker (1968) and Schutz (1964), none of these methods appears to have been effective in teaching the left-right discrimination to a high percentage of Ss. It is impossible to determine from the data presented by Bijou (1963) and Karraker (1968) whether Ss who learned the discrimination made very few errors. It would seem possible, however, that at least some of the Ss made a number of errors.

4. Purpose of Present Research

The purpose of the present research project was to develop a method which would ensure that a large percentage of preschool children acquire quickly and with a minimum of errors a discrimination involving the letters b and d. Two preliminary studies are reported in Chapter II. The principal experiment of this project is reported in Chapter III.

CHAPTER II PRELIMINARY STUDIES

1. Preliminary Experiment I

This study employed structural fading of the negative letter (S-) in a simultaneous discrimination task. The circular part of the negative letter, either b or d of the pair b-d, initially was absent and gradually was introduced. Two extensions from the stem were increased gradually until they met to form the circular part of the letter. It was thought that by having the circular part of the letter grow from the stem outward, this fading sequence might ensure that the child's behaviour would come under the control of the directional aspect of the letter.

Method

Subjects

The *S*s were 6 children from a Vancouver day care centre. The children ranged in age from four years, four months to six years, one month with a median age of five years, one month.

Materials and Apparatus

Cardboard cards with the sample letter b or d printed above the comparison letters b and d were used during the pretest. During the simultaneous discrimination phase the cards used showed both letters for the constant group and one letter and a stage of fading of the second letter for the progressive group. All the letters or near letter-shapes were printed in black ink on white cards. The letters were 5.0 inches in height and a maximum of approximately 2.5 inches in width. Figure 1 shows examples of the stimuli used for the progressive group. The letter d is shown as the positive stimulus (S+). Steps 2, 3, 14, and 20 of the progressive modification of b (S-) are shown. The positive letter was alone in step one; then in step two the stem of the negative letter also was shown. Over the next 19 steps the circular part of the negative letter was introduced gradually from the stem outward. The two extensions from the stem were increased gradually so that their combined lengths were 0.35, 0.40, 0.50, 0.60, 0.65, 0.70, 0.75, 0.80, 0.83, 0.86, 0.88, 0.90, 0.92, 0.94, 0.96, 0.98, 0.99, 0.995 and 1.00 times the circumference of the circular part of the letter.

Design and Procedure

There was a pretest of eight non-reinforced matching-to-sample trials. Children not achieving four

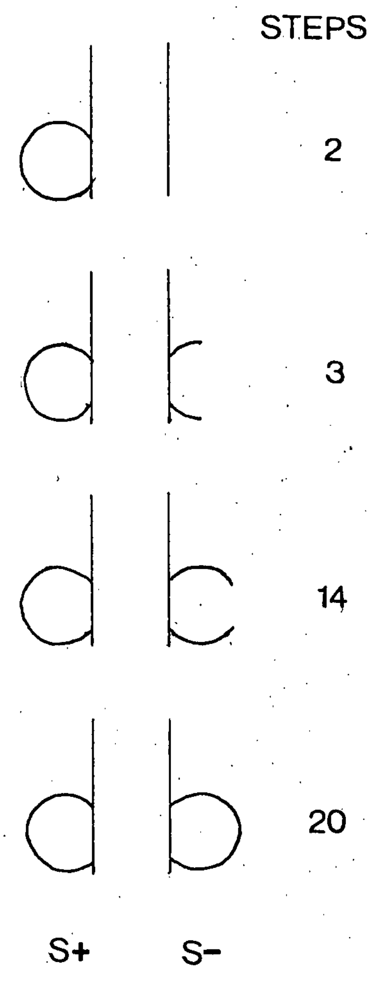


Figure 1. Positive stimulus d and steps 2, 3, 14 and 20 of the progressive modification of b.

successive correct matches during the pretest were assigned randomly to the control and experimental groups. For half of the Ss in each group b was the positive stimulus (S+). For the other half of the Ss, d was the positive stimulus. The Ss then received simultaneous discrimination trials. Subjects were instructed that one of the letters would be correct throughout the trials and they should indicate their choice by pointing on every trial. The S was told when he was correct or incorrect (ie., "right" or "wrong") and when correct he received a candy (ie., a continuous reinforcement schedule) which was put in a bag for his later consumption. In the progressive group the Ss received a backup procedure when an error was made. Other than for step 1 of the sequence, the S received the fading step appropriate to the preceding step, n-1. This backup procedure continued through n-2, n-3, etc. until the S was correct or reached the first step. Then he received the step succeeding the one upon which he was correct. The stimuli were presented so that the left-right position of the positive stimulus followed a Gellermann series. This randomization was modified in the progressive group when an error was made and there was a backup to the preceding step. Each stimulus presentation was shown until the S made a choice. The intertrial interval was approximately

3 seconds. Trials continued until the Ss reached a criterion of six successive correct responses on the final forms of the letters or until they had received 50 training trials.

Results and Discussion

None of the Ss in either group reached criterion. The control Ss performed at no better than chance level. For two of the three progressive Ss, responding was essentially without errors until the gap in the negative stimulus was closed; then consistent correct responding ceased. Even after there were a number of backup trials to the next to last step followed by progressions to the final value, consistent correct responding on the final values was not achieved. The third progressive S responded at somewhat better than chance level on the first 11 steps of fading. Then he began to make more errors as the gap in the negative letter was reduced in size and he never reached the final form of the negative stimulus.

It would seem that the behaviour of the progressive Ss remained under the control of the open-closed aspect of the circular part of the letter until the gap was made very small or was closed altogether. Then, in the absence of the open-closed feature of the stimulus, correct responding broke down. Similar breakdowns in correct responding toward the end or at the end of the fading sequence was seen in the previously mentioned studies of Bijou (1963), Karraker (1968), and Schutz (1964). In the case of the present study, one possible reason why the behaviour of the children never came under the control of the left-right dimension of the stimuli is that the gap in the negative letter might have been considerably more "distinctive" than the left-right aspect of the letters even toward the end of the fading sequence. According to Piaget and Inhelder (1956) the open-closed aspect of stimuli is one of the first topological features to which the young child attends. Presumably, then, this aspect would be very "distinctive".

2. <u>Preliminary Experiment II</u>

Since the fading method of the first experiment proved unsuccessful, another method which involved rotating the S- letter around the vertical axis was tried. It was thought that by having the negative stimulus gradually turn toward the left or right, this fading sequence might ensure that the children would attend to the direction in which the stimulus was turning and thus their behaviour would come under the control of the directional aspect of the letters.

Method

Subjects

The Ss were 15 children selected from a Vancouver day care centre. The children, ranging in age from three years, six months to six years, seven months, had a median age of five years, two months.

Materials and Apparatus

The stimuli were the letters b, d, p, and q, which measured approximately 7.5 inches in height and 2.0 inches in width. The circular part of each letter was made of thick black cardboard which was inserted in slits in narrow black poles, approximately 0.3 inch in diameter, which formed the stems of the letters. The poles were inserted in thick sheets of wood. Each sheet held a pair of letters, either b-d or p-q.

Procedure

The general procedure of the previous pilot study was followed. There was a pretest of eight non-reinforced matching-to-sample trials. Children not achieving four successive correct matches during the pretest were assigned randomly to the control and experimental groups. For half the Ss in each group b was the S+ letter. For the other half of the Ss d was the S+ letter. Subjects were instructed that one of the letters would be correct throughout the trials and they should indicate their choice by pointing appropriately on every trial. The S was told when he was correct or incorrect (ie., "right" or "wrong") and when correct he received a candy which was put in a bag for his later consumption. Figure 2 shows how the S- letter was rotated over trials for the progressive group. Steps 1, 3, 7, 14, and 19 of the progressive rotation of b are shown. In step one the upright form of the negative stimulus was set so that the circular part of the letter was perpendicular to the front of the body of the S, who was seated facing the letters. The circular part of the letter pointed toward the S. The negative letter was rotated gradually around its vertical axis until the circular part of the letter was parallel to the body of the S. The steps in the rotation from the perpendicular position were 10, 20, 30, 40, 50, 60, 65, 67½, 70, 72½, 75, 77½, 80, 82½, 85, 87, 88½ and 90 degrees. The circular part of the positive letter always was parallel to the front of the S. The constant group received the letters in the final position throughout the trials (ie., the circular parts of the positive and negative letters were parallel to the S and were facing in an opposite left-right direction). The Ss in the progressive group received a backup procedure when an error was made. Other than for step 1 of the sequence, the S received the fading

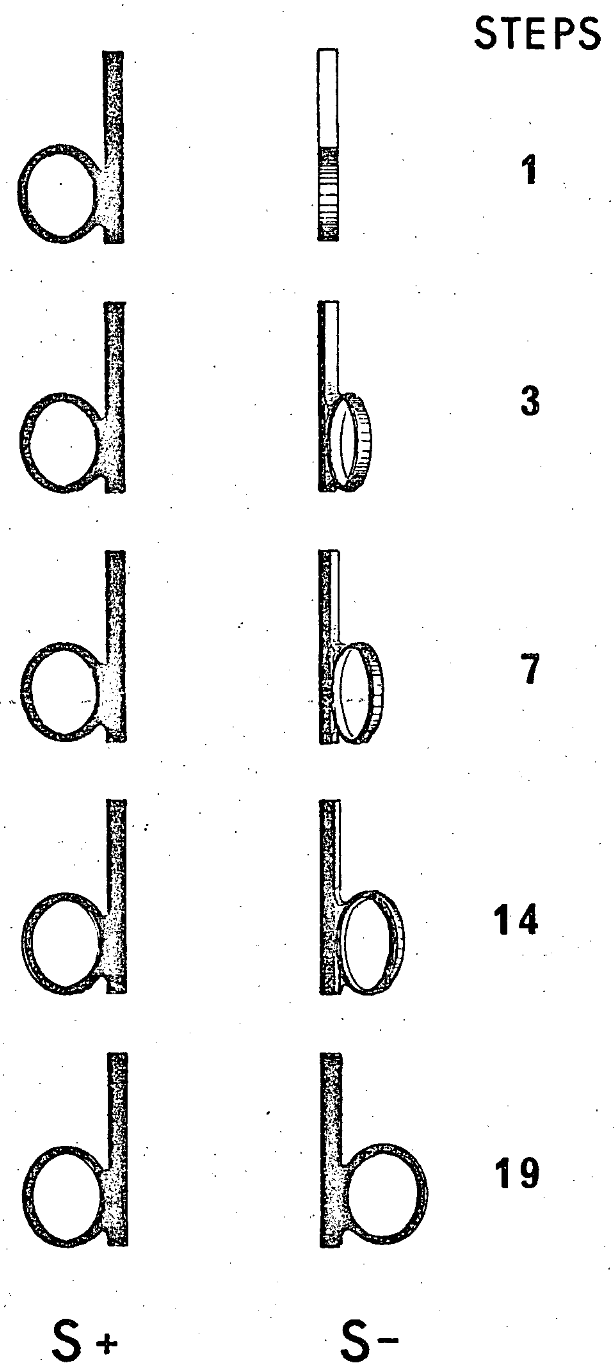


Figure 2. Positive stimulus d and steps 1, 3, 7, 14, and 19 of the progressive rotation of b.

step appropriate to the preceding step, n-1. This backup procedure continued through n-2, n-3, etc. until the S was correct or reached the first step. Then he received the step succeeding the one upon which he was correct. In both groups the stimuli were presented so that the left-right position of the positive stimulus followed a Gellermann series. This randomization was modified in the progressive group when an error was made and there was a backup to the preceding step. Each stimulus presentation was shown until the S made a choice. The intertrial interval was approximately 5 seconds. Trials continued until the Ss reached a criterion of six successive correct responses on the final forms of the letters or until they had received 50 training trials. After the criterion or the cutoff number of trials was reached, Ss received 10 simultaneous discrimination trials with the letters p and q. Criterion on this transfer task was six successive correct responses.

Results and Discussion

One of the eight control Ss and four of the seven progressive Ss reached criterion. A chi square test indicated that the difference between the groups in the number of Ss who reached criterion was not significant ($p<.10$). The Ss reaching criterion showed positive transfer when tested on p and q. The progressive method provided essentially "errorless" learning with only one of the four progressive Ss who reached criterion. Three progressive Ss who reached criterion made a number of errors. Two of these Ss made errors at the final step when the negative letter was in its final position. Several backups to the previous step followed by progressions to the final step were required before consistent correct responding on the final stage was achieved. The third S made errors at various steps throughout the program. Two of the three progressive Ss who did not reach criterion did not reach the final phase of fading. Due to numerous errors throughout the early part of the fading sequence, one of these Ss never went beyond the fourth step of fading. The second S responded correctly up to the last third of the program. Then correct responding broke down and the S never reached the final steps of the fading sequence. The third S reached the final step of fading but did not reach criterion even after a number of backups and progressions involving the final and next to last steps of the program.

While the fading procedure of this study was more effective than that of the first, the percentage of Ss (approximately 43 percent) who did not reach criterion was still high. It should be noted that, as in the first study, the behaviour of some Ss appeared to be under the control of the letters up to the last part of the program or the final step of fading. Then successive correct responding broke down and in some cases could not be regained even after a number of backups and progressions. According to Terrace (1966) such breakdowns in responding are observed when there has been an abrupt reduction of reinforcement density in the positive stimulus, when there have been large steps in the progressive change of the negative stimulus, particularly on the final steps, or when the dimension along which the values of the stimuli were changed was "inappropriate". Terrace is in no way precise as to what is meant by an "appropriate" or "inappropriate" dimension. As an example of fading along an "inappropriate" dimension Terrace cites a study involving training a group of pigeons to make a horizontal-vertical line discrimination. In this study the intensity of S- was increased gradually to that of S+. Whereas the previously mentioned fading from the discrimination of colour to the orientation discrimination was an effective procedure, the fading of light intensity was not. Discrimination performance was perfect until the last few increases in intensity, at which point consistent correct responding broke down. In the case of both preliminary studies there was no reduction in reinforcement density and the difference between the final steps of fading was very small. Thus it would appear that the failure of these fading sequences was due to the faded dimensions being "inappropriate".

It is possible to consider that an "appropriate" fading dimension might be one that is "relevant" to the final discrimination. For example, in the case of the experiments of Lawrence (1952) and Baker and Osgood (1954), the dimension which was progressively modified contained the values involved in the final discrimination. For example, in the latter study the final pitch discrimination was established after earlier training trials on "easier" pitch discriminations. In cases such as this, the faded dimension would seem to be very "relevant" to the final discrimination. Another example of "relevance" might occur when the faded dimension and the dimension containing the final discriminative stimuli are frequently associated; that is, stimuli falling along one of the dimensions often will have values along the other dimension. For example, a note of a certain pitch also will have a certain loudness. Thus, the dimension of sound frequency might be "relevant" to the dimension of sound intensity, and fading along one of the dimensions might facilitate learning a discrimination involving the other. An example of this type of "relevance" might be seen in the fading sequence of Terrace (1963a). As may be recalled from Chapter I, part of the fading in this experiment involved the gradual modification of the brightness of the negative stimulus until the stimuli differed only in wavelength. As stimuli of different wavelengths have values on both the wavelength and brightness continua, discrimination learning between different wavelengths might have been greatly facilitated by the gradual modification of brightness. It is obvious that there must be a variety of complex ways in which one dimension might be "relevant" to another dimension. In addition, the degree of "relevance" between two dimensions would seem to vary greatly.

Except in the case when the fading is done along the dimension of the final discrimination, there would appear, at this point, to be no _a priori_ method of determining whether and to what extent the faded dimension is "relevant" to the final discrimination. Since there seems to be no definable continuum of left-right directionality, the devising of a fading procedure which would be "relevant" to the left-right letter discrimination would seem to depend upon a "trial and error" approach.

The experiment reported in Chapter III is another attempt to devise a fading procedure which would be effective in establishing a right-left letter discrimination.

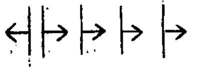
3. Summary

This chapter reported two preliminary attempts to develop a method which would teach preschool children to discriminate between the letters b and d quickly and with a minimum of errors. In both studies there was fading of the S- letter in a simultaneous discrimination task. Children who did not reach criterion on a pretest matching-to-sample task involving the letters b and d served as Ss. During training trials the children were reinforced with candy after each correct response. In both studies control Ss received the final form of the letter stimuli throughout the trials. For the progressive Ss in the first study, the circular part of the negative letter was initially absent and then gradually was introduced over trials. None of the progressive or control Ss reached criterion on the b-d discriminations in this experiment. In the second study three dimensional letters were used. For the progressive Ss the upright form of the negative letter initially was set so that the circular part of the letter was perpendicular to the front of the body of the S, who was seated facing the letters. The circular part of the letter pointed toward the S. The negative letter was rotated gradually around its vertical axis until the circular part of the letter was parallel to the body of the S. The circular part of the positive letter always was parallel to the front of the S. Slightly more than half the progressive Ss reached criterion on the b-d discrimination in this experiment. However, the majority of the progressive Ss who reached criterion made a number of errors.

Reasons as to why a fading program might not be very effective was discussed. It was concluded that the fading in both these studies was not done in a manner that was "relevant" or "appropriate" to the final discrimination.

CHAPTER III MAIN EXPERIMENT

1. Introduction

This experiment involved another attempt to develop a fading method which would be effective in establishing a left-right letter discrimination. As previously mentioned, there would appear, in many cases, to be no *a priori* method of determining whether and to what extent a fading sequence is "relevant" to the final discrimination. However, a recent study by Underwood (1971) suggested a method of fading which intuitively would seem to be particularly "relevant" to the left-right discrimination. In Underwood's study, *S*s were required on each trial to indicate which of the five stimuli shown was not the "same" as the rest. There were four principal phases in this "oddity" task. In the first phase the stimuli were arrows extending to the left or right from the mid-point of vertical lines (ie., ). In the second phase the arrows were replaced by ovals (ie., ). In the third phase the ovals were replaced by circles. The circles, however, were still in the middle of the vertical line. In the final "criterion" phase there were four sets of "oddity" problems, one set for each of the four combinations b-d, p-q, b-q, d-p. In this phase the circular part of the letters was in the usual position at the bottom of the stalk. To reach criterion Ss had to achieve 6 successive correct responses or 9 correct responses in 10 trials in each of the four sets. Although this method did not in any way provide "errorless" learning (for example, one S took 395 trials to reach criterion), 8 out of 10 Ss reached criterion.

This study can be criticized in that although a pretest was used, a reinforced baseline level of performance was not established for the Ss and there was no control group. As the Ss were five and six years of age, the likelihood that many of them could have learned the discrimination with a usual reinforcement procedure might have been high, particularly as there were many trials spread over a number of sessions.

The present study incorporated arrow discriminations into a fading program. A two-choice matching-to-sample task was used. Subjects who did not reach criterion on baseline trials involving the b-d stimuli were assigned to the control and experimental groups. The control Ss received the b-d stimuli throughout the training trials. The progressive Ss first received matching-to-sample trials involving arrows pointing either to the left or to the right. Subjects reaching criterion on the arrow stimuli received a fading program involving a gradual progression from arrows to final letter-forms. The Ss who did not reach criterion on the arrow discriminations received matching-to-sample trials with simultaneously moving arrows. The arrows intitially were moved vertically and later horizontally. The distance of the horizontal movement of the arrows gradually was reduced until the arrows were stationary. The Ss then received the previously mentioned fading sequence from stationary arrows to final letter-forms.

2. Method

Subjects

The Ss were 25 children from Vancouver and Burnaby day care centres. Shown in Table 1 are the age and sex of each of the Ss. The Ss are listed in 3 groups, Baseline Only, Control, and Progressive. These groupings are the result of the experimental procedure. The ages of the Baseline-Only Ss ranged from four years, four months to six years, four months with a median age of five years, seven months. The ages of the nine Control and nine Progressive Ss ranged, respectively, from four years,

TABLE 1

Age and Sex of Subjects in the Different Conditions

	Subject Number	Sex	Age Years	Months
Baseline Only	7	Female	4	4
	2	Male	4	4
	1	Male	5	4
	3	Male	5	7
	5	Female	5	9
	6	Female	5	11
	4	Male	6	4
Control	9	Male	4	3
	11	Male	4	5
	14	Female	4	5
	13	Male	4	8
	12	Male	4	10
	8	Female	5	0
	10	Female	5	5
	15	Male	5	10
	16	Male	5	10
Progressive	23	Female	4	3
	20	Male	4	7
	17	Female	4	9
	19	Female	4	9
	21	Male	4	9
	22	Male	4	9
	18	Male	5	9
	25	Female	5	9
	24	Male	6	0

three months to five years, ten months and from four years, three months to six years, zero months. The median ages of the Control and Progressive groups were four years, ten months and four years, nine months.

Materials and Apparatus

The letters b-d or p-q, arrows pointing to the left and right, and the stimuli for the fading sequence were printed in matching-to-sample form on white cardboard cards. For the b-d, p-q, and arrow stimuli there were cards for each of the four combinations of the two possible samples and the two possible positions of the correct match on the card (either on the left or on the right). The cardboard cards measured approximately 12.0 inches by 16.0 inches. Figure 3 shows the various phases in the fading sequence from thick stationary arrows to the final letter forms. The letters and numbers in brackets indicate, respectively, the abbreviated name of each phase and the number of steps in each phase. In the width phase (Wid) the width of the arrows was reduced over 6 steps. Then, in the separation phase (Sep) of 5 steps, the vertical separation between the shafts of the arrows was increased. The stalk of the arrows then was introduced gradually in the stalk phase (Sta), which involved 10 steps. In the next phase, the head phase (Hea) of 7 steps, the head of the arrows was gradually

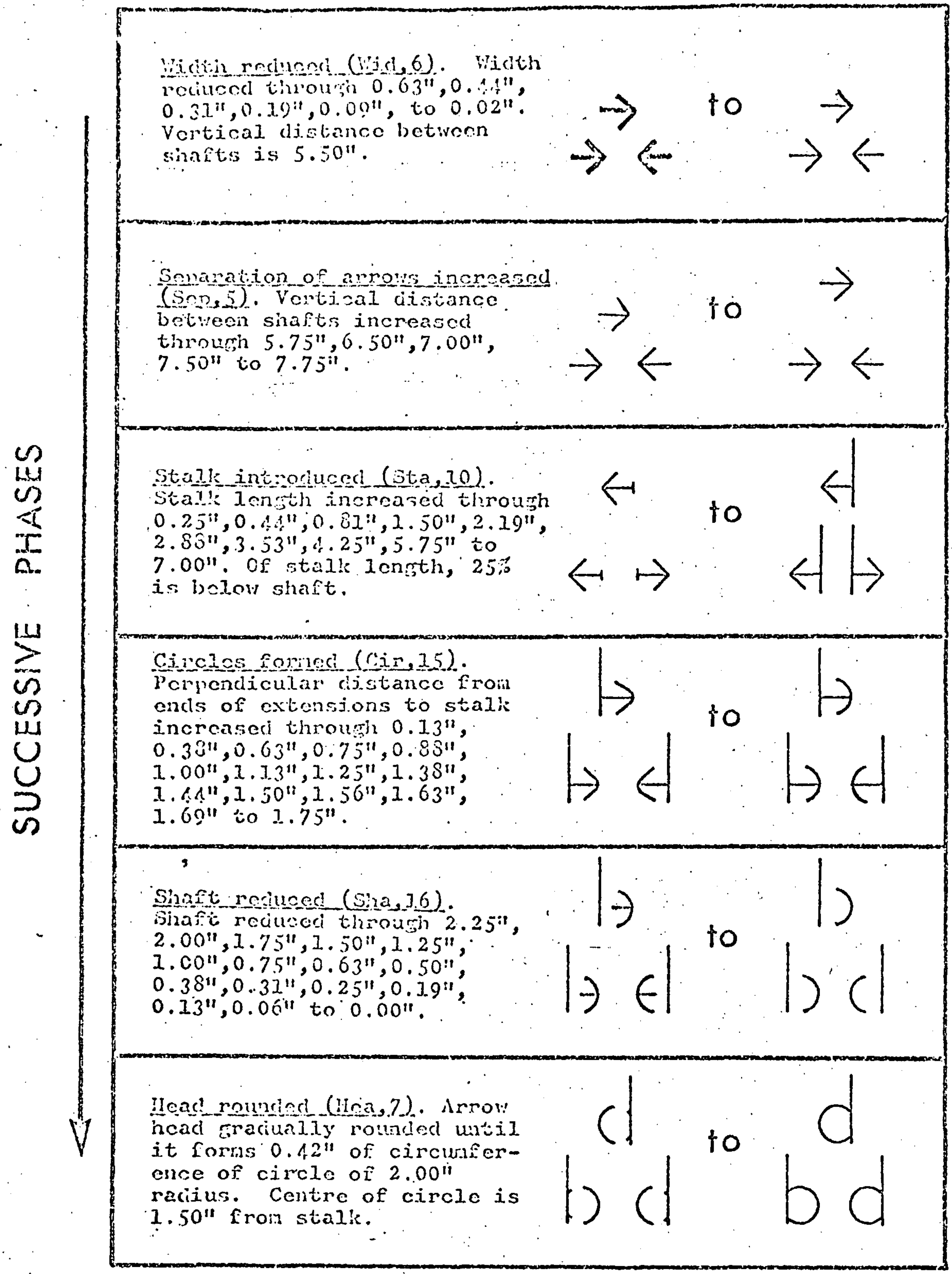


Figure 3. Summary and illustration of the phases in the progression of the stimuli from thick stationary arrows to final letter-forms. The letters and numbers in the brackets indicate, respectively, the abbreviation for each phase and the number of steps in each phase.

rounded. Then in the shaft phase (Sha) of 16 steps the length of the shaft of the arrow was reduced until the shaft disappeared. In the final phase, the circles phase (Cir) involving 15 steps, the circular part of the letters was completed by increasing gradually the length of two extensions from the stem outward until the extensions met.

The moving arrows were arranged by having arrow forms move along slits in a 48.0 by 12.0 inch plywood board. An upper slit in the board 2.5 inches from the top measured 44.0 inches by 0.6 inch. Four and one-half inches below the slit were two slits each 22.0 inches by 0.5 inch. The lower slits were separated horizontally by 2.0 inches. Arrows made of thick black cardboard were inserted into the slits so that the head of the arrow was in front of the slit while the shaft of the arrow showed through the slit. The arrows measured 4.0 inches in length. Each side of the head of the arrow was 2.7 inches long. The angular separation of the head of the arrow was approximately 86 degrees. The width of both the head of the arrow and the stalk which showed through the slit was 0.6 inches. It was arranged so that the <u>E</u> could move three arrows simultaneously from behind the plywood.

Procedure

Figure 4 provides a summary of the procedure which is outlined below.

<u>Baseline trials and general procedure</u>. Subjects were brought individually into a private room in the day care centre and seated in a chair so that the E was facing the child across a table. Each child had baseline trials which involved matching the normal p-q forms for the first 5 trials and the final b-d forms for the remaining trials. When the first card was shown, the child was asked to "point to the picture which was or did the same thing or was like the picture on the top". The child was told that the first picture he pointed to would be considered his final choice. He was instructed that he would be told when he was correct or incorrect (ie., "right" or "wrong") and every once in a while, when he was correct, he would receive a candy which would be put in a bag for his later consumption. If the child chose the correct letter on the first trial the E said "right" and put a candy in the child's bag. If the child was incorrect another card identical to the first was shown. The E said, "Try the other side". After the first successful trial the next card of the series was shown and the E urged the child to "try to be right every time". The E then made no further explanatory comments unless the child said he did not

BASELINE (All Ss)

- Reinforced matching-to-sample with p and q - 5 trials.

- Reinforced matching-to-sample with b and d. Trials until criterion of 10 successive correct responses or cutoff of 25 trials (If S correct on trial 25, more trials until error made or criterion reached). Ss 1 to 7, who reached criterion, received transfer trials. Remaining Ss randomly assigned to either Control or Experimental Condition.

Control Condition
(Ss 8 to 16)

- Reinforced matching-to-sample with b and d. Trials until criterion of 10 successive correct responses or cutoff of 150 trials (If S correct on trial 150, more trials until error made or criterion reached).

Experimental Condition
(Ss 17 to 25)

- Reinforced matching-to-sample with stationary arrows. Trials until criterion of 8 successive correct responses or cutoff of 10 trials (If S correct on trial 10, more trials until error made or criterion reached).

- Ss 17 to 20, who did not reach arrow criterion, received moving arrow program and then fading series from thick stationary arrows (⇐ ⇒) to b-d. After moving arrow program, probe trials with b-d approximately every 15 trials (generally at end of a phase). If S incorrect on probe, more trials with b and d until S reached criterion of 10 successive correct responses or made an error and fading resumed.

- Ss 21 to 25, who reached arrow criterion, received fading series from thin stationary arrows (← →) to b-d. Probe trials with b-d approximately every 15 trials (generally at end of a phase). If S incorrect on probe, fading resumed. If S correct on probe, more trials with b and d until S reached criterion of 10 successive correct responses or made an error and fading resumed.

TRANSFER (All Ss)

- Reinforced matching-to-sample with p and q. Trials until criterion of 10 successive correct responses or cutoff of 10 trials (If S correct on trial 10, more trials until error made or criterion reached).

Figure 4. Summary of experimental procedure.

understand the task or exhibited such behaviour as pointing to the sample stimulus or both comparison stimuli when the card was presented. If the child behaved in this manner, the preceding instructions were repeated.

Baseline trials continued until the Ss reached a criterion of 10 consecutive correct matches on the b-d stimuli or until they received 30 baseline trials. If an S was correct on trial 30, he received further trials until he made an error or reached criterion. The Ss who reached criterion on the baseline trials were eliminated as it was considered that their behaviour had come under the control of the left-right aspect of the letters prior to the experiment or during the baseline trials. The Ss who did not reach criterion were assigned randomly to the experimental and control groups. The assignment to one of the groups occurred immediately upon the S's completion of the baseline trials. Then, the S immediately received further training trials appropriate to the particular condition to which he had been assigned.

The baseline and training trials had a number of features in common. A fixed ratio (1:3) reinforcement schedule was used throughout. The stimuli were presented so that the left-right position of the correct match followed a Gellermann series. Whether the correct matches were facing inward or outward was randomized. Each stimulus presentation was shown until the S made a choice. With all the stimuli presented on cards, the intertrial interval was approximately 3 seconds. During the intertrial interval the E put the candy in the bag and noted the correctness of the response.

Control procedure. Reinforced matching-to-sample trials with the b-d stimuli continued for the Control Ss until the Ss reached a criterion of 10 consecutive correct responses or until they received, in addition to the baseline trials, 150 trials. If the S was correct on trial 150, trials were continued until the S reached criterion or made an error.

Progressive procedure. In the Progressive group the Ss were given 10 reinforced trials of arrow cards following the baseline trials. The Ss who reached a criterion of 8 successive correct matches on the arrow cards began the fading series at the Sep phase. The Ss who did not reach this criterion started the fading series with moving arrows. The arrows first were moved vertically and then, horizontally. Figure 5 shows how the movement was accomplished. The two upper diagrams show for the first step of the movement fading, the beginning positions of the arrows (shaded) before the movement began, and the end position (unshaded) after the movement. The vertical movements were always of the maximum length while the horizontal movements were decreased gradually over six steps until the arrows were stationary in the centre of the board. The steps by which movement was reduced were 1.00, 0.56, 0.28, 0.11, 0.02, and 0.00 of the maximum movement of 18.0 inches.

Questioning of Ss in pilot studies indicated that children sometimes considered that the correct comparison stimulus was the one closer to the sample. As can be seen in the two upper diagrams in Figure 5, the correct comparison is usually closer to the sample during most of the movement. To control for the false hypothesis that the comparison closer to the sample was the correct one, the relative positions of the stimuli were modified on some trials in the manner indicated in the lower two diagrams of Figure 5. As can be seen in these diagrams the correct comparison stimulus during much or all of the movement was farther away from the sample than was the correct comparison. This variation in arrow positioning was used every third or fourth trial of the vertical movements and every third or fourth trial on the first step of the horizontal movements and on the 0.28 step of the horizontal movements.

With the moving arrows the Ss were instructed not

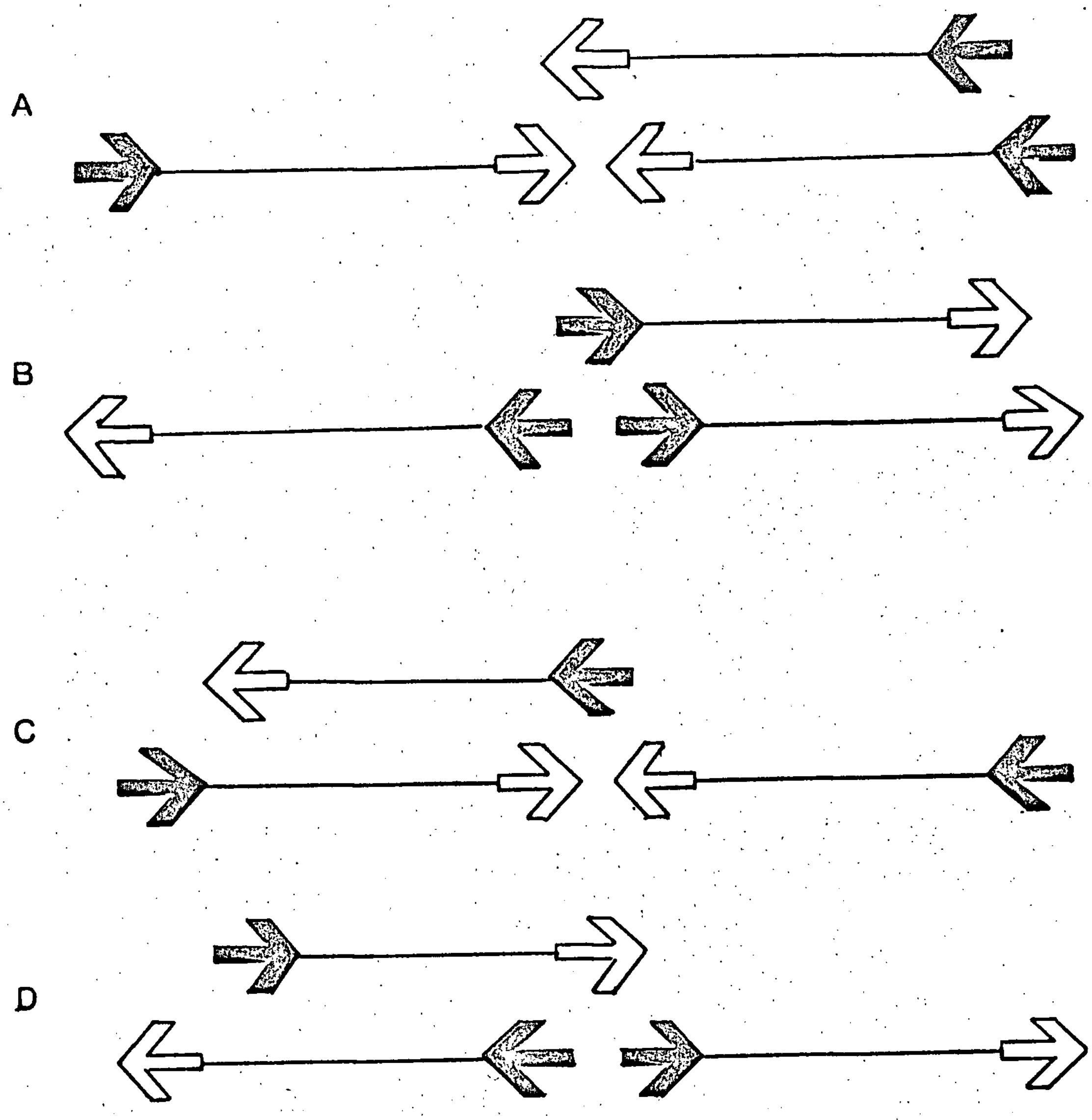


Figure 5. Illustration of how the arrows were moved. Parts A and B show for the first step the beginning positions of the arrows (shaded) before the movements began and the end positions (unshaded) after the movements. Parts C and D show for the first step the modifications of the beginning positions (shaded) and the end positions (unshaded) of the arrows. Such variations in the positions of the arrows were shown at intervals to negate any possible false hypothesis that the comparison stimulus closer to the sample stimulus for most of all the run was the correct match.

to indicate their choice of the moving comparison stimuli until the E said "now", which occurred after most of the movement had occurred. In the case of the moving arrows the intertrial interval was approximately 7 seconds.

The Ss had to achieve 6 successive correct choices when the arrows were moving vertically before they received the horizontal movement trials. During the horizontal movement trials, the Ss were required to make 4 successive correct choices on the longest runs before the fading began. After the moving fades were completed, the Ss were required to make 4 successive correct choices on the stationary arrows. Then the Ss started the fading sequence beginning with the Wid stage of the cards. The Ss were required to achieve 4 successive correct choices on the first step of the Wid stage of the cards before they began to progress through the sequence. If an S requiring the moving arrows did not reach the Wid stage in approximately one-half hour, trials were recommenced in approximately two hours.

All Progressive Ss received a backup procedure following errors. Other than for step 1 of the sequence, the S received the fading step appropriate to the preceding step, n-1. This backup procedure continued through n-2, n-3, etc. until the S was correct or until the first step was reached. Then he received the step succeeding the one upon which he was correct. The previously mentioned randomization over trials of the left-right position of the correct match and the direction in which the comparison stimuli faced (ie., inward or outward) was modified when an error was made; in the backup procedure the S received the same stimulus presentation for each step as he had received initially.

For all the Progressive Ss trials continued until the Ss achieved 10 successive correct trials on the final b-d stimuli or until they received, in addition to the baseline trials, 150 trials. If the S was correct on trial 150, trials were continued until the S reached criterion or made an error. The Progressive Ss were "probed" with the final value of b-d approximately every 15 trials. The non-reinforced probe trials were made to determine whether the Ss required the complete fading sequence in order to discriminate between the letters. As the Ss differed with regard to the number of trials required in the various phases and stages, where the probes occurred varied for each S. In general, however, probes were made only at the end of a phase of fading. The probes were not done during the moving arrow trials. If the S was correct on the first probe, more probes immediately were given until the S made 10 successive correct matches or made an error. If an error was made, the S received the stimulus presentation which had been given immediately preceding the probe trials; then the fading proceeded.

Transfer task. After a criterion number of correct discriminations or after the S had reached a cutoff number of trials, a matching-to-sample transfer task involving the letters p and q was given. There were 10 reinforced (1:3) trials with a criterion of 10 successive correct responses. If the S was correct on trial 10, the number of transfer trials was extended until the S made an error or reached criterion.

3. Results

Criterion was reached by 7 of the 25 Ss during the baseline trials. Eight of the nine Progressive Ss and one of the Control Ss reached criterion on the b-d training trials. A chi square tested indicated that the difference between the groups in the number of Ss who reached criterion was significant ($p < .01$). All Ss who reached criterion on the b-d stimuli reached criterion on the p-q transfer trials.

As the number of trials completed by the Ss varied, in order to permit comparison between the Control and Progressive Ss, the number of correct responses times 100 divided by the number of trials (ie., the percentage of trials correct) was computed for each S. Figure 6 shows these percentage scores for the Control and Progressive Ss in both the baseline and training trials. The height of the striped bar indicates the baseline score while the height of the darkened bar indicates the training score. The height of the unfilled bar above the darkened area indicates for the Progressive Ss the score computed by omitting the results of the stationary arrow series which immediately followed the baseline trials. This arrow series served to determine whether or not the Progressive Ss required the moving arrows.

As can be seen, the median baseline score was 50 percent (S 13) in the Control group and 52 percent (S 20) in the Progressive group. The scores ranged from 37.5 percent (S 11) to 53 percent (S 12) in the case of the Control Ss and from 30 percent (S 17) to 60 percent (S 25) in the case of the Progressive group. In the training stage for the Control group the scores ranged from 25.3 percent (S 8) to 100 percent (S 16) with a median of 50.9 percent (S 12). For the Progressive group, the scores for the training trials, when all trials were included, ranged

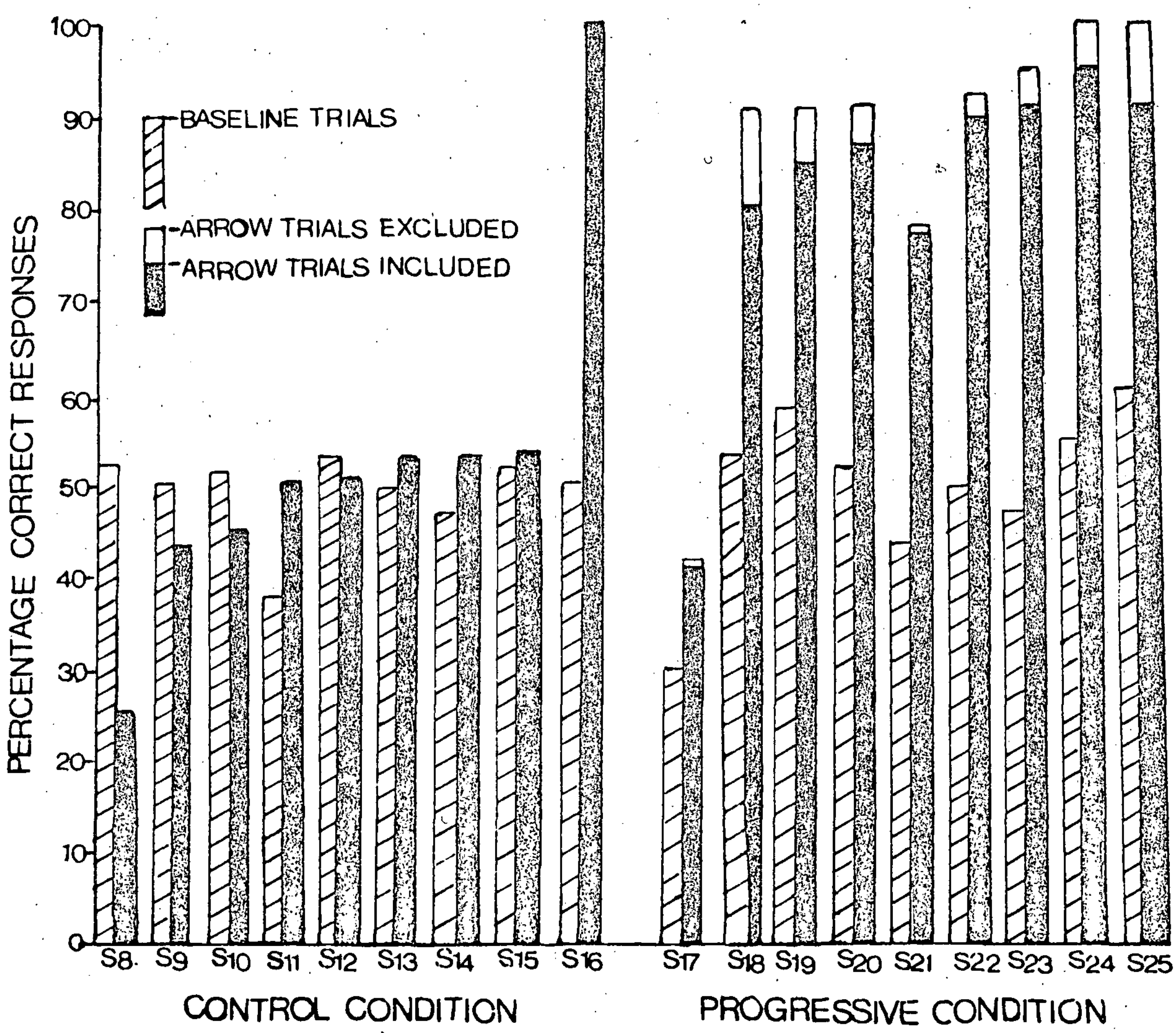


Figure 6. The percentage of trials on which Control and Progressive Ss responded correctly. For each Progressive S two percentages are shown. One percentage was calculated by including the arrow trials which immediately followed baseline trials in the Progressive condition. The other percentage was calculated by excluding the arrow trials.

from 42 percent (S 17) to 95 percent (S 24) with a median of 87 percent (S 20). Thus only S 17, the one Progressive S who did not reach criterion, responded at essentially chance level. The other eight Progressive Ss (Ss 18 to 25) had scores greater than or equal to 77 percent; four of these Ss (Ss 22 to 25) had scores equal to or greater than 90 percent. When the stationary arrow trials were omitted the scores improved for all Ss. These scores ranged from 42.5 percent (S 17) to 100 percent (S 24, S 25) with a median of 91.4 percent (S 20). Thus seven of the Progressive Ss (Ss 18, 19, 20, 22, 23, 24, 25) had scores of greater than 90 percent while the others, S 17 and S 21, had scores of 42.5 percent and 77.9 percent respectively.

Figure 7 (p. 64) shows the cumulative number of correct responses of the Baseline Only Ss, those Ss who reached criterion on the baseline trials, the Progressive Ss, and the Control Ss. The short vertical lines below the graphs indicate the beginning of the baseline, training, and transfer stages. In the case of the Progressive group, the beginning of each phase of fading also is indicated. The symbols under the ordinate refer to the stage or phase and the stimuli used. A key explains the various symbols. For the Progressive Ss, the short vertical lines above the graphs indicate the probe trials.

A typical performance of a Control S is shown in the record of S 13. As can be seen he had 15 correct responses in 30 baseline trials and 80 correct responses in 152 training trials. Like all Ss who did not reach criterion on the b-d trials he did not reach criterion on the p-q transfer task.

In the case of S 16, the one Control S who reached criterion, he had 15 correct responses in the 30 baseline trials. However, on trial 1 of the training session his successful run began.

Four of the experimental Ss (Ss 17 to 20) required the moving arrows. The record of S 17 indicates the performance of the one experimental S who did not reach criterion. In the first training session of 20 trials on the Ver M phase, she was correct on 14 trials. In the next session, involving 10 trials on the Ver M phase and 10 trials on the Hor M phase, she was correct on, respectively, 3 and 4 trials. She was the only S who required two sessions and who never learned the moving arrow discrimination.

The record of S 18 shows the performance of one of the Ss who received the moving arrows and reached criterion. He had 16 correct responses in 30 baseline trials. On the Ver M phase he made two errors before he made the run of six successive correct responses. One other S (S 20) experienced a similar minor difficulty at the beginning of the Ver M phase. Typical of all the Ss who received the moving arrows and reached criterion, S 18 had a little difficulty at the final step of the Hor M phase when movement had ceased. He required backups to the next to last step two different times before he could achieve four successive correct responses on the stationary arrows on the board. He then made no additional errors. He was the only S requiring the moving arrows who did not require the complete program. Three other Ss (Ss 21, 22, 25) did not require the complete program. Subject 25 and S 18 reached criterion on the first probe which occurred during or after the Sep phase. Two other Ss (Ss 21, 22) reached criterion on the second probes after, respectively, the Hea and Sha phases.

The record of S 23 shows the performance of an S who did not require the moving arrows. She and S 24 were the two Ss not requiring the moving arrows who required the complete fading program. She had 14 correct responses in 30 baseline trials. Her only difficulty in the training stage was in the Hea phase, where she made two errors in both step 4 and step 5 of the phase. Two other Ss (S 19, S 22) made one error on this phase, both at step 4.

As can be seen on the record of S 21, this S had difficulty in the Arr-Sep phases. He initially reached criterion on the Arr trials. However, as indicated by the number of errors in the Arr-Sep phases he had difficulty in commencing the fading. A backup procedure to the Arr phase was required three different times. On two of the three backups the S made one or more errors on the Arr phase before progressing to the Sep phase, where errors then were made after the first two backups. Only after the third backup was the S able to progress successfully through the Sep phase.

An analysis of the various phases of fading was done by determining the number of Ss who were incorrect on greater than 10 percent of the trials on that phase. Due to the Ver M, Wid, Sep, and Hea phases having fewer than 10 steps, it was possible for an S to make greater than 10 percent errors on these phases by making only one mistake. However, except for the two previously mentioned Ss who each made one error on the Hea phase, all the Ss having greater than 10 percent errors on a particular phase made more than one error on that phase. Only S 17, the S who did not reach criterion, made more than 5 errors on any stage. In the Ver M and Hor M phases three Ss

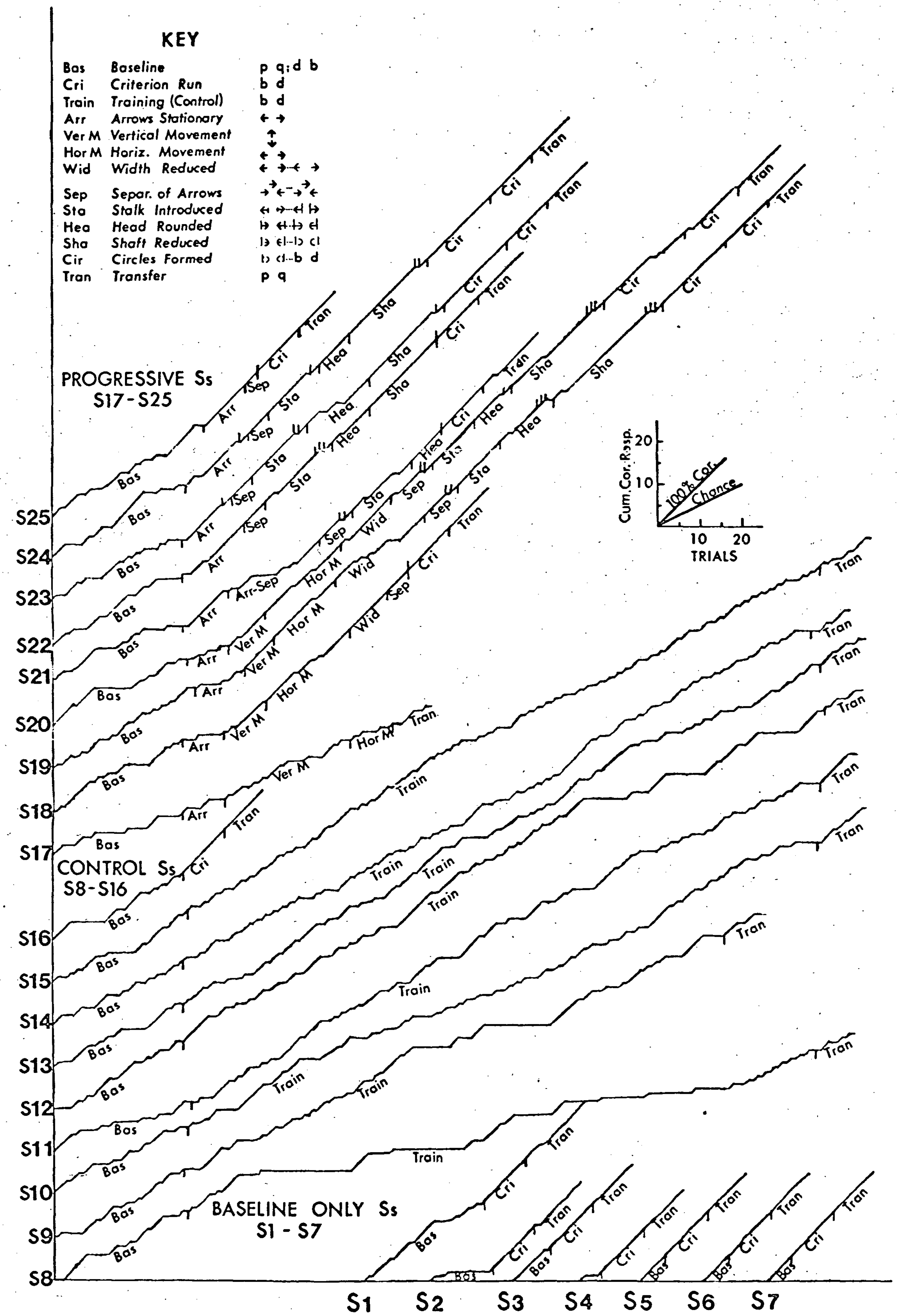


Figure 7. Cumulative correct responses of Ss in the Control condition, in the Progressive condition, and in the Baseline-Only group, the group that reached criterion on baseline trials. The short vertical lines below the graphs indicate the beginning of the stages of the trials. In the case of the Progressive condition, these lines also indicate the beginning of the phases of fading. The symbols under the graphs refer to the various stages and phases. These symbols are explained in the key, which shows a summary and illustration of each stage and phase. Except for the Sep phase, the key provides examples of only the comparison stimuli.

(Ss 17, 18, 20) made errors on more than 10 percent of the trials. In the Hea phase three Ss (Ss 19, 22, 23) made greater than 10 percent errors. In each of the other phases only one S made errors on more than 10 percent of the trials.

4. Discussion

General Summary and Comment

The results clearly demonstrated the effectiveness of the fading method. Although the Control and Progressive Ss showed essentially the same baseline performance, the number of Progressive Ss who reached criterion greatly exceeded the number of Control Ss who reached criterion. Furthermore, the great majority of the Progressive Ss who reached criterion made very few errors. When the initial 10 stationary arrow trials were excluded from the computation, the great majority of the experimental Ss who reached criterion were correct on more than 90 percent of the trials. When the computation included the initial arrow series, the percentage correct scores of all Ss were reduced, but only those of the Ss requiring the moving arrows went below 90 percent. In the case of the Ss who required the moving arrows, it would seem that the score resulting from excluding the arrow trials would be the most appropriate indicator of how well Ss who require the moving arrows perform with regard to learning without errors. Presumably, the stationary arrow trials served mainly to indicate that these Ss required the moving arrows and were not effective in ensuring that the behaviour of these Ss came under the control of left-right directionality. However, the Ss who did not require the moving arrows acquired a left-right discrimination during the stationary arrow trials. Thus it would seem that for these Ss the percentage correct score resulting from including the stationary arrow trials would be appropriate. Thus, consideration of the percentage correct score including the stationary arrow trials for Ss not requiring the moving arrows and excluding these trials for Ss requiring the moving arrows shows that all but one of the Progressive Ss who reached criterion made fewer than 10 percent errors.

There appears to be no generally accepted cut-off point where performance is no longer considered to be "errorless". However, it would seem that Ss who respond correctly on more than 90 percent of the trials would be considered to have exhibited "errorless" learning. Hence, with regard to the reduction of errors, the fading technique of the present study would seem to compare favourably with the previously mentioned successful fading studies of Terrace (1963a, 1963b), Sidman and Stoddard

(1967), and Moore and Goldiamond (1964).

It is important to note, however, that two Progressive Ss made a number of errors; one of these Ss was incorrect on 20 percent of the trials, while the other performed at essentially chance level and never proceeded past the first step of the moving arrow phase. There is a slight possibility that the relatively poor performance of the former S may have resulted from his reaching criterion on the arrow trials by chance. Thus he may have been "incorrectly" assigned to the group which received only stationary stimuli. When errors on the first step of fading required backups several times to the arrow stimuli, this S experienced difficulty with the arrows.

With regard to the Progressive S who did not progress past the vertical movement discrimination, it is possible that her lack of success was due, at least in part to her exhibiting behaviour which would seem incompatible with the behaviour required for successful performance of the task. She was considered by her day care centre teacher to be above average in intelligence and willingness to cooperate. However, after making several errors in the testing situation she repeatedly stood up and sat down. She often looked about the room and asked several times when she might leave the room. On many trials she did not look at the arrows as they moved.

Consideration of the findings of Rudel and Teuber (1963) indicate that the occurrence of children who do not learn easily an up-down discrimination would be infrequent in a large sample of children. As may be recalled from Chapter I, it was found that fewer than seven percent of preschool children from a low socioeconomic background did not learn an up-down discrimination within 50 trials. It is possible that the percentage of children who do not learn to discriminate between arrows moving in an opposite up-down direction might be considerably lower than the percentage found by Rudel and Teuber. Presumably a discrimination involving moving arrows would be easier than one involving stationary U-shapes. Furthermore, although there is no evidence, it seems possible that the matching-to-sample task employed in the present study would be easier than the simultaneous discrimination task employed by Rudel and Teuber.

As mentioned earlier, it was found that only 7 of the 25 Ss achieved criterion on the baseline trials under a simple differential reinforcement procedure and only 1 of 9 Control Ss was successful with a possible 150 more such trials. These findings are in agreement with the previously cited normative studies (e.g., Davidson, 1935; Gibson, et al., 1962; Newhall, 1937), which indicated that the behaviour of the majority of preschool children was not under the control of the left-right aspect of stimuli. Furthermore, the failure of this procedure to teach many children the discrimination in a matching-to-sample task parallels Rudel and Teuber's (1963) similar lack of success with young children in a simultaneous discrimination task. However, the fact that approximately one-third of the children were successful under the reinforcement procedure supports the criticism of the studies of Bijou (1963) and Underwood (1971) concerning their lack of baseline trials and/or control groups. Only with some form of control procedure can the effectiveness of a fading method be determined. The findings of the present study suggest that a control group might be omitted if there were a sufficient number of baseline trials. Consideration of the performance of the Baseline-Only and Control Ss indicate that Ss who reach criterion do so within a limited number of trials; any lengthy extension of trials does not seem to produce an increase in the number of Ss who reach criterion. While all the Baseline-Only Ss began their first trial of the criterion run by trial 28, one

Control S did not begin the criterion run until the first trial after the baseline trials. It would seem that a baseline procedure of approximately 40 trials would be sufficient to eliminate most, if not all, of the Ss who would learn the left-right letter discrimination under a differential reinforcement procedure in a matching-to-sample task.

It is interesting to note that any Ss who were successful in the b-d discrimination, whether in the Baseline-Only group, or the Control and Progressive groups, successfully transferred to the p-q discrimination task. As might have been predicted, once the child has come under control of the directional component of the first pair, the second pair, which are very similar to the first, should pose no problem. It would be interesting to see whether the child, after acquiring such letter discriminations, would be able to transfer to directional discriminations between two and three dimensional figures which are quite dissimilar to the arrow and letter forms.

Reasons for the Success of the Program and Possible Modifications

The effectiveness of the present fading method with regard to both the number of Ss who learned the left-right letter discrimination and the very few errors made by these Ss may have resulted from the fading being done in small steps along what would seem to be a very "relevant" continuum, or perhaps more appropriately stated, a very relevant sequence. Thus this program was a successful combination of the techniques of Lawrence (1952) and Terrace (1963a, 1963b) in that the fading was along presumably the "relevant continuum" and was done very gradually.

It would seem that the use of arrows was an important factor contributing to the success of this fading sequence. Results indicate that the directional component of arrows is considerably more "distinctive" than the directional aspect of letters. Many Ss who did not reach criterion on the baseline trials learned easily to discriminate between the stationary arrows. Furthermore, even when Ss correctly matched the arrow stimuli they did not necessarily reach criterion on the first probe trials. Even Ss who verbally had mentioned the directional difference between the arrows did not necessarily respond differentially to the letters on the first probes. The use of movement with the arrows for Ss who initially did not discriminate between the stationary arrows presumably increased the "distinctiveness" of the directional component of the arrows. Due to innate factors of the S and/or his previous learning, movement would seem to be a very "distinctive" aspect of stimuli.

Furthermore, by having the arrows move vertically rather than horizontally on the first stage of the fading, this program possibly ensured that the S's behaviour would come more quickly under the control of the orientation of the stimuli. As previously mentioned in Chapter I, Rudel and Teuber (1963) found that very few preschool children learned to discriminate between left-right reversals within 50 trials; however, the great majority of these children learned easily an up-down discrimination. Presumably the use of movement with arrow stimuli would facilitate this up-down discrimination learning, and once this discrimination was learned the S would transfer successfully to the horizontal movement discrimination and on through the program.

It is an interesting conjecture that the first part of the program from moving arrows to stationary arrows may parallel in some abbreviated form the stages that a child normally would pass through in his preschool years. Due to both the reinforcement contingencies of everyday living and the possibility that movement may be innately "distinctive" to humans, the child who has not been taught formally the various discriminations still may pass through in order at least three of four stages of discrimination learning. These stages involve learning to discriminate between (a) objects moving in an opposite up-down direction, (b) stationary objects facing in an opposite up-down direction, (c) objects moving in an opposite left-right direction, and (d) stationary objects facing in an opposite left-right direction.

Possible modifications of the fading sequence probably would include shortening some phases and lengthening others. Elimination of steps seems particularly feasible in the case of the Sha () and Cir () phases, each of which involved very gradual fading over 15 or more steps. As all Ss requiring the moving arrows made errors when the movement ceased, an improved program might increase the number of steps so that the transition from movement to no movement would be very gradual. Furthermore, consideration of the number and locus of errors in the Hea phase () would suggest that more steps be added, particularly at level 4.

Comparison of the Program with Other Training Methods

Although it is difficult to compare across studies the success of various fading methods in teaching the left-right letter discrimination, it would seem that the effectiveness of the present method, as reflected in the number of successful Ss and the percentage of correct trials, was greater than the success of the fading methods of the pilot studies and the studies of Bijou (1963), Karraker (1968), and Schutz (1964).

In considering the effectiveness of the present fading method in relation to methods other than fading, it is important to question why the Ss instead of receiving a fading method simply should not be told verbally about the directional aspects of the letters. There are at least three important responses to this question. First, it is possible that due to a variety of reasons the child's behaviour might not be under the control of verbal instructions. For example the child of foreign parentage may not speak or understand the language of instruction. In addition, particularly in teaching situations involving large classes, the child often will be attending to stimuli other than the teacher's instructions. In these types of situation the fading sequence adapted to teaching machines, would seem to be very useful.

Secondly, even if children do acquire the b-d discrimination with verbal instructions, they may make more errors in reaching criterion than do children who receive a fading method. While it is not clear how many errors were made by the three Ss in Jeffrey's (1958) study who reached criterion after verbal instructions, consideration of the number of trials to reach criterion would suggest that they may have made a number of errors. As mentioned in Chapter I, possibly undesirable behaviour may result from learning with errors. According to Terrace (1966) it has been regularly observed that Ss who have learned with errors exhibit emotional responses in the presence of the negative stimulus. Furthermore, even after a stable near perfect rate of responding has been reached after learning with errors, there may be reoccurrences of incorrect responding (Terrace, 1963a). In the case of Ss who have learned with no or few errors, these emotional responses and disruptions in performance have not been observed.

Finally it is possible that verbal instructions would not be effective in teaching the discrimination to many children, even if they are under the control of the instructions. In Jeffrey's (1958) study it was found that the majority of the control group, who received instructions including gestures concerning the directionality of the letters every 10 or 20 trials, did not learn to identify correctly the letters. By allowing errors, verbal instructions may permit responding to come under the control of stimuli other than those which are experimentally manipulated. As mentioned previously, under certain conditions permanent faulty performance may result due to an intermittent reinforcement effect (Terrace, 1966).

It is interesting to compare the effectiveness of the present method with the techniques involving arm movement employed by Jeffrey (1958) and Hendrickson and Muehl (1962). Other than the method of the present study, the techniques of Jeffrey and Hendrickson and Muehl appear to be the only ones which have been shown experimentally to teach a high percentage of _S_s to make the left-right discrimination. In order to make the comparison between the arm-moving technique and the fading method of the present study it would seem appropriate to compare only Jeffrey's method with the fading technique; in the case of the experiment of Hendrickson and Muehl, the effects of arm movement were confounded by the presence of arrows below the letters.

The comparison between the method of Jeffrey and that of the present study is difficult in that the studies varied with respect to a number of variables. For example, the criterion tasks were quite different. The _S_s in Jeffrey's study were required to name the letters "Jack" and "Jill", while the _S_s of the present study did a matching-to-sample task. In the present study only _S_s who had failed to achieve criterion on the baseline trials were employed, while in Jeffrey's study there was no baseline elimination procedure.

Even with this difficulty in making a comparison it might be safe to say that the success rate of the present study, 8 successful Ss in 9 Ss, was roughly equivalent to Jeffrey's rate of 13 successful Ss in 14 Ss. Furthermore, as mentioned in Chapter I, consideration of the number of trials required to reach criterion by the Ss in Jeffrey's study who had the arm moving stage would suggest that the performance of at least some of these Ss was not without a number of errors. Hence, even after criterion was reached, their performance could have been subject to reoccurrences of incorrect responding similar to the bursts of incorrect responding found by Terrace (1963a). In the case of the present method, these disruptions of correct responding presumably would not occur with the majority of Progressive Ss, who performed with minimal errors.

Theoretical Implications

It is important to consider the extent to which the findings of the present study are in agreement with Orton's theory concerning the relationship of cerebral dominance and perception. Orton's attempt to explain in terms of incomplete cerebral dominance why many children's behaviour is not controlled by the left-right aspect of stimuli has been by far the most important theoretical influence on research on reversals in reading. Orton (1937) postulated that cerebral dominance must be attained before the child is able to discriminate between objects facing in an opposite left-right direction. Before this dominance is achieved the stimuli are registered and interpreted by both hemispheres and thus apparently cannot be "correctly processed" by the brain.

A number of studies have been conducted to determine whether there is a relationship between incomplete cerebral dominance and reading disability. Typically, incomplete cerebral dominance has been inferred from mixed lateral preference; that is, one side of the body is not dominant in all activities. An example of mixed lateral preference occurs when a person who writes with his right hand kicks with his left foot or sights with his left eye. Generally in these studies, standardized tests of reading accuracy, speed, and/or comprehension have been used to measure reading disability. A number of criticisms of these studies can be made. It seems obvious that poor performance on the tests used in these studies has a very complex etiology; thus a poor score does not necessarily result from the fact that the S's behaviour is not under the control of the left-right aspect of letters and words. Furthermore, incomplete cerebral dominance probably cannot be inferred reliably from mixed lateral preference. At least for some activities, environmental influences such as peer pressure or the design of equipment probably determine to a great extent which side the child uses. Thus it is not surprising that the results of these studies are conflicting. While certain studies (e.g., Harris 1957, Orton 1937) have indicated a relationship between reading disability and mixed lateral preference, others have not (e.g., Balow, 1963; Belmont and Birch, 1965).

With regard to the present study it would seem clear, however, that incomplete cerebral dominance was not responsible for the poor performance of at least most of the Ss who did not reach criterion. It is difficult to conceive that the Progressive Ss' problems with incomplete cerebral dominance as reflected by poor performance on the baseline trials could be "cured" by the fading sequence in such a short time.

It is quite possible as suggested by Money (1966) that the poor performance of children on left-right discrimination tasks may be due to the fact that preschool children are not reinforced for responding differentially to differences in orientation, particularly to left-right orientation. Possibly the reason that young children learn the up-down discrimination before the left-right discrimination (Rudel and Teuber, 1963) is that up-down discriminations are reinforced earlier. A child who turns an ink bottle or a haul-truck full of dirt upside down over a rug may be punished and certainly will not be reinforced; yet the child who rotates the same object 180 degrees about the vertical axis will be neither reinforced nor punished. Generally children are not required to make the left-right discrimination until they begin to read; then after years of being irrelevant, left-right directionality becomes a critical dimension to which the child must learn to attend. This learning probably is fairly difficult in that the child's previous experience of three or four years must be revised.

5. Summary

This study compared a fading sequence, which at least intuitively seemed to be "relevant" to the final right-left discrimination of the letters b-d, to a control procedure in which the final forms of the letters were presented throughout the trials. The Ss who did not reach criterion on the baseline matching-to-sample trials with the letters b-d were assigned to the Progressive and Control groups. All Progressive Ss received a series of matching-to-sample trials involving arrows pointing either to the left or right. Those who reached criterion on the arrow stimuli received a fading program involving a gradual progression from arrows to final letter-forms. The Ss who did not reach criterion on the arrow series received matching trials involving simultaneously moving arrows. The arrows were moved vertically and then horizontally. The distance of the horizontal run was reduced gradually until the arrows were stationary. Then, the Ss received the fading sequence from stationary arrows to final letter-forms.

Eight of the nine Progressive Ss reached criterion on the b-d discrimination. Seven of the Progressive Ss who reached criterion responded correctly on more than 90 percent of the trials while the eighth S was correct on 77 percent of the trials. Only one of the nine Control Ss reached criterion. All Ss reaching criterion on the b-d discrimination transferred to the p-q discrimination.

The discussion of the results of the study included reference to the following points:

1. The effectiveness of the present fading sequence as compared to both other fading sequences, including those involving left-right letter discriminations, and methods

other than fading.

2. Possible reasons for the "deviant" performances of the Progressive S who did not reach criterion and the Progressive S who made a fair number of errors while learning the discrimination.

3. Reasons as to the effectiveness of the program and any possible modifications.

4. Theoretical implications of the results.

REFERENCES

Baker, R.A. and Osgood, S.W. Discrimination transfer along a pitch continuum. Journal of Experimental Psychology, 1954,48,241-246.

Balow, I.H. Lateral dominance characteristics and reading achievement in the first grade. Journal of Psychology, 1963,55,323-328.

Belmont, I. and Birch, H.G. Lateral dominance, lateral awareness and reading disability. Child Development, 1965,36,57-71.

Bijou, S.W. Studies in the experimental development of left-right concepts in retarded children using fading techniques. International Review of Research in Mental Retardation, 1963,3,66-95.

Davidson, H. A study of the confusing letters b,d,p, and q. Journal of Genetic Psychology, 1935,47,458-468.

Fellow, B.J. The discrimination process and development. Oxford: Pergamon Press, 1966.

Gibson, E., Gibson, J., Pick, A., and Osser, H.A. Developmental study of the discrimination of letter-like forms. Journal of Comparative and Physiological Psychology, 1962,55,897-906.

Harris, A.J. Lateral dominance, directional confusion and reading disability. Journal of Psychology, 1957,44, 283-294.

Hendrickson, L.N. and Muehl, S. The effect of attention and motor response pretraining on learning to discriminate b and d in kindergarten children. Journal of Educational Psychology, 1962,53,236-241.

Hill, M.B. A study of the process of word discrimination in individuals beginning to read. Journal of Educational Research, 1936,29,487-500.

House, B.J. and Zeaman, D. Transfer of a discrimination from objects to patterns. Journal of Experimental Psychology, 1960,59,298-302.

Jeffrey, W.E. Variables in early discrimination learning: Motor responses in training a left-right discrimination. Child Development, 1958,29,269-275.

Jenkins, H.M. and Harrison, R.H. Effect of discrimination training on auditory generalization. Journal of Experimental Psychology, 1960,59,246-253.

Karraker, R.J. Teaching beginning readers to distinguish between similar letters of the alphabet. United States Office of Education Project No. 6-1955-24, 1968.

Kennedy, H. Reversals, reversals, reversals! Journal of Experimental Education, 1954,23,161-170.

Lawrence, D.H. The transfer of a discrimination along a continuum. Journal of Comparative and Physiological Psychology, 1952,45,511-516.

Money, J. On learning and not learning to read. In J. Money (Ed.) The disabled reader. Baltimore: John Hopkins Press, 1966. Pp. 21-40.

Moore, R. and Goldiamond, I. Errorless establishment of visual discrimination using fading procedures. Journal of the Experimental Analysis of Behaviour, 1964,7,269-272.

Newhall, S.M. Identification by young children of differently oriented visual forms. Child Development, 1937,8,105-111.

Orton, S.T. Reading, writing and speech problems in children. New York: Norton, 1937.

Piaget, J. and Inhelder, B. The child's conception of space. New York: Humanities Press, 1956.

Popp, H.M. Visual discrimination of alphabet letters. The Reading Teacher, 1964,17,221-226.

Rudel, R. and Teuber, H. Discrimination of direction of line in children. Journal of Comparative and Physiological Psychology, 1963, 56, 892-898.

Schutz, R.E. Acquisition of alphabet-letter discrimination with and without errors. Paper read at the Annual Meeting of the American Psychological Association, Los Angeles, California, 1964.

Sidman, M. & Stoddard, L.T. The effectiveness of fading in programming a simultaneous form discrimination for retarded children. Journal of the Experimental Analysis of Behaviour, 1967, 10, 3-15.

Swanson, R. and Benton, A.L. Some aspects of the genetic development of right-left discrimination. Child Development, 1955, 29, 123-133.

Teegarden, L. Clinical identification of the prospective non-reader. Child Development, 1932, 3, 346-358.

Terrace, H.S. Stimulus control. In W.K. Honig (Ed.) Operant behaviour: areas of research and application. New York: Appleton-Century Crofts, 1966. Pp. 271-344.

Terrace, H.S. Discrimination learning with and without errors. Journal of the Experimental Analysis of Behaviour, 1963a, 6, 1-27.

Terrace, H.S. Errorless transfer of a discrimination across 2 continua. Journal of the Experimental Analysis of Behaviour, 1963b, 6, 223-232.

Underwood, B.J. A program for grapheme discrimination for preschool children. Unpublished doctoral dissertation, University of Arizona, 1971.

Wechsler, D. & Hagin, R. The problem of axial rotation in reading disability. Perceptual and Motor Skills, 1964, 19, 319-326.

Wilson, F.T. & Flemming, C.W. Reversals in reading and writing made by pupils in kindergarten and primary grades. Journal of Genetic Psychology, 1938, 53, 3-31.

Wolfe, L. An experimental study of reversals in reading. American Journal of Psychology, 1939, 52, 533-561.