ERRORLESS ACQUISITION OF NUMBER CONCEPTS BY YOUNG CHILDREN

by

Joseph Russell Patterson

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SIGNED: Joseph R Patterson

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Ralph J. Wetzel
R. J. Wetzel
Professor of Psychology

9-28-73
Date

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ABSTRACT

Thirty second grade children not demonstrating conservation of number on a classic Piagetian test were assigned to either a number training or form training control group. The number training consisted of three 50-problem matching to sample programs which were presented on an automated apparatus. Each phase of training involved more difficult problems due to increased irrelevant stimulus dimensions and greater number of items in the sets to be matched. A redundant stimulus cue, illumination, was faded-out in five stages in each program in an attempt to obtain errorless acquisition of the concept of "same number." After each phase of training, the conservation of number test was readministered. The form training control group overlearned a 50-problem form matching program and were tested after each session on the conservation of number test.

Eleven number training subjects were successful in completing all three phases of training, but no significant improvement was found on the conservation of number test.

Analysis of the number training data showed significant illumination stages by training phases interactions indicating the process of transfer of stimulus control within the program.

INTRODUCTION

Research on children's acquisition of number conservation has produced an extensive and confusing body of literature. Conflicting theoretical positions are common, methodologies are varied, and results have been disparate. From a review of this literature, attention to the relevant stimulus dimension emerges as a critical factor in number conservation and generally in discrimination learning. An effective method for training conservation which avoids several problems of extraneous variable control is suggested by the techniques of errorless discrimination training.

Jean Piaget (1952) defined number conservation as the child's ability to recognize the invariance of the number of items in a set in the face of variations in other dimensions of the set. The child's ability to conserve presumably indicates the onset of logical reasoning and the ability to deal with reality on representational terms. Piaget's (1968) theory is nativistic in that given a reasonably supportive environment, and practice, cognitive development unfolds in a relatively determined rate and sequence which universally falls into three stages. The first is characterized by the recognition of quantitative equivalence only when the correspondence between elements is actually perceived. In the second, there is a preservation of equivalence provided that the geometric redistribution of elements is not

very great. In the final stages of full and lasting conservation, equivalence is immediately apprehended, irrespective of the nature of the conflicting perceptual cues.

Piaget also originated methods for assessing conservation which have been used extensively. A test for a child's ability to conserve number involves the following sequence of events: (1) an S is shown two identical sets of objects; (2) he is then asked to judge whether the two sets are numerically equal; (3) if the S says that they are equal, E alters some perceptual but no numerical properties of one of the sets: (4) S is asked once more if the two sets (changed versus unchanged) are still equal with respect to number; and (5) S is asked to explain his judgment. If S says the sets still have equal number and is able to explain his answer logically, he is judged a "conserver."

Summarizing Piaget's theoretical system and research, Flavell (1963) notes their extraordinary penchant for eliciting critical reactions. Many of these criticisms, according to Flavell, are of the kind which, " . . . attract the first-year graduate student mentality the way a light attracts a moth (p. 31)." First among criticisms of Piaget are what Flavell has referred to as "complaints" which refer to relatively clear-cut points, easily detected, and unequivocally deserving criticism. One complaint is that Piaget's theories contain

a considerable amount of "excess baggage"; another is that he occasionally jousts with straw men in his theorizing. For example, he is prone to overidentify current theoretical learning orientations with their empiricism-associationism ancestors of the nineteenth century (Kohnstamm 1963). Another complaint is that Piaget may state that certaub data support a theoretical assertion without indicating how they do, or even could, support it (Flavell 1963). Beilin (1965) criticizes Piagetian theory on the grounds that inferring both structural invariance and response variability from the same body of data places the theory in the position of offering either a paradox or a contradiction. Beilin concludes that the description of cognitive development as either unitary or nonunitary eludes consensus. Elkind (1967) points out that Piaget's theory is a theory of conservation of identity and not equivalence but that Piaget did not make the distinction clear.

There is much criticism of Piaget's methodology. Feigenbaum (1968) criticizes Piaget for not mentioning situational variables in his reporting techniques. Zimiles (1966) discusses factors other than inadequacy of the child's cognitive structures which may lead to nonconservation (e.g., gamesmanship and interviewer expectations). The use of relational language in the classical conservation assessment test has been a point of recurring controversy. Piaget (1952, 1968) has steadfastly denied that language is a critical factor. The

decisive argument according to Piaget is that when the correct answer is arrived at, it is clear what the child was thinking about earlier. Wohlwill (1960) emphasized the importance of verbal mediators while Mermelstein and Shulman (1967) found significant effects of varied techniques of questioning in conservation responses of culturally deprived children. Griffiths, Shantz, and Sigel (1967) and Harasym, Boersma, and Maguire (1971) found a developmental progression in the use of relational terms in conservation tasks which paralleled Piaget's stages of conservation attainment. Griffiths, et al. (1967) as well as Rothenberg (1969) found fewer conservers identified in response to the question of "same" and this difference was most pronounced among lower class children.

Among alternate explanations of conservation performance, Reese and Lipsitt (1970) have listed perceptual, language, and learning interpretations. They regard the studies by Bruner, Olver and Greenfield (1966), Gelman (1969), and Mehler and Bever (1967) to have generally a perceptual orientation which argues that conservation performance involves learning to ignore misleading perceptual information presented in conservation proglems. Reese and Lipsitt add that such a position is not contrary to Piaget's, but that the conflict arises over how the misleading cues are to be overcome. A number of researchers (Griffiths, Shantz and Sigel, 1967; Harasym, Boersma and Maguire, 1971; Mermelstein and Shulman, 1967; Rothenberg, 1969; and Wohlwill, 1960) see conservation ability as being at least partially a function

of the child's grasp of the language involved in Piaget's assessment methods. Furthermore, the simultaneous appearance of relational language comprehension and conservation ability would indicate that verbal mediation may be essential to conservation concept development. Still other theorists view training as primary to conservation attainment and criticize the Piagetians for failing to consider the large amount of background knowledge necessary and the time needed to train children for conservation mastery (Kingsley and Hall, 1967; Staats, Brewer, and Gross, 1970). The research which is to build a comprehensive theory, according to Staats (Staats et al. 1970), must study the antecedent conditions (learning) that produce the complex behaviors (conservation of number). He concludes that the concept of number is strictly learned and consists of various skilled repertoires of skill. Thus, the child's invariance of response to number depends upon the "invariance" properties of his training. "Complex cognitive skill acquisition can only be understood in learning analyses of the hierarchically ordered skills of which the complex repertoire is composed (p. 59)."

Flavell (1963) served as Piaget's translator and interpreter for most Americans. He concluded that training of conservation was extremely difficult if not impossible. This idea plus Piaget's general depreciation of learning theory have inspired many number conservation training attempts. This literature on training is difficult to interpret or summarize. First of all, the two major

theoretical positions, Piaget's cognitive structures approach and learning theory, use different language which makes comparison difficult. For example, Gelman's (1969) study using oddity training procedures to induce number discrimination was regarded as a perceptual interpretation by Reese and Lipsitt (1970). That same study would be considered a differentiation hypotheses by Wohlwill and Lowe (1962) and could reasonably be classed as a Learning Theory approach using discrimination training procedures. A second reason for the difficulty of comparison in the training literature lies in the fact that the methods of training and assessing the effects of training are diverse and inextricably tied to the theoretical positions of the investigators. A critical factor in the assessment of training effectiveness is the definition of a conserving response. Staats, Brewer and Gross (1970) say counting is fundamental to conservation and one of the multiple cognitive factors to be shaped and reinforced in training. Piaget (1952), on the other hand, does not see counting as even necessary to conservation since he theorizes that development of a transitive logic allows the child to realize that initially equal sets maintain their identities regardless of rearrangement and thus are equal without recourse to a counting strategy. Because of the prominence of artifacts and multiple cognitive factors involved, Zimiles (1966) believes that efforts to identify and devise methods for training on conservation appear misplaced and that many training procedures are successful only because they succeed in removing

artifactual barriers. The more recent opinion of Reese and Lipsitt (1970) is not so pessimistic, although they list a number of factors confounding conservation training studies and conclude that it is not yet possible to make any general statements about the teachability of the concepts assessed by the Piagetian tests.

From the morass of research in conservation training, a number of training procedures may be listed. Generally these are based on concepts taken either from Piagetian theory or learning theory though some procedures may not fulfill the requirements of either major theory. A Piagetian approach has been to attempt to lead the child to maintain constancy of number through inference from experiences with addition and subtraction. No significant improvement in conservation on transfer tests has been found by this method (Wohlwill and Lowe, 1962; Wallach, Wall, and Anderson, 1967; Winer, 1968). A second unsuccessful Piagetian procedure has been to rearrange the stimulus sets to force the child to differentiate the proper conceptual dimension from other irrelevant but highly visible cues which typically show substantial correlation with that of number (Wohlwill and Lowe, 1962; Beilin, 1965; Zimiles, 1966). Smedslund (1961) suggested conflict induction as a means of reorganizing the child's intellectual actions to bring about conservation performance. The conflict induction procedures used by Beilen (1965) and Gruen (1965) were not particularly effective in conservation training. Also derived from Piagetian theory is the view that compelling stimulus variables prevent

the child from conserving. Reduction of stimulus availability which involves screening the effects of the transformation from the child was used in a number of studies (Feigenbaum and Sulkin, 1964; Mehler and Bever, 1967, 1968) to bring about conserving responses by reducing stimulus dependence. Many of the children reverted to nonconservation once the screening procedure was dropped. A final Piagetian method which Brainerd and Allen (1971) see as a feature common to all successful number training programs is specification of the inverse transformation leading to reversibility. Reversibility training is practice in, or observation of, rearranging items back into original arrangements. Wallach and Sprott (1964) suggest that the effects of this training procedure are due to the child's imagining the inverse operation and realizing that it would again bring about the situation implying equality.

Among learning theory approaches, feedback and social reinforcement for conserving responses has been used with mixed results. Reinforced practice in counting was found ineffective by Wohlwill and Lowe (1962) and Gruen (1965). Beilin (1965) found verbal feedback and reinforcement for conserving responses somewhat effective as a training method, however, verbal rule instruction was more effective. The approach of analyzing conservation into a number of components which have then been trained in hierarchical fashion has been successful in a number of studies (Kingsley and Hall, 1967; Rothenberg and Orost, 1969; Staats, Brewer and Gross, 1970). Recently the effect of

modeling conservation performance has been tested and in both cases (Rosenthal and Zimmerman 1972; Zimmerman and Rosenthal 1972), it has been an effective and efficient means of teaching number conservation. These findings indicate that some prior successful training methods may have set up modeling situations which led to their success more than the instructional procedure per se. Conservation has also been seen by learning theorists as a problem of learning to discriminate and respond to the relevant cue of number in the face of other irrelevant stimulus variables. Wohlwill and Lowe (1962) indicate that Piagetian theory has not adequately dealt with this aspect of the problem. In a well designed study, Gelman (1969) demonstrated that discrimination training on a large number of problems containing many different stimuli in which the number dimension was the only relevant attribute would lead to positive transfer to classical number conservation tests. O'Bryan and Boersma (1971) recorded reflected eye movement patterns while children studied the classical conservation testing material and further strengthened the attention to relevant attribute position with the findings that changes in viewing strategy were associated with changes in conservation responding.

In a recent review of attempts to train number conservation and demonstrate transfer to new materials, Brainerd and Allen (1971) reinterpret the Piagetian position on the effectiveness of training. They state that Piaget and the Geneva School do not hold that training is impossible or as difficult as may have been inferred from Piagetian

theory (Flavell,1963). Brainerd and Allen discuss nine number conservation training studies and conclude that seven were successful. They discount the negative results of Wohlwill and Lowe (1962) for their failure to make a direct test of Piaget's theory and those of Mermelstein and Meyer (1969) for their posttesting for substance conservation rather than number conservation. They conclude that the evidence for specific transfer of induced conservation has been found without exception and that such transfer may reasonably be used as a test for adequate induction of conservation. Brainerd and Allen regard the operation of specifying the inverse transformation to be the common element in all the successful studies in their review. This supposed commonality in training procedures is interpreted by these authors as support for the Piagetian theory that a concept of reversibility will lead the child to conserve. According to this theory, a child who acknowledges the equivalence of two sets when they may be perceptually compared (one to one correspondence) can learn to imagine the items of the set which is then rearranged as being put back into its original arrangement and thus comes to conserve number.

In order to explain successful training procedures by Piaget's concept of reversibility, Brainerd and Allen have had to do some stretching. The authors of two studies which they list as successful are not so generous with their own results. Gruen (1965) states that neither of his training conditions was particularly effective and that verbal pretraining alone was about as effective as either of his

training conditions. Winer (1968, p. 203) performed two experiments and found, "only a slight, nonsignificant difference in favor of the group receiving the conflict trials . . . ." Brainerd and Allen also admit that in some cases the specification of the inverse transformation has been verbal while in others it has been perceptual, while in still others it has been a mixture of verbal and perceptual with additional factors of feedback and reinforcement present.

There is some commonality among the various training methods and explanations, though the common element may not involve reversibility. Zimiles (1966) points out that the principal effect of successful conservation training which emphasizes reversibility is to communicate to the child the relevant cue of numerosity and the irrelevance of the transforming operation. Wallach, Wall and Anderson (1967) interpret the Wallach and Sprott (1964) findings by saying that the reversibility training procedure may well have been successful, not because it led the child to recognize reversibility, but because it led him to stop relying on a misleading cue. O'Bryan and Boersma's (1971) eye movement findings add further operational evidence to the importance of attention to relevant stimulus cues in conservation tasks. The importance of attention in discrimination learning is discussed by Mackintosh (1956) who notes that if animals do not automatically attend to all cues, part of what they must learn in order to solve a discrimination problem is to attend to the relevant cues. Jeffrey (1968) proposes that an explanation of human

problem solving behavior will be found with a more adequate understanding of the development of attention and variables controlling cue salience. It therefore seems more parsimonious to regard the common factor in successful conservation training studies to be operations which cause the child to attend to and respond on the basis of discrimination of the relevant stimulus dimension of numerosity and to disregard all other irrelevant cues. The advantage of this theoretical position is that it does not require an assumption of a mediating cognitive operation such as thinking of the inverse transformation of the set to bring about again a condition inferring equality.

The literature on so-called "error-less" discrimination training suggests means of effectively training number discrimination. By eliminating or drastically reducing the number of error responses, this approach reduces some of the confounding variables present in trial and error procedures. One of these is the class of stimuli resulting from the behavior of the organism to his own preceding responses, listed by Harlow (1952) as an "error-factor producer." Others are the problem of position guided responding and the "lose-stay phenomenon" in matching to sample discrimination learning mentioned by Levin and Maurer (1969).

Errorless training programs generally use a salient supporting (redundant) stimulus cue such as brightness to aid in rapidly shaping attention to a second less salient relevant cue. The

redundant cue is faded out in a number of steps allowing transfer of stimulus control to the initially less salient relevant cue with a minimum of error responses. The literature on stimulus preference and attentional factors in children bears upon the problems of supporting or confounding cues introduced in errorless discrimination learning (Corah 1966; Thomas 1966; Ginsberg 1969). Holland (1960) used color cues with fading to teach abstract concepts of form and letters of the alphabet to children on a teaching machine. Hively (1962) analyzed programming variables on a two-choice matching to sample apparatus in which a fading illumination cue was used to teach children to match forms in a nearly errorless sequence. The number of errors made on a post-learning criterion program was found to be a function of errors generated during the training program. Other factors contributing to errors in the matching to sample procedure used by Hively were "incorrect hypotheses" generated by use of random number tables in program design and the number of stimuli change brought about by advancing or regressing through the program served as strong reinforcers which at times were not contingent upon correct responding. Terrace (1963a) found that errors are not a necessary condition for the formation of an operant discrimination of color in pigeons. He used the same technique of fading brightness and duration to train pigeons in a red-green discrimination without errors and then transfer this discrimination to one between vertical and horizontal lines (Terrace 1963b). The difficulty of this transfer was a

function of the number of errors made in learning the original discrimination. Moore and Goldiamond (1964) used fading illumination cues on a four-choice delayed matching to sample apparatus to teach young children a geometric form discrimination in an almost errorless sequence. They concluded that errors produce extinction trials making behavior more difficult to maintain. Ray (1967) used a similar procedure to train monkeys to discriminate a tilted line on an eight-choice matching to sample apparatus with the percentage of incorrect responses to the tilted lines a function of the rate of change of supporting cues in the program. Sidman and Stoddard (1968) used a fading program to effectively train retarded children to a simultaneous form discrimination. Stoddard and Sidman (1967) also tested the hypothesis that inappropriate behavior is increased by a history of errors within learning and concluded that errorless discrimination learning challenges the prevalent view that S-R learning can be described as a process of error elimination. They found error responses during the learning process detrimental to further learning.

The present study examined the possibility that children's failure on conservation tests may be a function of inattention to the relevant numerical attributes of the test or attention to irrelevant features. A programmed sequence of discriminations using a salient supporting cue and fading procedures to transfer stimulus control to the number dimension was designed to train nonconserving children to attend to and match sets of items on the basis of number and to

ignore irrelevant stimulus dimensions. The irrelevant stimulus dimensions introduced were item size, shape, and color and set density and configuration. Children thus trained to attend to quantity attributes by a nonverbal and relatively errorless number discrimination program were then tested for transfer on a classic verbal conversation of number task.

METHOD

Subjects

Forty-nine children from three second grade classrooms were administered a conservation of number pretest, and the scores were used as basis for selection of subjects for the study. The population from which the subjects was drawn was predominantly Mexican-American with a few Yaqui Indian children. Most of the children were bilingual and all came from a low socioeconomic status neighborhood in Tucson, Arizona. The three classrooms from which the children were selected was part of a program which emphasized a permissive atmosphere, enriched environment, and encouragement of verbalization and expression. These children had been found to be lagging in development of intellectual and academic performance with their "culturally deprived" backgrounds generally considered to be a prime cause.

Pretests

All subjects were tested with the Conservation of Number section of the Intellectual Tasks Test (Hughes 1967). The test was a classical conservation of number task in which sets of objects (dominoes turned face down) were arranged in two equal number and spatially aligned groups on a table before the subject, and the subject was asked if there were the same number of items in each group. After the child answered for two sets with equal spatial configuration, one of the

sets was arranged into a new configuration without adding or subtracting any of the objects. The tester then asked again if there were the same number of items in each of the two groups. Non-conservation was shown by a failure to respond to this third question by an indication of equality. Three questions, two to verify equality of groups with identical configurations and one to conserve equality of groups with different configurations, were asked for groups of seven items. Three questions, one to verify equality of groups with identical configurations and two to conserve equality of groups with different configurations, were asked for groups of fifteen items. One item was then added to each group and these sets of 16 items arranged in different configurations. The conservation question was repeated. Two items were then removed from one of the groups and the child was asked which group had the most items. After this response, the child was asked to count the 16 items in the rectangular array. Disregarding the counting question, there were eight possible correct answers and the subject was given one point for each correct response.

Subject Selection

The thirty lowest scoring children were selected as subjects for the study with 15 subjects assigned non-systematically to both the Number Training Experimental Group and the Form Training Control Group. The mean scores from a maximum possible score of 8.00 on the pretest for the Experimental and Control groups were 3.40 and 3.33 respectively. The mean score for the 19 Ss eliminated was 6.95. No effort was made to balance for sex (14 female, 16 male) in subject assignment

but there were an equal number of each sex in the Experimental and Control groups (seven females and eight males per group).

General Procedures

All training on the match-to-sample (MTS) apparatus and all testing for conservation of number was done in a mobile laboratory housed in a 32 foot house trailer which was parked on the school grounds near the classrooms from which the subjects were taken. Before the experiment was begun all of the children in the three classrooms were given a tour of the trailer and shown the MTS apparatus. It was explained that from time to time some of the children would be able to come out to the trailer and play a game with the machine. All training on the MTS was accomplished in one room of the three room trailer and all testing was done in another room. These two rooms were divided by the apparatus room from which both the training and testing activities could be viewed through one-way windows. A floor plan of the mobile laboratory is shown in Figure 1.

A female assistant was thoroughly trained in administration of the number conservation tests and served as tester during all phases of the program. The assistant did not know the subject's treatment condition and did not observe them during any phase of training. The experimenter (E) brought the child to the training room and gave him instructions in how to operate the apparatus in order to "play the game." The MTS was begun at the frame before the first slide, so that the top panel was blank but illuminated and the bottom panels were

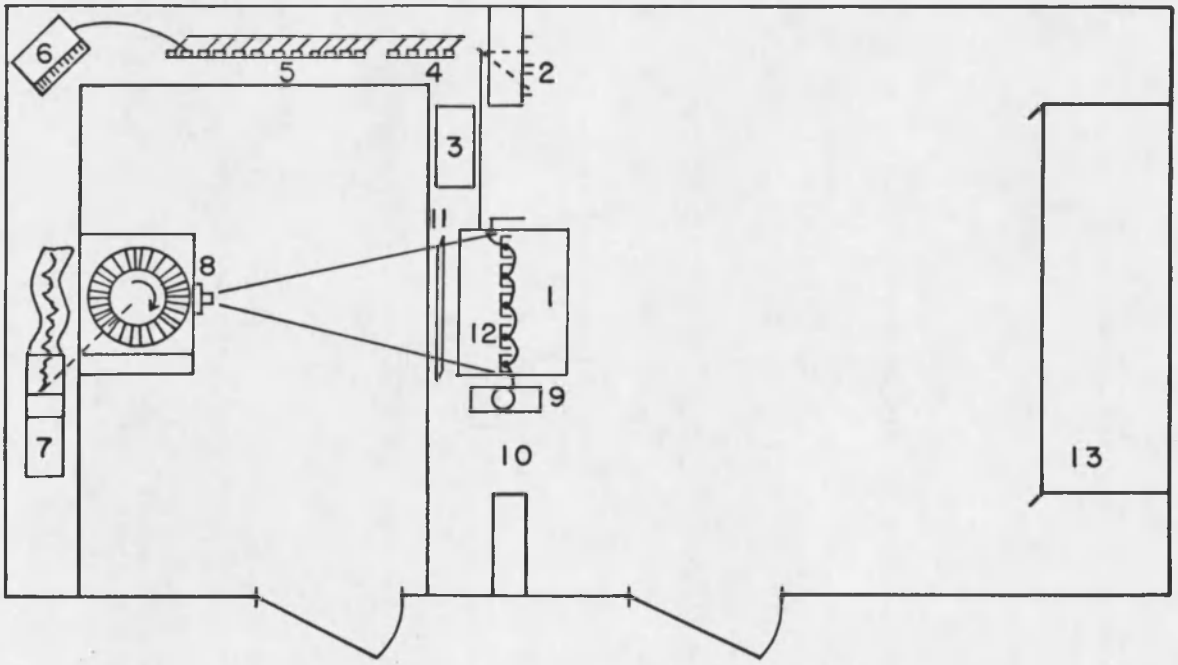

FIGURE 1. Floor Plan of Mobile Laboratory

1. Matching-to-sample display panels
2. Door chime and buzzer
3. Intercom
4. Response counters
5. Relay board
6. 20-pen event recorder
7. Cumulative recorder
8. Projector
9. Davis dispenser
10. One-way window
11. Shutter
12. Response key photocells
13. Experimenter's table

blank and darkened by the shutter. The instructions were identical for both the number Training Group and the Form Training Control Group. E gave each child (S) the following instructions.

> "This is our game. You stand here in front of it and I will show you how to play our game." (E then demonstrated the MTS with the blank panels.) "When you push this top window, the little windows will light up." "You push the top window." "Now look at the bottom windows. See, there are five little windows." "You push one of the little bottom windows. See what happens?" (At this point the first sample stimulus is lit up on the sample panel.) "Now I will show you how to make the bell ring." (E prompted the child to push the sample panel.) "Now you must push the little window on the bottom which is like the picture in the top window. If you choose the correct one, the bell will ring and tell you that you got the best answer." (E pointed out the correct matching choice to the child.) "It is this one here. You push this one to make the bell ring this time." "That bell means that you got the best answer." "Do you understand how to make the bell ring? Tell me how." (If the S failed to demonstrate a verbal understanding of the response chain required, the instructions were repeated.) "You must try to make the bell ring as many times as you can. I think you can make the bell ring a lot of times. Now you must play the game by yourself. I will sit over here and do some work."

After giving the instructions, the experimenter went to a table in the room and busied himself with the observation sheets. If the child began to respond to the MTS, he was not interacted with until he finished the program. If he did not begin the task for a few minutes or began to engage in some other behavior, the experimenter gently encouraged him to begin. If the child did not then begin, the instructions were given again in exactly the same manner as the first time. Error criterion was reached when there were 10 error responses to a single frame which constituted termination of training. Extinction was defined as refusing to respond for five minutes or asking to leave the training situation.

After MTS training, the child was taken into the other room where the assistant gave the conservation of number test. This same procedure was followed for all phases of the program with training and testing extending over a three-week period.

Apparatus

A modified Gerbrands Matching-to-Sample apparatus with frosted plexiglass panels was set in one wall of the training room about 30 inches from the floor and within easy reach of the average child five to seven years old. The apparatus consisted of a sample panel 15 inches long by 3 inches high with five 3X5 response panels lined up below it as shown in Figure 2. The frosted plexiglass panels showed images projected on them from the rear by a Kodak Carrousel projector (see Figure 1). Above the panels was a door chime for signalling correct responses and a buzzer for signalling incorrect responses. The apparatus control room immediately behind the response panels housed all of the apparatus to operate the MTS and record data. This apparatus consisted of photocells to light-key correct response panels and electrical relay boards for programming the shutter, Carrousel projector, response and error counters, Gerbrands cumulative event recorder, and an Esterline-Angus 20-pen event recorder.

The child operated the apparatus by first pressing the illuminated sample panel for one-half second, which caused the shutter to drop thus lighting the response panels with the matching choice stimuli. This procedure was included to help orient the child's

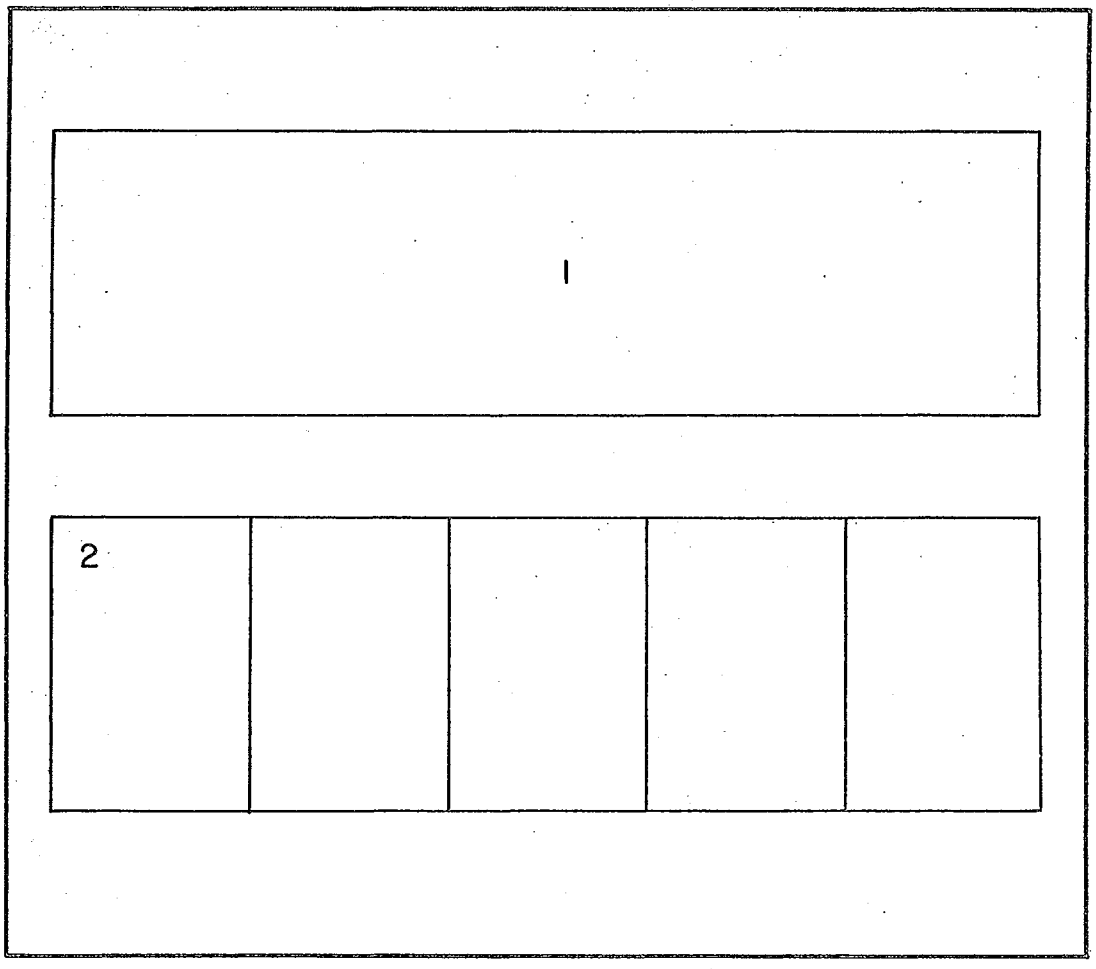

FIGURE 2. Matching-to-Sample Apparatus.

1. Sample panel
2. Response panels

attention to the sample stimuli. A matching response consisted of pressing one of the response panels for a minimum of one-half second. Hitting, tapping, running the hand across the panels, or pressing more than one response panel at a time had no effect. When the child pressed one of the response panels, a bell rang if it was a correct match or a buzzer sounded if it was an incorrect matching response. After a correct match, the Carrousel projector advanced to the next slide in the program and the shutter flipped up to blank out the response panels. The process of first pressing the lighted sample panel followed by pressing the response panel to match was repeated. After an incorrect matching response, the slide did not change nor did the shutter flip up. Only the buzzer sounded to indicate an incorrect response. The child had to continue attempting to match the sample for this slide until he made a correct response. After a correct response which was preceded by one or more error responses, the program backed up to the preceding slide to which the child had already made an initial correct response. This error correction procedure was designed so that the program only advanced after a correct first-choice response on any one trial thus insuring that stimulus change was contingent upon correct responding and that progression through the program was contingent upon first-choice correct responding.

Data Recording

One counter recorded total number of responses while a second recorded total error responses. The Gerbrands Cumulative recorder was attached by a pull chain to the slide drum of the Carrousel projector

so that advances or back-spacing of the projector would chart progress through the program. This record allowed analysis for total number of responses and total time at task as well as number of responses and average time per response for each ten slide advance through the program. The cumulative record also served as an overall graphic representation of progress through the program. The Esterline-Angus 20-channel recorder gave a complete record of all responses to each response panel thus allowing for a trial by trial analysis of responding.

Number Training Program

Stimuli presented on the Matching-to-Sample apparatus were first photographed on high speed Ektachrome type-B color film. The slides were then projected by the Carrousel projector onto the backs of the frosted plexiglass panels of the MTS. The number training program consisted of three phases (Phases I, II, and III) with 50 slides in each phase. A redundant cue was used as an aid in acquisition of number discrimination in each of the three phases of the number training program. This redundant cue was an illumination gradient between the correct choice stimuli and the incorrect choice stimuli. The sample was always presented at full illumination and served as the standard for 100% illumination. The correct matching choice was always presented at 100% illumination while the incorrect matching choices were faded-in in five steps (10 slide blocks hereafter called Stages) of 10%, 30%, 50%, 70% and 100% illumination during each 50 slide phase of the program. The overall effect of this procedure was to have the

correct matching choice "spot lighted" during the first parts of each phase of training with the incorrect choices gradually brought up to equal illumination. This fading process was accomplished by photographing the incorrect stimuli through Bourgess overlay sheets with light transmission value of 10%, 30%, 50%, and 70%.

For all phases of the program the number of items in the various matching response panels, the position of the correct matching response panel, and all irrelevant stimulus dimensions were assigned by a system of randomized Latin squares so that: (1) all the variable stimuli assigned to any one response panel were balanced; (2) all variable stimuli were introduced an equal number of times; (3) all response panels served as correct matching panel equally; (4) no variable was assigned to the same panel twice in succession; (5) and no response panel served as correct matching panel twice in succession. This elaborate assignment of variables was done in an effort to prevent patterning or "superstitious" responding.

Phase I (50 slides): The number of items in the sample and choices varied from one to five. All items were photographs of one-inch white squares arranged in single vertical columns with equal distance between items in each set. Thus, Phase I held the stimulus dimensions of color, size and shape of item and density and configuration of set constant as illustrated in Figure 3.

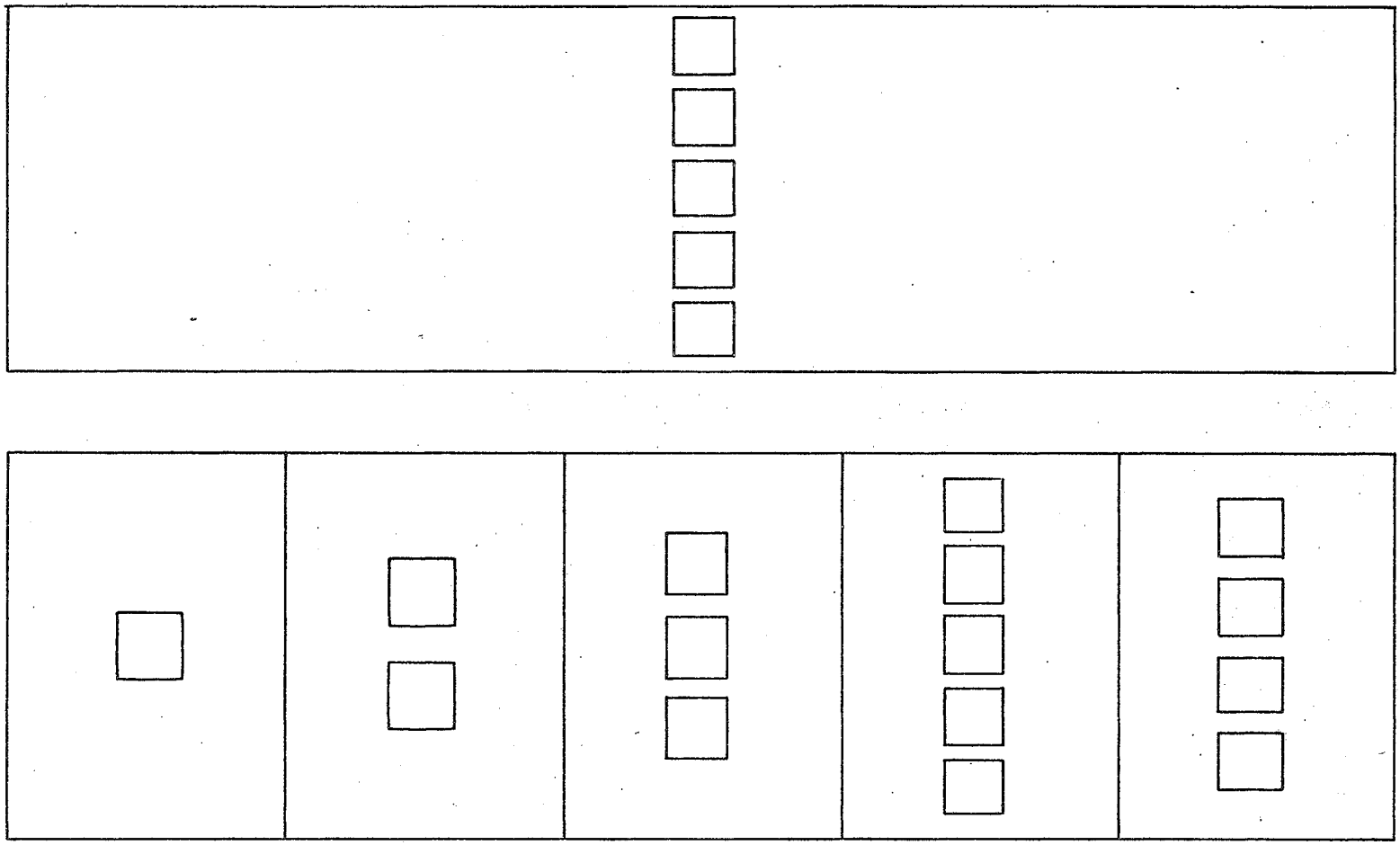

FIGURE 3. Slide 49, Phase I, Number Training Program.

Phase II (50 slides): The number of items in the sample and choices were 2, 4, 6, 8 and 10 per set. The sample items were reduced to 5/8 inch white squares arranged in a single horizontal row with only the number of the sample items varying from trial to trial. The matching choices varied across three sizes (1", 5/8" and 3/8") and the set density in the choices varied from denser than sample, same as sample, and less than sample. These size and density variables were assigned as described above and were balanced across trials. The color and shape of the items and the configuration of the sets were held constant for Phase II although the configuration of the sample differed from the choices. The sample was always a horizontal row while the choices were always a vertical column or columns depending on the number of items in the choice set. This difference was necessitated by the size of the response panels. This difference was held constant throughout Phase II. Figure 4 shows a typical Phase II stimulus presentation.

Phase III (50 slides): During Phase III, the number of items in the sample and matching choices were 3, 6, 9, 12 or 15 per set. The items in the sample were 3/8 inch white squares arranged in a single horizontal row as in Phase II. Only the number dimension varied across trials for the sample. The three levels of item size and three levels of set density varied for the matching choices as Phase II. Five variations of color (red, green, yellow, white, and blue); five variations of item shape (square, rectangle, triangle, octagon, and diamond); and five variations of set configuration

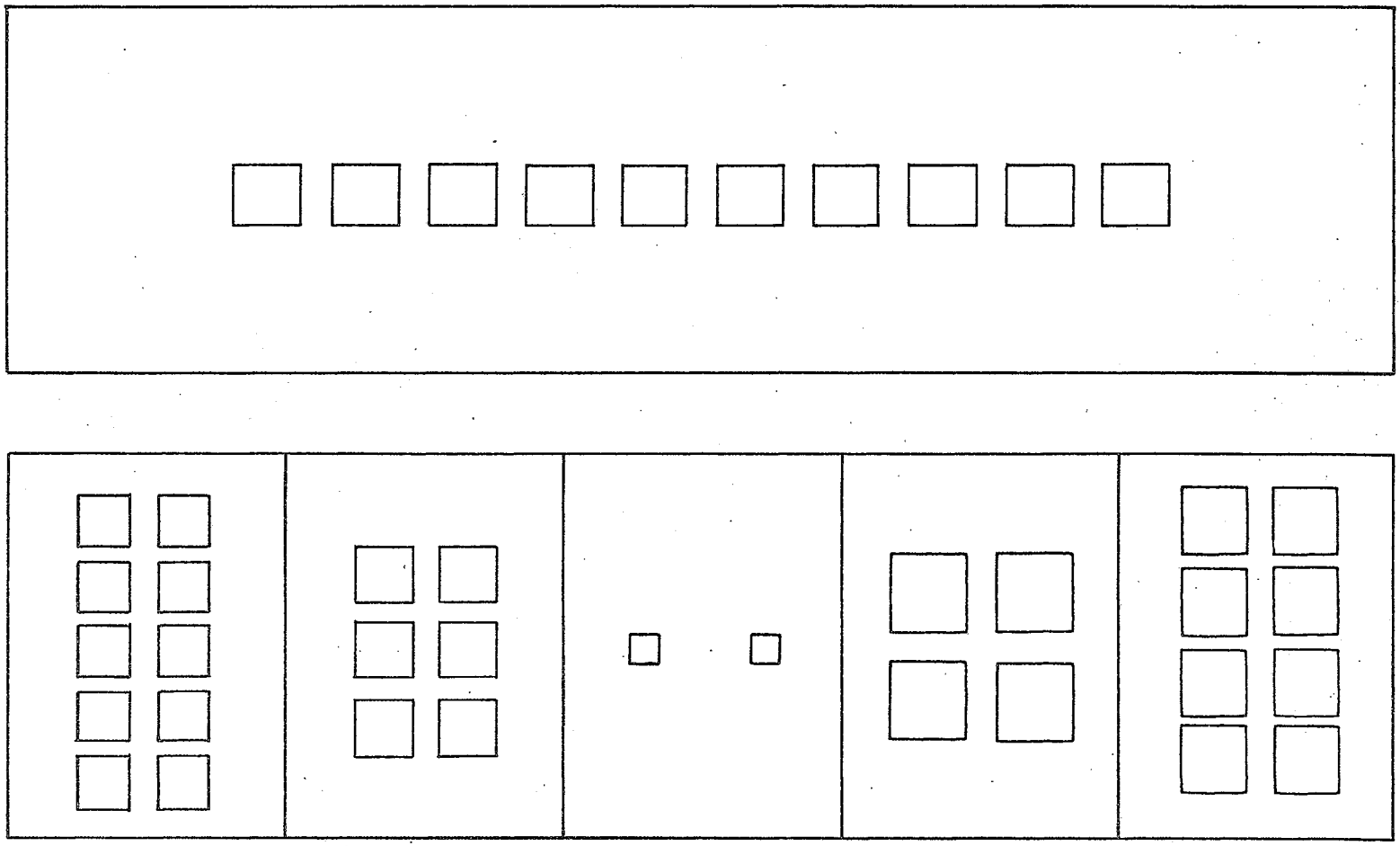

FIGURE 4. Slide 49, Phase II, Number Training Program.

(column , row, cluster, square and triangle) were introduced as irrelevant stimulus dimensions in the matching choices. Figure 5 shows a typical Phase III stimulus array.

These procedures used a redundant illumination due to bring responding under control of the number cues during Phase I. The illumination cue was then reintroduced at the beginning of Phases II and III when the number of items to be discriminated was increased and the irrelevant stimulus dimensions of item shape, color and size and the set density and configuration was introduced.

Form Training Control Program: Subjects in the control group received training on the MTS apparatus after receiving the same instructions as the number training group. The control group was presented a 50 slide program in which the relevant cue for correct matching was item shape. Irrelevant dimensions were item size (three variations), item color (five variations), and solid versus outlined forms. Number was not introduced since all samples and choices were single items. The position of the correct matching choice and the assignment of the irrelevant stimulus dimensions were determined by the same procedure as the stimuli in the number training program described above. There was only one control program of 50 slides so that the control group over-learned the discrimination during Phases II and III of training. Figure 6 shows an example of the control program stimuli.

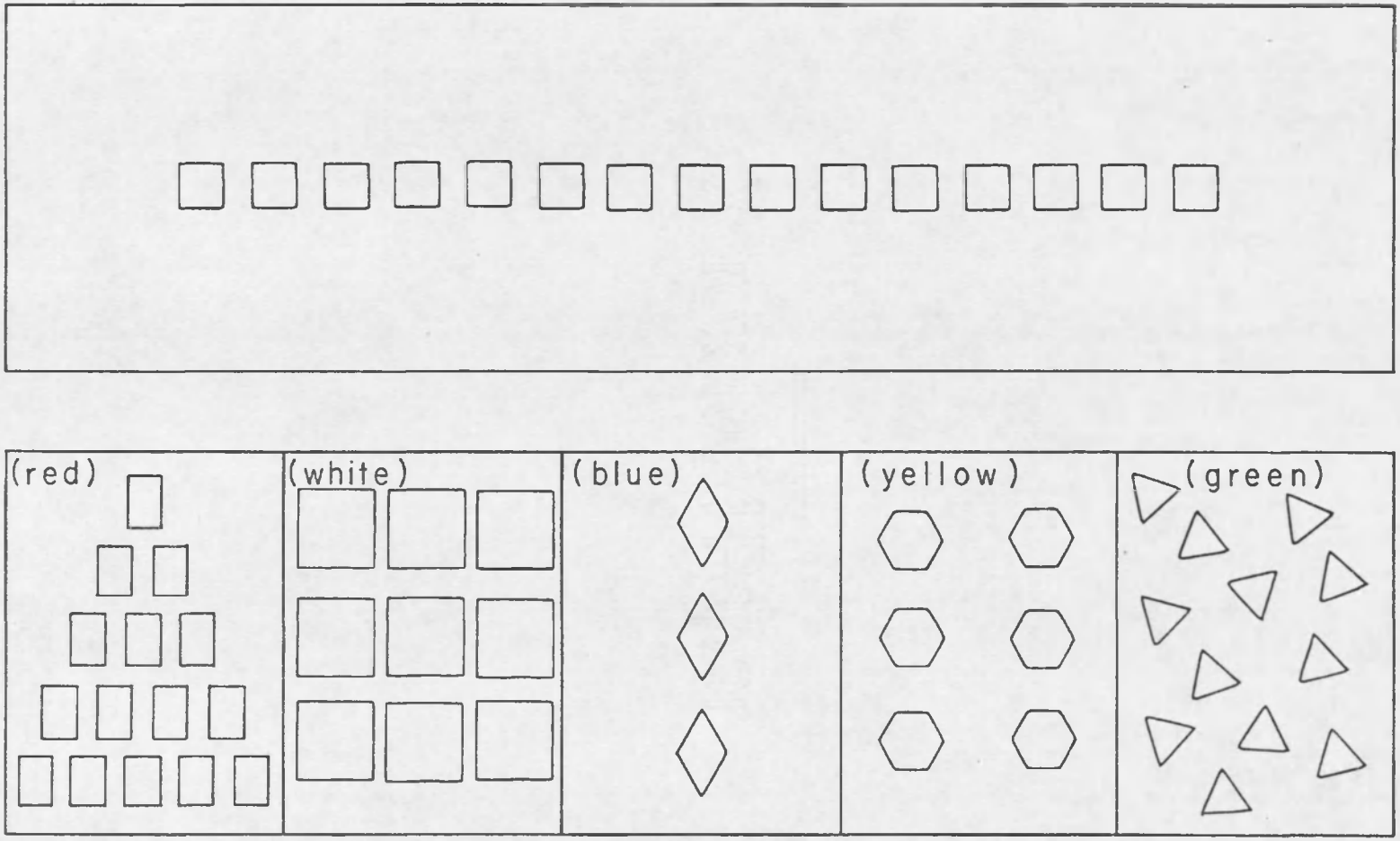

FIGURE 5. Slide 49, Phase III, Number Training Program -- Color of items shown in parentheses.

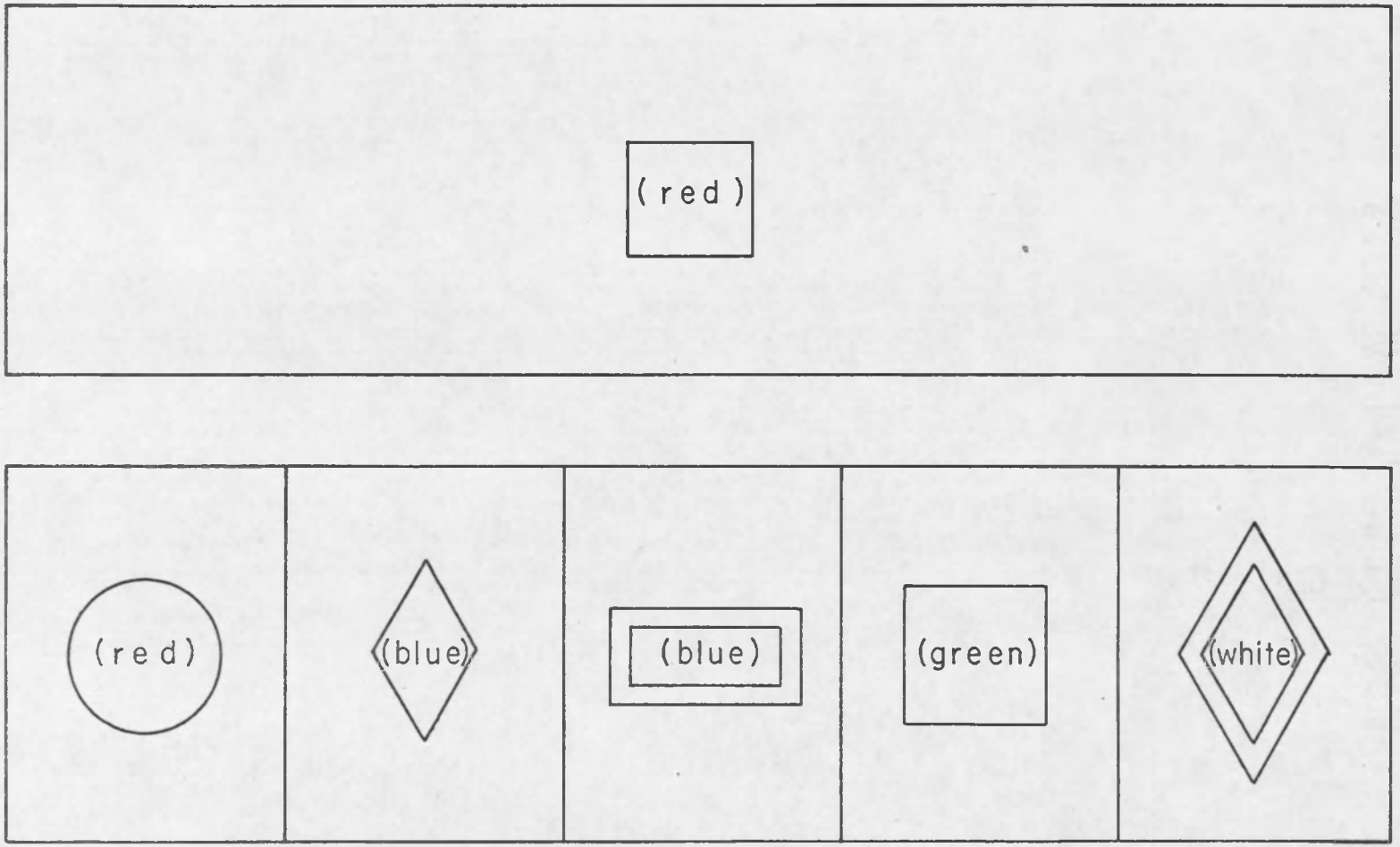

FIGURE 6. Slide 49, Control Program.

Posttests

Immediately after each phase of training, all of the subjects were administered the same test for conservation of number as used for pretesting and described above.

RESULTS

Form Training Control Group

All 15 Ss in the control group learned the discrimination with very few errors. The discrimination was simple and the 50 slide sequence was overlearned for Phase II and III. Response rates increased from phase to phase and errors decreased. Figure 7 shows typical cumulative records for control group subjects.

Number Training Group

Of the 15 Experimental Group Ss given training on the number discrimination program, 11 were successful in completing all three phases before reaching the error criterion. Of these 11, recording apparatus failures prevented data collection for two Ss during the Phase I training eliminating these Ss from some of the statistical computations. There were four subjects who were unsuccessful in completing all phases of training. Of these four, one extinguished before completion of both Phases II and III; one reached error criterion on Phase II and then incurred apparatus failure on Phase III; and two reached error criterion before completion of training on all three phases. All of these unsuccessful Ss did complete the first three Stages in each phase and these data were used to make some of the comparisons to be discussed below. Figure 8 shows cumulative records of representative successful and unsuccessful subjects.

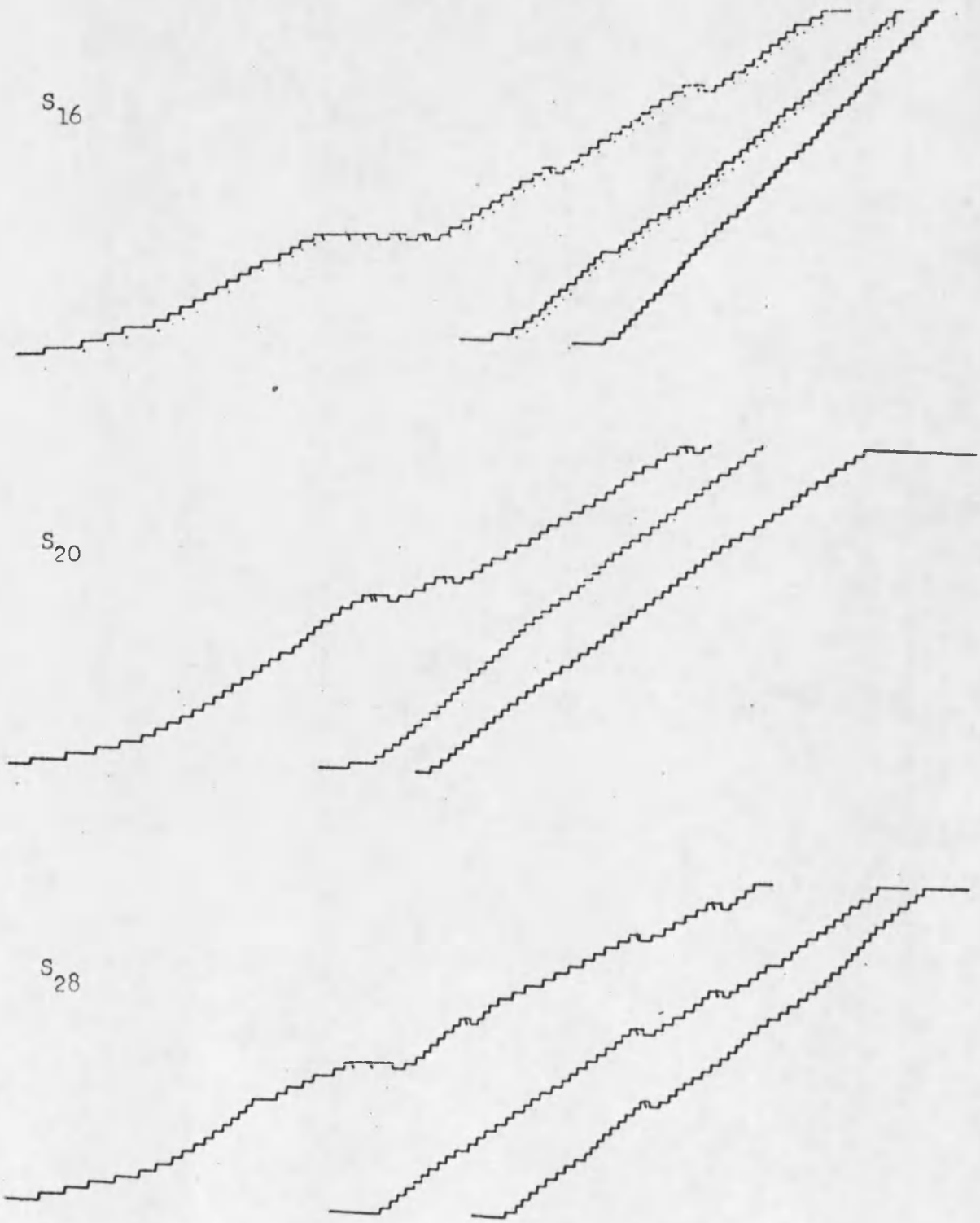

FIGURE 7. Representative Cumulative Records for Control Group.

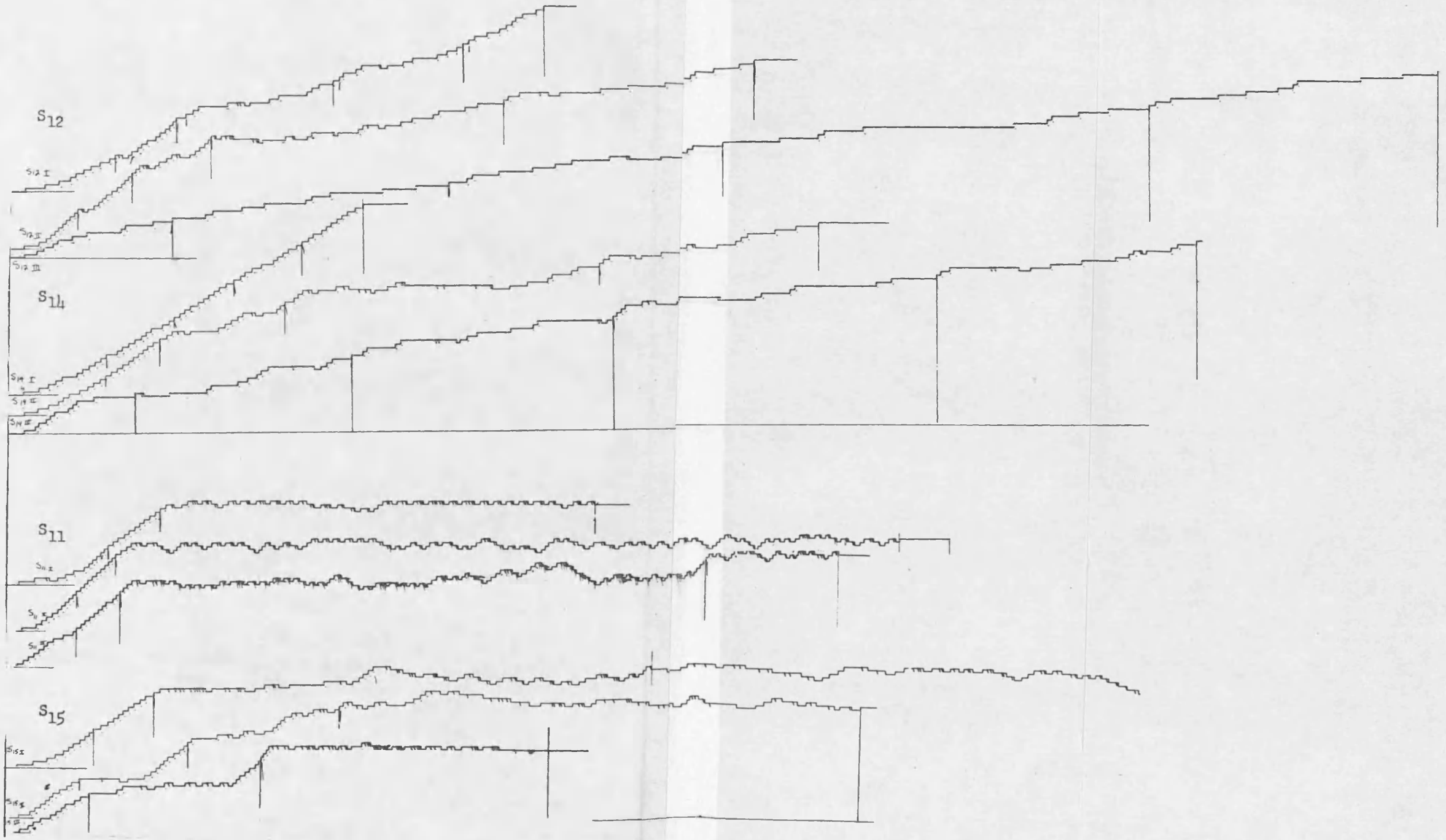

FIGURE 8. Representative Cumulative Records of Successful and Unsuccessful Subjects.

Error Data

The mean percentage of error responses was calculated for each of the five stages within each phase of training for each subject. These data show that those Ss with greater overall error percentages did not uniformly produce the greater number of errors during the last stages of the three phases of the program. Although the unsuccessful Ss have overall error percentages very similar to the successful subjects, their errors for the last stage completed are extremely high indicating a relatively errorless first two stages with a sudden increase in error responding just before reaching error criterion and termination of training.

Errors were further analyzed in terms of the number of responses required for each subject to make a ten frame advance (number of responses per stage) in the program. Recall that each phase of training had five stages corresponding to the changes in the illumination cue. A one-way repeated measures analysis of variance for subjects by stages within phases of training was done on the data from the nine successfully trained Ss. Table 1 summarizes this analysis.

This analysis showed that there was no significant phase main effect ($F=2.838$, df 2/16, $P > .10$.) nor was there any significant interaction effect between phases and stages within phases ($F=1.61$, df 8/32, $P > .10$). There was a highly significant stages main effect ($F=8.061$, df 4/32, $P < .01$). These findings indicate that there was not a significant difference in total responses for completion of the

TABLE 1: Analysis of Variance for Responses per Stage for Successful Subjects

Source	df	MS	F	P
Phases (A)	2	1331.59	2.84	>.10
Stages (B)	4	1889.95	8.06	<.01
Subjects (S)	8			
A X B	8	308.29	1.61	>.10
A X S	16	469.125		
B X S	32	234.44		
A X B X C	64	124.58		

three phases of training but that there was a significant difference in number of responses per stage within the three phases. Figure 9 shows the progress of training for each phase of the program across the five stages within each phase. Note that for all three phases errors increase from initially errorless responding to a point midway through the program and then uniformly diminish during the final stages. The shapes of these curves are indicative of the process of transfer of stimulus control from the fading illumination cue to number cues. The course of learning within the program is further illustrated by comparing the errors for successful subjects against those of the four unsuccessful subjects for each phase of training in Figure 9. This graphic comparison clearly indicates a specific point at which the unsuccessful subjects were unable to make further progress. This is the same point at which successful subjects began to reduce errors.

Response Latency Data

Response rate was measured by calculating each subject's mean latency of response in seconds from the onset of the choice stimuli to the matching choice response for each stage within each phase of the program. These data for the nine successful subjects were subjected to a one-way repeated measures analysis of variance for subjects within phases. Table 2 gives a summary of this analysis.

Response latency showed no significant phases main effect ($F=2.08$, df 2/16, $P > .10$) or stages main effect ($F=1.53$, df 4/32,

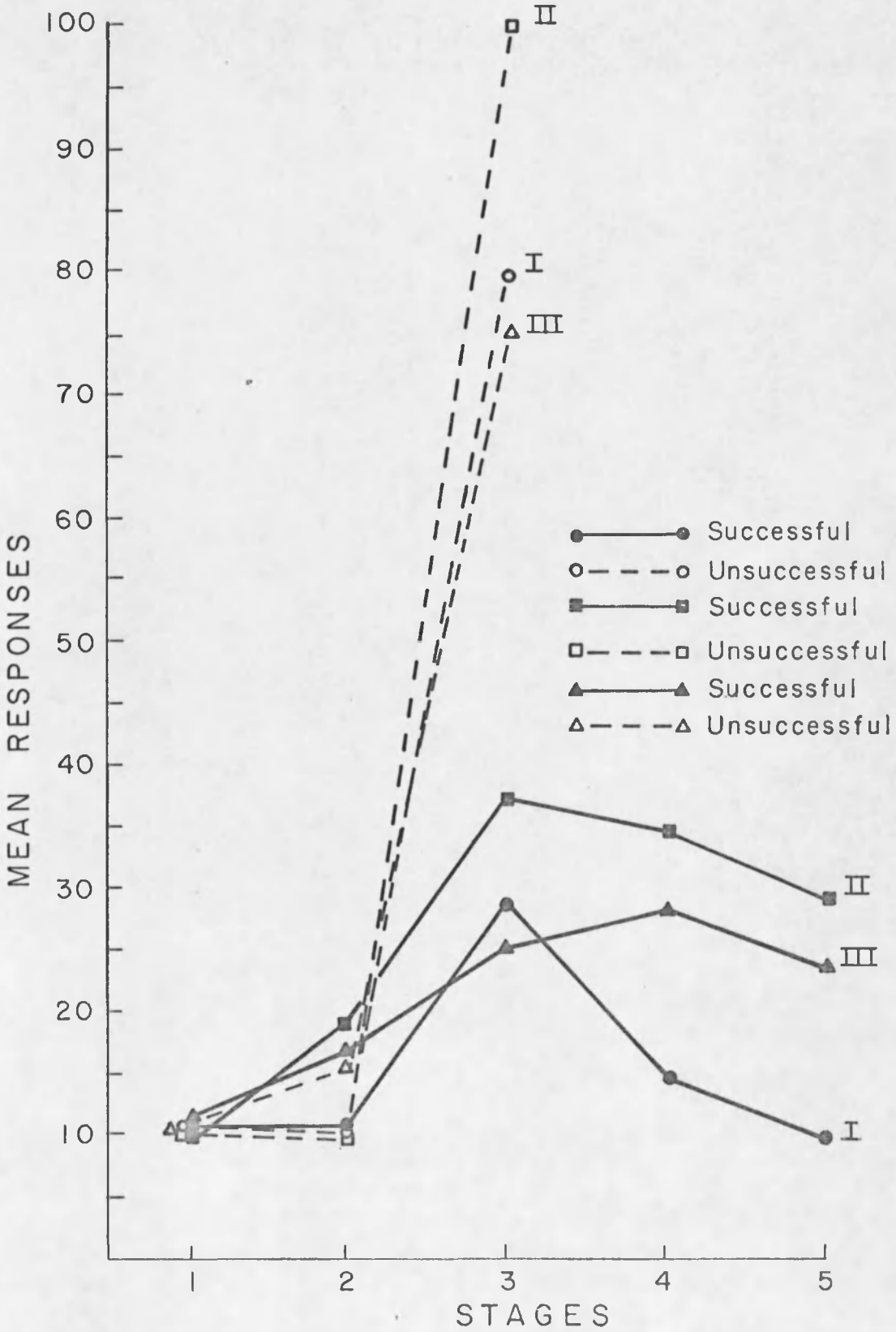

Figure 9. Mean Responses for Each Phase across Stages.

TABLE 2: Analysis of Variance for Mean Response Latency Per Stage for Successful Subjects

Source	df	MS	F	P
Phase (A)	2	131.04	2.08	>.10
Stage (B)	4	16.20	1.53	>.10
Subject (S)	8			
A X B	8	40.02	5.75	<.01
A X S	16	63.11		
B X S	32	10.62		
A X B X S	64	6.96		

$P > .10$). There was, however, a significant phases by stages interaction effect ($F=5.752$, df 8/32, $P < .01$). This interaction can be seen in Figure 10 which shows the mean latencies for each stage plotted across the three phases and Figure 11 which shows the latencies for each phase plotted across the five stages. As these data indicate, responses were slow during Stage 1 of Phase I even though the illumination gradient was high. As the response topography for operation of the apparatus was learned and the relatively simple discrimination presented by the salient illumination cue was learned, speed of responding increased. This response speed stabilized and appeared to slow some as stimulus control was transferred to the number cue. The latency remained fairly short for the remainder of Phase I, probably due to the fact that the number in the sets of items in Phase I was never greater than five and may have been matched on a perceptual basis. After an initial decrease in response latency through Stage 2 of Phase II, responses slowed down considerably for the rest of Phase II. In Phase III response latency was quite short on the first stage of the phase and increased through Stage 4 then dropped for the final stage. Figures 10 and 11 illustrate these response latency changes across stages and across phases.

Figure 12 compares the latencies of the unsuccessful subjects with the successful subjects. For Stages 1, 2, and 3 of both Phase I and II the response latencies of the unsuccessful subjects were very

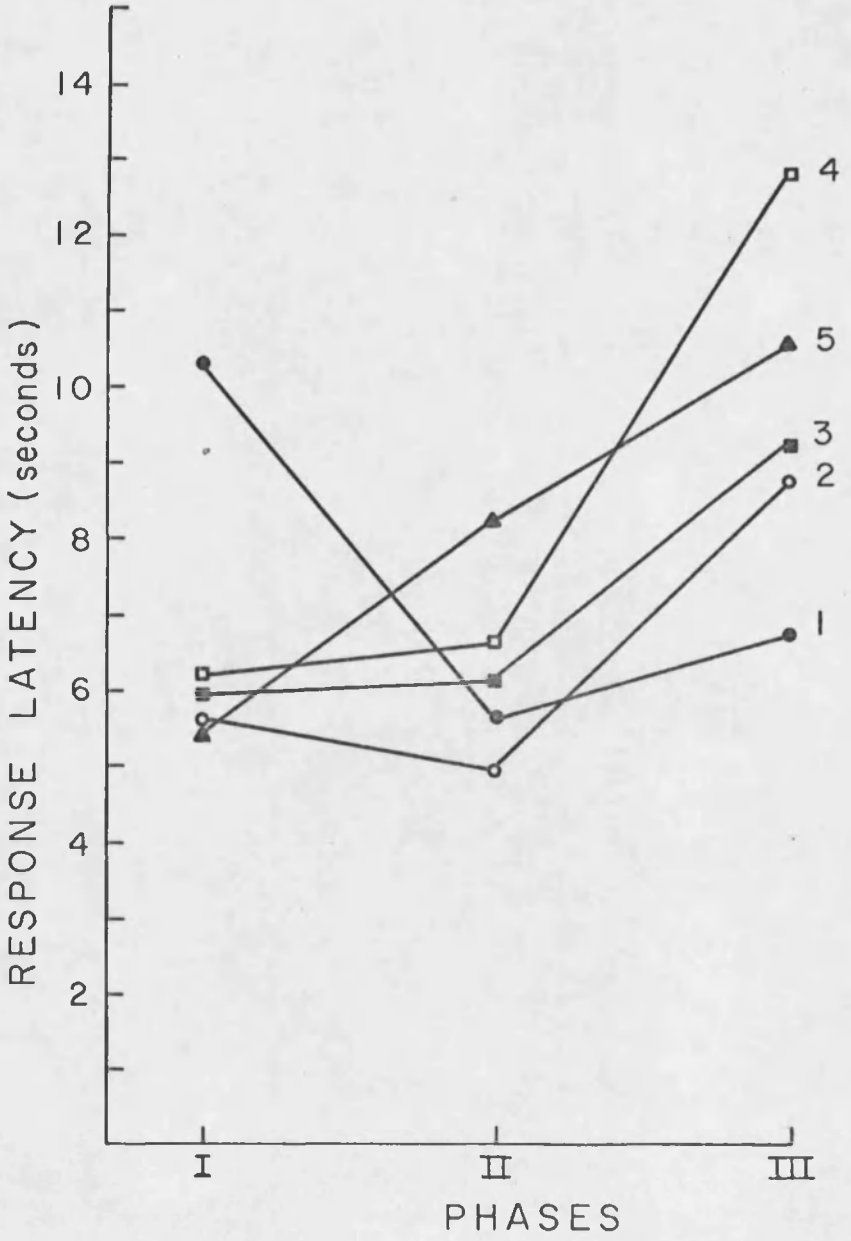

Figure 10. Response Latency for Stages across Phases.

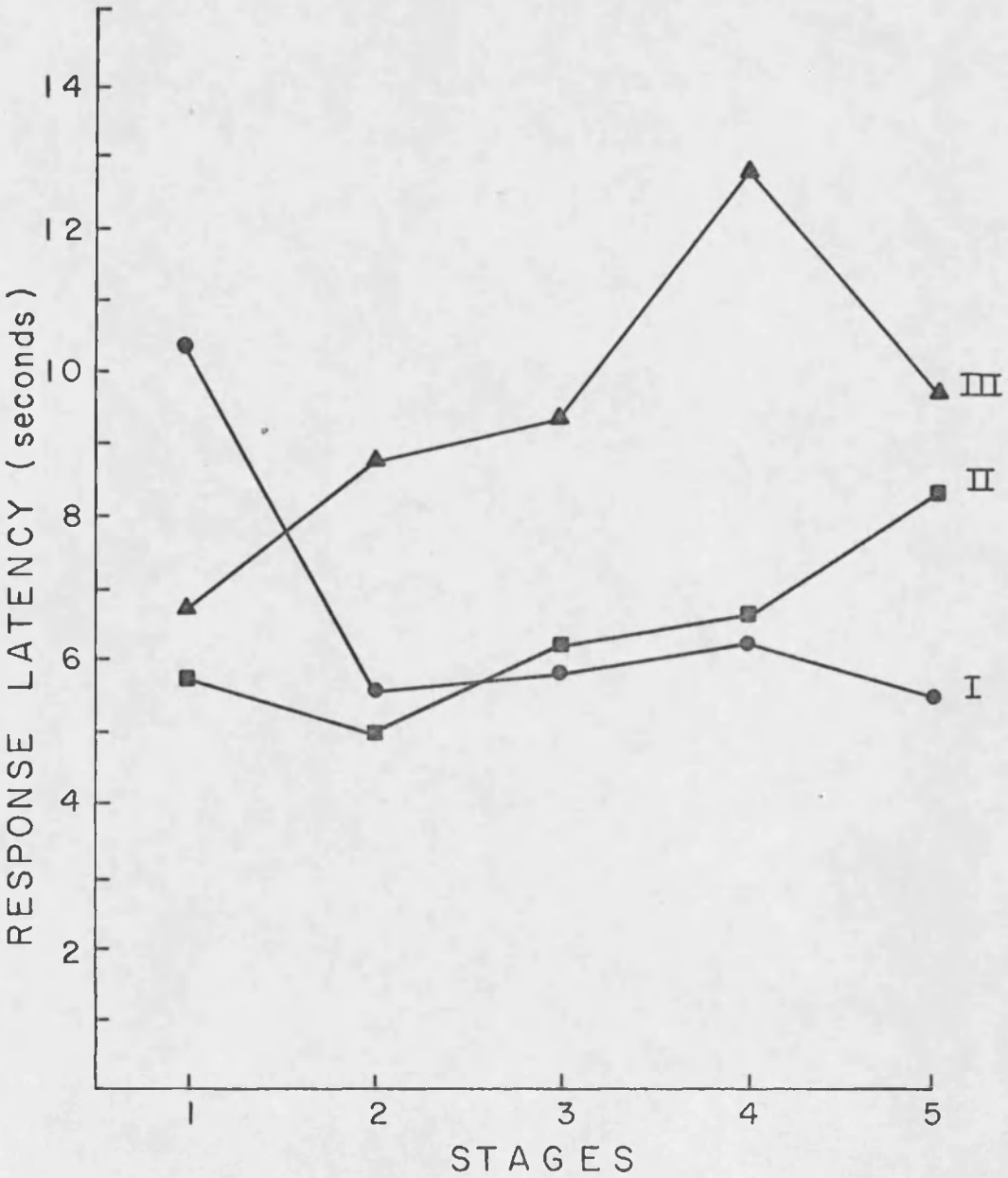

Figure 11. Response Latency for Phases across Stages.

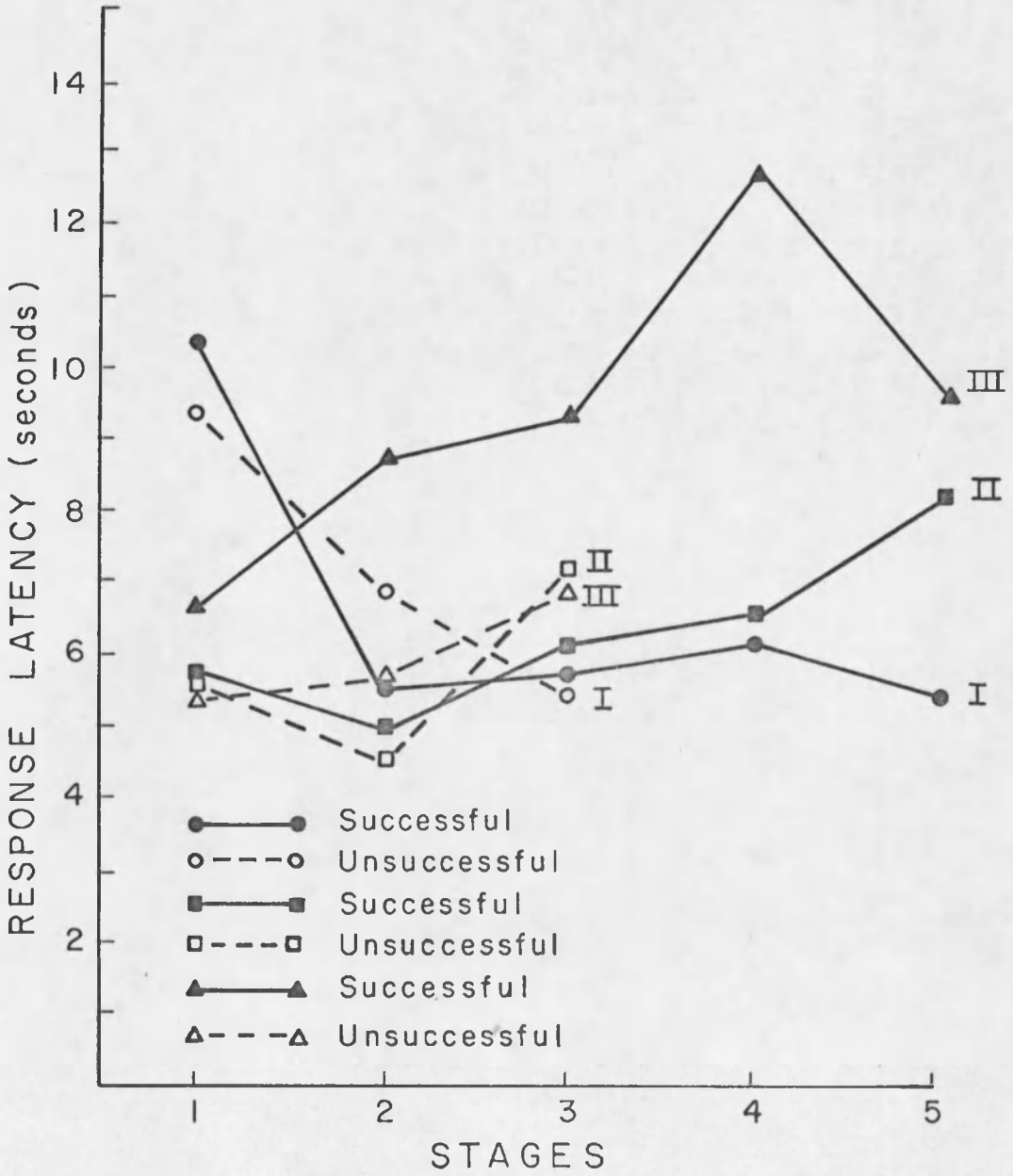

Figure 12. Response Latency for Phases across Stages: Successful vs. Unsuccessful Subjects.

similar to those of the successful subjects. In Phase III, the unsuccessful subjects began the training with shorter latencies and, although increasing some through Stage 3, had consistently shorter latencies than the successful subjects.

Error-Response Latency Correlations

Pearson-r correlations between number of responses per stage (error measure) and response latencies were computed for the final criterion stage of each phase of training and for the total training program. The correlation between errors and response latency for the total program (-.71) is only slightly less than for each of the final stages of the three phases (-.77, -.77, -.78) which indicates that slower responding consistently led to fewer errors.

Other Behavior

While the subjects were responding to the MTS apparatus, the experimenter made an observational record of the child's behavior. One class of behavior considered significant was whether the subject showed overt signs of counting, such as using the fingers to count or vocalizing the number of items in the sets. Of the eleven successfully trained subjects, eight counted in Phase I; seven in Phase II, and seven in Phase III. Of the four unsuccessful subjects, only one showed signs of counting. This subject was so careful in counting that although making few errors she appeared to grow tired of the laborious task and asked to be excused. Another behavior of interest was a response maximizing scheme developed by many of the successful

subjects during Phase II and Phase III. This response pattern involved making a first matching choice on the basis of a "best guess". If this guess led to an error, as it did in many instances, the child would then count the items in one or two alternate choices in order to make a correct choice. This scheme was actually the most efficient means of progressing through the program, especially for Phase III in which the sets of items were large and counting was difficult and time consuming.

Transfer to Conservation of Number Test

Table 3 summarizes the 2X3 repeated measures analysis of variance for treatment groups by treatment phases which showed no significant difference between the treatment and control groups.

The four unsuccessfully trained subjects were then deleted from the treatment group and the 11 successfully trained subjects were compared with the 15 control subjects. Table 4 summarizes the analysis of variance which showed no significant difference between the treatment and control groups.

As a further test for transfer of training the subjects were asked to count 16 items (dominoes face down on a table in a 4X4 array) after each posttest. Table 5 shows the number of the 11 successfully trained subjects who correctly counted compared to the 15 control subjects who correctly count 16 rectangular items in a rectangular array and that there was no improvement in counting ability across tests for the training group as opposed to the control group which appeared to show some improvement.

TABLE 3: Analysis of Variance for Conservation Scores of Training vs. Control Group

Source	df	MS	F	P
Between				
Treatment (B)	1	17.96	2.27	$> .10$
Error S (B)	28			
Within				
Phases (A)	2	.70	< 1.0	N.S.
Phase X Treatment (A X B)	2	1.14	< 1.0	N.S.
Error (S (B) A)	56			

TABLE 4: Analysis of Variance for Conservation Scores of Successfully Trained vs. Control Group

Source	df	MS	F	P
Between				
Treatment (B)	1	.20	<1.0	N.S.
Error S (B)	24			
Within				
Phases (A)	2	.25	<1.0	N.S.
Phases X Treatment (A X B)	2	.01	<1.0	N.S.
Error S (B) A	48			

TABLE 5: Percentage of Subjects Counting Correctly

Group	Phase		
	I	II	III
Successful (n=11)	36%	45%	27%
Control (n=15)	47%	60%	66%

Table 6 shows the number of children who verified the equality of the sets which were perceptually the "same," that is gave a "same" response to questions A1, A2, and B1. It can be seen that for neither the experimental nor the control group was there a significantly greater number of subjects verifying "sameness" of the spatially aligned sets.

TABLE 6: Subjects Verifying Equivalence of Spatially Aligned Equivalent Sets

Group	Phase								
	I			II			III		
	A_1	A_2	B_1	A_1	A_2	B_1	A_1	A_2	B_1
Experimental n=15	10	11	7	12	12	9	10	9	11
Control n=15	9	11	8	11	10	7	10	11	10

DISCUSSION

This study is based on the assumption that attention to the relevant stimulus attribute is critical in a child's understanding of number conservation and that children can be taught to attend to the relevant stimulus attribute by use of errorless training techniques. Specifically, training a group of nonconserving children to attend to and match on the basis of number attributes in a series of matching to sample problems should lead to increased conservation responding on a classical Piagetian number conservation test.

Eleven of fifteen nonconserving children learned to respond to the relevant attribute of number while disregarding the irrelevant attributes of item shape, size, and color and set density and configuration in the programmed sequence of matching problems. Although these children learned the nonverbal program, no significant improvement was found when they were tested for transfer to the classical conservation of number task. This would suggest that for this population of children, the classical Piagetian test involves more than a measurement of the child's understanding of the concept of "same number." Suppositions as to what these factors are will be presented later in this discussion.

Although the transfer of training was not significant, the study does clearly illustrate a process of number discrimination acquisition. This process was demonstrated to be due in part to the training program's effectiveness in controlling several variables

potentially significant in matching to sample discrimination learning and number concept acquisition.

A major and, hence, potentially confounding variable in number concept training and assessment is the child's language comprehension (Wohlwill, 1960; Griffiths, Shantz, and Sigel, 1967; Mermelstein and Shulman, 1967; and Harasym, Boersma, and Maguire, 1971). In this study the influence of language is considerably reduced by presenting minimal instructions which do not label the relevant attribute of number. The child's response was brought under the control of number stimuli solely through the stimulus programming. Rather than verbally instructing the children to respond on the basis of "same number," responding on the basis of "same" (matching responding) was brought quickly under control of the salient redundant stimulus attribute of illumination. This short, built-in history of reinforcement for responding on the basis of sameness was then used to bring responding under control of the second component, "number", with the fading of the redundant cue. Verbal understanding or misunderstanding was thus eliminated as a contributing factor to the child's progress through the program.

Several researchers have pointed to error factors (Harlow, 1952) such as perseveration of position guided responding (Hively, 1962), the lose-stay phenomenon (Levin and Maurer, 1969), and other superstitious response patterns that may prevent learning or obscure its progress. The fading cue and back-up procedure used in the program eliminated these problems by first building in a short history

of reinforcement for matching responses with salient cue which appeared in all response panels an equal number of times. As the redundant cue was faded, the matching-response was strong enough to resist extinction until number became the discriminative stimulus for further matching responses. As Harlow (1952) pointed out, error factors are due in part to the organism's response to his own prior responses and to reinforcement available through random or position guided responding in trial and error learning. The procedures followed in this study very carefully controlled this history by minimizing the occurrence of any response other than the one which was intended to be strengthened.

Both the error data and the response latency data illustrate transfer of stimulus control from the supporting illumination cue to the number cue in each of the three training phases. These findings are similar to those of previous "errorless" training programs (Hively, 1962; Terrace 1963a, 1963b; Moore and Goldiamond, 1964; and Stoddard and Sidman, 1967).

The error data indicate that in this program errors did not significantly increase with increased problem difficulty. The almost identical learning curves generated in the three phases of the program demonstrate that more difficult problems can be introduced while errors are held minimal. This also eliminated problems associated with error responding such as reduction in the reinforcement level. Although errors did not vary significantly between phases, there were significant variations within each phase, between stages of the fading

illumination cue, which illustrate the point at which transfer of stimulus control from illumination to number occurred within each phase. This point of transfer appeared to be between Stage 3 and 4 for Phases I and II and between Stages 4 and 5 for Phase III. It may be that this shift in the point of transfer for Phase III was due to the increased problem difficulty, though this study did not yield data to this point. Of most importance to further development of training programs is the finding that in each phase of training there is an obvious point at which number cues become functional for correct responding and the removal of supporting illumination cues does not lead to increased error responses.

The point of transfer is also indicated by a comparison of the error data from the successful subjects with that from the unsuccessful subjects. At the point at which successful subjects' errors began to diminish, unsuccessful subjects' errors increased significantly even though unsuccessful subjects made as few or even slightly fewer errors for the first two stages of each phase.

Analysis of the response latency data also provides a rather clear picture of the process of acquiring number discrimination through transfer of stimulus control. The strong interaction between increased problem difficulty across phases and reduction of supporting illumination cue in stages within the phases washed out any statistically significant main effects of either. The major proportion of the interaction occurred between the first and last stages across phases of training. The initial slow responding during the first stage of the

first phase in which there was essentially no discrimination to be made seems to indicate the process of learning the correct response topography. By the last stage of the first phase, response latency was quite short even though incorrect choices were at full illumination and correct responding required a five choice discrimination. These data show the process of transfer of stimulus control to number cues which were small enough to be matched quickly, possibly even on a perceptual basis. Phases II and III have opposite trends in response latency with very short latencies for the first stage and increasing latencies through Stage 5 as stimulus control was transferred to more complex number cues which could not be quickly compared. These data are in agreement with Katz's (1968) findings in which response latency increased as a function of number of irrelevant cues in concept formation tasks with older and more intelligent children. The unsuccessful children in this study responded similarly to Katz's younger children whose response latencies decreased as a function of the number of irrelevant cues present.

The negative correlations between errors and response latencies were expected, since a counting strategy would lead to reduction of errors and slower responding. Conversely, reliance on perceptual comparisons would lead to increased errors and reduced latencies. Kagan, et al (1964) suggest that longer response times are indicative of a general reflective mode associated with more rapid concept acquisition. Peters (1967) found low socioeconomic children to be

more impulsive and less able to delay response to salient irrelevant cues in conservation tasks.

Reasons for the absence of positive transfer to the classic number conservation test can only be postulated. Of immediate relevance to these findings is the recurring controversy concerning the role of language in the solution of Piagetian conservation tasks. Piaget (1952, 1968) has steadfastly denied that language is a critical factor. Wohlwill (1960) emphasized the importance of verbal mediators and Mermelstein and Shulman (1967) found significant effects of varied techniques of questioning in conservation responses of culturally deprived children. Griffiths, Shantz, and Sigel (1967) and Harasym, Boersma, and Maguire (1971) found a developmental progression in the use of relational terms in conservation tasks which paralleled Piaget's stages of conservation attainment. Griffiths, et al. (1967) as well as Rothenberg (1969) found fewer conservers identified in response to the question of "same," and this difference was most pronounced among lower class children.

All of the successful training studies reviewed in this paper trained subjects in the correct relational terms to use in response to the conservation tasks presented. Kingsley and Hall (1967), Rothenberg and Orost (1969), Beilin (1965), and Gruen (1965) directly pretrained their subjects in appropriate use of the relational terms presented during training and testing. The conservation training procedures of Wallach and Sprott (1964); Wallach, Wall, and Anderson

(1967); Gelman (1969), and Roll (1970) were verbal and used the relational terms functional to the conservation testing so that verbal learning was concomitant with number concept learning. Two recent successful number conservation training studies (Rosenthal and Zimmerman, 1972; Zimmerman and Rosenthal, 1972) modeled appropriate use of relational terms in solving conservation problems. Wohlwill and Lowe's (1962) unsuccessful nonverbal training procedure led them to conclude that the verbal problem is especially important when attempting to apply automatic teaching methods to number conservation acquisition. The success of the present training program in bringing about a functional relationship between number stimuli and matching responses while carefully precluding any verbal training may indicate that the verbal aspect of the classic conservation task is more important to so-called conservation performance than the Piagetians would admit. Besides the lack of transfer to the classical test, the failure of these children to improve counting ability and the failure to verify equality of perceptually aligned sets of objects in the test are certainly in contradiction to expectations and surprising in light of the apparent success of the program which required counting and matching of equivalent sets in order to complete training.

A second relevant point of controversy is the importance of the transforming operations which the child witnesses in the conservation test. Piaget's (1968) criticism of Mehler and Bever (1967) also applies to this study. He pointed out that their use of static arrays

did not directly test for conservation of number which Piaget then defined as invariance of number despite transformation of the collection of objects. In his attempts to clarify Piagetian theory, Elkind (1967) stated that all conservation problems actually assess two forms of conservation, identity and equivalence, and that Piaget's theory is a theory of conservation of identity rather than equivalence. Conservation of identity occurs when the child maintains that the transformed set has the same number of items as it had prior to the operation. By a transitive logic he can then state that since the transformed set was at first equivalent to the nontransformed set, and since it maintained its identity, it must be equivalent to the nontransformed set. This is why Piaget argues that counting is not necessary in order to conserve number. The end result, equivalence conservation, is the observable condition by which the experimenter infers that the subject conserved identity.

An alternative explanation of the importance of the transforming operation is presented by Gelman (1969) who points out that stimulus change involved in the transformation may be seen as a salient cue which is irrelevant to correct responding. Gelman's hypothesis that training a child to respond to relevant quantitative relations would lead to conservation on standard conservation tests is similar to the hypothesis presented in the present study. There is also a striking similarity between the matching procedures used in this study and the successful oddity training procedures used by

Gelman. Gelman varied the relevant number of items in a set from three to six while varying irrelevant cues of form, configuration, color, and size.

There are two important differences between the nonverbal programmed training in this study and Gelman's procedures. First, as noted above, Gelman used a verbal training method which included the relational terms later used in the conservation testing. Secondly, the items in Gelman's procedure were transformed while the child observed the operations, thus including rearrangement of items as another irrelevant cue to be ignored for correct conservation responding. The results of the present study are in agreement with Gelman's findings that the nonconserving child does have to learn to respond consistently to quantity and not be distracted by irrelevant cues, but may not have to learn, de novo, to define quantity and invariance. However, his supposition that training which extinguishes the use of irrelevant cues should also bring out the "correct" verbal response was not confirmed by the results of this study.

In future research, the addition of verbal pretraining procedures to those in the present study would help to clarify the problem of relational terms in the conservation transfer task. The position that the transforming operation involves nothing but another salient irrelevant cue for conservation responding could also be tested with procedures which systematically extinguish responding to stimulus change in the same manner as other irrelevant cues were dealt with in this study.

There are also a number of questions concerning the stimulus programming and the process of transfer of stimulus control which are unanswered by this study. First, except for the first phase, the effectiveness of the fading procedures at each problem difficulty level was not tested independently of prior learning on less difficult problems. Second, the number of steps or levels of illumination used in the fading process was not varied. Effectiveness of the fading procedures as well as location of the critical points within the program showing transfer of stimulus control could be illustrated by such program variations. Third, the possible interactions between different fading procedures and problem difficulty was not tested. These three questions are now being investigated using the same stimuli developed in the present study.

REFERENCES

Beilin, H. Learning and operational convergence in logical thought development. Journal of Experimental Child Psychology, 1965, 2, 315-339.

Brainerd, C. J. and Allen, T. W. Experimental inductions of the conservation of "first-order" quantative invariants. Psychological Bulletin, 1971, 75(2), 128-144.

Bruner, J. A., Olver, R. R. and Greenfield, P. M. Studies in Cognitive Growth, New York, Wiley, 1966.

Corah, N. L. The influence of some stimulus characteristics on color and form perception in nursery-school children. Child Development, 1966, 37, 205-211.

Elkind, D. Piaget's conservation problems. Child Development, 1967, 38, 15-27.

Feigenbaum, H.D. Task complexity and IQ variables in Piaget's conservation. Child Development, 1968, 49(1), 579-589.

Feigenbaum, H. D. and Sulkin, H. Piaget's problem of conservation of discontinuous quantities: a teaching experience. Journal of Genetic Psychology, 1964, 105, 91-97.

Flavell, W. H. The Developmental Psychology of Jean Piaget. Princeton, Van Nostrand, 1963.

Gelman, R. Conservation acquisition: a problem of learning to attend to relevant attributes. Journal of Experimental Child Psychology, 1969, 7, 167-187.

Ginsberg, R. Number and color responses in the young child. Journal of Experimental Child Psychology, 1969, 7, 265-273.

Griffiths, J. A., Shantz, C. A. and Sigel, I. E. A methodological problem in conservation studies: the use of relational terms. Child Development, 1967, 38(3), 841-848.

Gruen, G. E. Experiences affecting the development of number conservation.in children. Child Development, 1965, 36, 963-979.

Harasym, C. R., Boersma, F. J. and Maguire, T. D. Semantic differential analysis of relational terms used in conservation. Child Development, 1971, 42, 767-779.

Harlow, H. F. Learning set and error factor theory. In S. Koch (Ed.) Psychology: A study of a science. Study 1, Vol. 2. McGraw-Hill, New York, 1952.

Hively, W. Programming stimuli in matching to sample. Journal of the Experimental Analysis of Behavior, 1962, 5, 279-298.

Holland, J. Teaching machines: an application of principles from the lab. Journal of Experimental Analysis of Behavior, 1960, 3, 275-283.

Hughes, M. Intellectual Tasks Kit. Arizona Center for Early Childhood Education, College of Education, University of Arizona, 1967.

Jeffrey, W. E. The orienting reflex and attention in cognitive development. Psychological Review, 1968, 75(4), 323-334.

Kagan, J., Rosman, D., Day, D., Albert, J., and Phillips, W. Information processing in the child. Psychological Monographs, 1964, 78(1), whole number 578.

Katz, P. A. The role of irrelevant cues in the formation of concepts by lower class children. Journal of Educational Psychology, 1968, 59(4), 223-238.

Kingsley, R.C. and Hall, V. C. Training conservation through the use of learning sets. Child Development, 1967, 38, 1111-1126.

Kohnstamm, G. A. An evaluation of part of Piaget's theory; Acta Psychologica, 1963, 21, 313-356.

Levin, G. R. and Maurer, D. M. The solution process in children's matching-to-sample. Developmental Psychology, 1969, 1, 679-690.

Mackintosh, N. J. Selective attention in animal discrimination learning. Psychological Bulletin, 1965, 64, 124-140.

Mehler, J. and Bever, T. G. Cognitive capacities of very young children. Science, 1967, 158, 141-142.

Mehler, J. and Bever, T. G. Reply by J. Mehler and T. G. Bever. Science, 1968, 162, 979-981.

Mermelstein, E. and Meyer, E. Conservation training techniques and their effects on different populations. Child Development, 1969, 40, 471-490.

Mermelstein, E. and Shulman, L. S. Lack of formal schooling and the acquisition of conservation. Child Development, 1967, 38, 39-52.

Moore, T. and Goldiamond, G. Errorless establishment of a visual discrimination using fading procedures. Journal of the Experimental Analysis of Behavior, 1964, 7, 269-275.

O'Bryan, K. G. and Boersma, F. J. Eye movements, perceptual activity, and conservation development. Journal of Experimental Child Psychology, 1971, 12, 152-169.

Peters, D. L. Task variations and individual differences in Piaget's conservation of number. Merrill-Palmer Quarterly, 1967, 13(4), 243-258.

Piaget, J. The Child's Conception of Number. W. W. Norton, New York, 1952.

Piaget, J. Quantification, conservation, and nativism. Science, 1968, 162 (3857), 976-979.

Ray. B. A. The course of acquisition of a line-tilt discrimination by rhesus monkeys. Journal of the Experimental Analysis of Behavior, 1967, 10, 17-33.

Reese, H. W. and Lipsitt, L. P. Experimental Child Psychology. New York, Academic Press, 1970.

Roll, S. Reversibility training and stimulus desirability as factors in conservation of number. Child Development, 1970, 41(2), 501-507.

Rosenthal, T. L. and Zimmerman, B. J. Modeling by exemplification and instruction in training conservation. Developmental Psychology, 1972, 6(3), 392-406.

Rothenberg, B. B. Conservation of number among four and five year old children: some methodological considerations. Child Development, 1969, 40, 383-406.

Rothenberg, B. B. and Orost, J. H. The training of conservation of number in young children. Child Development, 1969, 40, 707-726.

Sidman, M. and Stoddard, L. T. The effectiveness of fading in simultaneous form discrimination for retarded children. Journal for the Experimental Analysis of Behavior, 1968, 10, 3-16.

Smedslund, J. The acquisition of conservation of substance and weight in children VI: practice on continuous and discontinuous material in conflict situations without external reinforcement. Scandinavian Journal of Psychology, 1961, 2, 203-210.

Staats, W. W., Brewer, B. A. and Gross, M. C. Learning and cognitive development: representative samples, cumulative-hierarchical learning, and experimental-longitudinal methods. Monographs of the Society for Research in Child Development, 1970, 35(8), 1-85.

Stoddard, L. T. and Sidman, M. The effects of errors on children's performance on a circle-ellipse discrimination. Journal of the Experimental Analysis of Behavior, 1967, 10, 261-270.

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

Terrace, H. S. Errorless transfer of a discrimination across two continua. Journal of the Experimental Analysis of Behavior, 1963, 6, 223-323(b).

Thomas, H. Preference for random shapes: ages six through nineteen years old. Child Development, 1966, 37(2), 843-859.

Wallach, L. and Sprott, R. L. Inducing number conservation in children. Child Development, 1964, 35, 1057-1071.

Wallach, L., Wall, A. L. and Anderson, L. Number conservation: the roles of reversibility, additions-subtractions, and misleading perceptual cues. Child Development, 1967, 38, 425-442.

Winer, G. A. Induced set and acquisition of number conservation. Child Development, 1968, 39, 195-205.

Wohlwill, J. G. A study of the development of number concept by scalogram analysis. Journal of Genetic Psychology, 1960, 96, 345-375.

Wohlwill, J. G. and Lowe, R. C. Experimental analysis of the development of the conservation of number. Child Development, 1962, 33, 153-167.

Zimiles, A. A. The development of conservation and differentiation of number. Monographs of the Society for Research in Child Development, 1966, 31(6), whole number 108.

Zimmerman, B. J. and Rosenthal, T. L. Conserving and retaining equalities and inequalities through observation and correction. Arizona Center for Educational Research and Development, University of Arizona, Tucson, Arizona., 1972.