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Conditioning Precurrent (Problem Solving) Behavior of Children[1]

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ABSTRACT

Five normal preschool children were presented with a symbol-counting task designed to require responses which altered the problem so as to enable reliable solutions. Continuous reinforcement (praise + exchangeable token) of correct solutions for 5 to 10 sessions (baseline) did not affect development of precurrent altering behaviors or improved solution performance. Training procedures which directly reinforced (praise) precurrent responses were effective in increasing precurrent behaviors and the accuracy of solution responses. Once conditioned, precurrent behaviors and accurate solutions were maintained when only the solution –contingent reinforcement was provided– a return to baseline contingencies. Subsequent removal of solution-contingent reinforcement for 4 subjects decreased performance of 2 children, but had no effect on the performance of 2 other children. Next, instructions prohibiting overt emission of precurrent responses were added to the baseline contingencies for all subjects. Prohibition instructions decreased precurrent responses to zero and decreased accuracy of solutions in all children. The consistent performance of precurrent behaviors which was disrupted during prohibition and the high accuracy of solutions which declined during extinction and prohibition were recovered when subjects were returned to baseline contingencies.

RESUMEN

Se sometió a cinco niños en edad prescolar a una tarea de contar símbolos, planeada para que se dieran respuestas que alteraran el problema de modo que se produjeran soluciones confiables. El reforzamiento continuo (halago + fichas canjeables) de las

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soluciones correctas por 5 a 10 sesiones (línea base) no afectó el desarrollo de conductas de alteración o la mejoría en la ejecución para solucionar problemas. Los procedimientos de entrenamiento que reforzaron directamente (halago) las respuestas precurrentes aumentaron las conductas precurrentes y la precisión de las respuestas de solución. Una vez condicionadas, las conductas precurrentes y las soluciones precisas se mantuvieron cuando el reforzamiento contingente a la solución se proporcionaba solamente –un regreso a las contingencias de línea base. La remoción subsecuente del reforzamiento contingente a la solución en 4 sujetos disminuyó la ejecución en dos niños, pero no tuvo efecto en la ejecución de los otros dos. Después, se agregaron instrucciones prohibiendo la emisión manifiesta de respuestas precurrentes para todos los sujetos a las contingencias de línea base. Las instrucciones de prohibición disminuyeron las respuestas precurrentes a cero y disminuyeron la precisión de las soluciones en todos los niños. La ejecución consistente de las conductas precurrentes, interferida por la prohibición, y la alta precisión de las soluciones que declinó durante la extinción y la prohibición, se recuperaron cuando los sujetos fueron sometidos nuevamente a las contingencias de línea base.

An individual is said to be confronted with a problem when a situation is presented which does not immediately lead to a solution response. Investigation of the processes acting as the individual arrives at the solution has been the focus of problem solving research. Traditionally, such processes have been identified (1) as mental activity (Inhelder & Piaget, 1958; Piaget, 1970), (2) metaphorically as computer processes (de Groot, 1965; Newell, Simon, & Shaw, 1965), or (3) as hypothetical, implicit stimulus-response interactions (Gagné, 1966; Staats, 1966). A fourth approach to problem solving, and the one adopted here, views the processes functionally, without recourse to hypothetical variables (Bijou, 1976; Skinner, 1966).

In a functional analysis, problem solving is described as a complex interaction in which variables affecting the probability of a solution response are manipulated by the problem solver. A problem solving episode is divided into two stages. The first, the Precurrent Stage, involves operants which function to increase the probability that a solution response will be emitted and reinforced. These responses are termed precurrent since by altering the problem situation they strengthen (prompt) other behaviors which enter into the solution-reinforcement contingency. The second stage, the Solution Stage, involves operants under the stimulus control of the altered problem (Grimm, Bijou, & Parsons, 1973; Skinner, 1966). Solution behaviors result in reinforcement.

So analyzed, a problem solving episode takes on the *formal* characteristics of an operant chain. Briefly, a chain consists of a sequence of responses in which each response produces the conditions which make the next response probable, and the terminal response produces reinforcement which maintains the entire sequence. The stimuli linking the successive responses of the chain are thought to function as both conditioned reinforcers (strengthening the prior response) and as discriminative stimuli (setting the occasion for the subsequent response) (Hendry, 1969). Application of this formulation to problem-solving interactions suggests that behaviors in the Precurrent Stage are acquired and maintained as early components of a chain as a result of their effect upon the probability of the solution response-reinforcement contingency. Such a notion has received empirical support in studies of possible precurrent behaviors in pigeons (Eckerman, Lanson, & Cumming, 1968; Rachlin & Green, 1972) and young children (Grimm, et al., 1973; Parsons & Ferraro, in press).

A chaining analysis of precurrent behavior is not without implications for developmental theory or application. For example, in the initial development of problem solving behavior, the chaining analysis suggests five interrelated conditions under which precurrent interactions may fail to materialize. First, the setting events (Bijou & Baer, 1961) may preclude a problem solving episode if deprivation of the reinforcer is insufficient. Second, a problem solving sequence may fail to occur if required responses are not part of the subject's repertoire due to organismic or environmental conditions (Anastasi, 1958). Third, failure of problem solution may result due to the absence of conditioned reinforcers within the sequence resulting in a failure to maintain the response flow, even in the case where precurrent behaviors are "on the correct path" to a solution. A fourth potential constraint involves the discriminative function of the stimuli within the sequence (i.e., the problem itself and resultant alterations of the problem). A given stimulus may control responses which compete with problem solving, or precurrent behaviors may be evoked by aspects of the problem irrelevant to its solution.

The fifth potential difficulty is actually a special case of the preceding four. It has been suggested that in cases where discriminative stimuli are response-produced, if the responses are covert, they may produce stimuli too weak to function effectively in controlling subsequent responses in the sequence (Skinner, 1957). Such a limitation for the child is also troublesome for the researcher, teacher, and parent. For, while behavior analysis models of chaining have been available for some time (e.g., Boren & Devine, 1968; Sidman & Rosenberger, 1967), the application of behavior principles to complex human behavior has concentrated almost exclusively on the strengthening of overt "solution" responses rather than the precurrent phases of a complex sequence (e.g., Chadwick & Day, 1971; Conlon, Hall, & Hanley, 1973; Lovitt & Esveldt, 1970; Smeets & Striefel, 1975). This tendency to concentrate on terminal behaviors reflects the fact that remediation of unreliable precurrent interactions is difficult when some of the component interactions are not amenable to observation or direct control.

We may overcome this apparent obstacle by adopting Skinner's (1957) assumptions that covert interactions are governed by the same principles as overt interactions, and that covert interactions may readily evolve from overt interactions. Thus, in basic and applied research, as well as in the day-to-day management of children's development, precurrent interactions could be required at an overt level. Under these conditions responses and response-produced stimuli would no longer be inferred. Rather, such interactions could be monitored and manipulated in accordance with a natural science approach to behavior.

The present investigation applied such a research strategy to the development of arithmetic problem solving behavior in young children. Children were presented problems that could be reliably solved only if rudimentary precurrent interactions occurred at the covert or overt level. The research addressed itself to several issues concerning the acquisition and maintenance of problem solving which are raised by the chaining analysis. (1) Would precurrent behaviors necessary for reliable solutions be acquired under conditions of continuous differential reinforcement for correct *solution* responses? (2) If not, would training of overt precurrent behaviors result in improvement of solution accuracy? (3) If functional precurrent behaviors were conditioned, would they be maintained without direct reinforcement, but simply by the solution-contingent reinforcement? (4) Would discontinuation of solution-contingent reinforcement and/or prohibition of precurrent elements of the sequence disrupt problem solving and solution performance? (5) If disrupted by extinction procedures for solutions (or prohibition of precurrent behaviors), would the problem solving sequence require additional conditioning in order to be reinstated in the child's functional repertoire?

Method

Subjects

Five normal children (2 boys and 3 girls) attending a university nursery school served as subjects. The children ranged in age between 50 and 61 months. A child was selected for study if during initial screening sessions he/she solved sample task items at an accuracy less than 90% correct. Two children were excluded from the study because of their initial performance. One child was excluded because he lacked a counting repertoire, and another child was excluded because she refused to return for the third session.

Laboratory Setting and Reinforcers

The experimental room was 2.4 X 2.7 m., well illuminated, sound attenuated, and located adjacent to the nursery school. The subject and experimenter were seated at a table facing a 50-light bulb display box used to dispense (illuminate) conditioned reinforcers (bulbs in a cumulative manner) to the child. One column of 10 illuminated bulbs was exchangeable for a "small toy" (e.g., balloon, toy car) and two columns, 20 illuminated bulbs, yielded a "large toy" (e.g., rubber ball, soap bubbles). Thus, illuminated bulbs served as tokens.

Stimulus Materials (Problems)

The materials consisted of 15 mimeographed pages of quantity-matching problems similar to those found in most primary grade arithmetic programs. A sample page of problems is shown in Figure 1. A problem consisted of two sets of symbols divided by a vertical line. The set on the left was of a specified quantity (e.g., 5 arrows) and served as a "sample". The set on the right was of greater quantity and composed of different symbols (e.g., 10 balls). Each page consisted of six problems with one each of sample quantity, 5, 6, 7, 8, 9, and 10 – a total of 90 different problems. Page position of set size was randomized with this restriction.

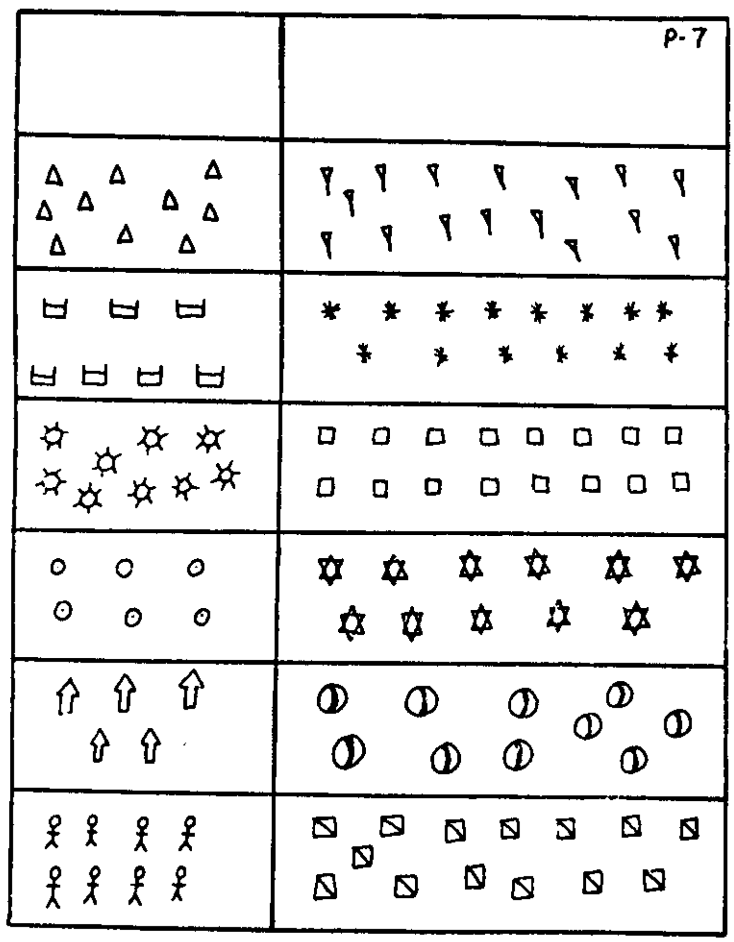

Figure 1. Sample page of quantity matching problems. Symbols on the left portion of the page served as the sample. A correct solution response involved circling an equal number of symbols on the right.

Solution and Precurrent Response Definitions and Reliability

Of major interest was the probability that the child would circle an equivalent number of symbols on the right side of a problem as were shown in the sample. Solution accuracy was judged solely by the appropriateness of the circle, regardless of the child's other behavior. Circles which bisected a symbol were scored as incorrect. An independent judge rescored all items. The realibility of scoring solution (circle) responses was above 0.95 in all phases of the study as computed by the following formula:

$$\frac{\text{agreements}}{\text{agreements} + \text{disagreements}} = r$$

Analysis of precurrent behaviors focused on the subject's overt counting and marking of the symbols. During training, children were instructed to count symbols aloud on the left and right sides of problems, and mark each symbol with a diagonal slash as it was enumerated. Scoring reliability on symbol marking was obtained. The judge recorded a "yes" if the symbols of an item were marked and a "no" otherwise. The clear nature of this judgement yielded perfect reliability.

General Procedures

Two to four (median four) days per week the children were individually escorted to the room. The session began when the experimenter presented to the child a sheet of problems. While the child worked on the problems the experimenter observed the child and recorded the accuracy of solution responses. As in all conditions, after the child completed an item, regardless of the accuracy of the solution, the experimenter instructed the child to continue on to the next problem (e.g., "Go ahead"). Response contingencies varied with experimental condition and are described below. When the child had finished the entire page the experimenter presented the child with another page selected at random from the 15 pages. This procedure was followed until the child had earned 20 tokens or 15 min had elapsed since the beginning of the session. Immediately following the termination of the task the experimenter aided the child in the exchange of tokens for a toy and escorted the child back to the classroom. In all conditions the experimenter limited conversation to periods when the child was not in the presence of the problems sheets, except for praise and correction statements as described below.

Baseline Procedures: Reinforcement of Solutions

Initial session. All subjects began under baseline procedures. The experimenter explained the light bulb-toy exchange system and that bulbs would be illuminated if the child determined the number of symbols on the left sides of problems and correctly circled the same number of symbols on the right sides of problems. Then, the experimenter modeled the solution of a problem, pointing to each appropriate symbol, but neither counted aloud nor marked on the paper other than the circle response (solution). With the exception of these initial instructions, the procedures were identical to all subsequent baseline sessions.

All baseline sessions. The contingencies in effect during baseline were designed to be as conducive as possible to the development of problem solution responses without attempting to directly condition precurrent behavior. The experimenter praised the child (e.g., "Good job") and illuminated one light bulb contingent upon each correct solution. Incorrect solutions were neither praised nor followed by token reinforcement, an extinction procedure.

Training: Reinforcement of Overt Precurrent Behavior

Training concentrated upon component responses of verbal counting and altering the symbols in correspondence with vocal counting. First, the child was instructed to engage in explicit (overt) counting and marking of the symbols so that these responses could be monitored and directly strengthened by experimenter-delivered praise. Audible counting was praised. Overt altering of the problems (marking counted symbols with a diagonal pencil slash) was also praised. Second, the procedures specified that these supplementary praise statements for precurrent responses be systematically deleted such that control of the entire problem solving sequence ultimately could be maintained by the terminal, solution-contingent praise and token reinforcement. The fading of supplementary praise statements was carried out in three phases.

In phase one of training, the experimenter praised each correct vocal counting and explicit marking response to the stimuli on both the left and right portions of each problem. Any detectable errors of counting or marking were immediately corrected. The experimenter stopped the child ("Stop") and instructed the child to begin the problem again. As in baseline, correct solutions were given praise and token reinforcement and errors in the solution response were not corrected. This phase of training differed from baseline in that overt counting and marking were praised if correct and corrected if incorrect. Otherwise, the procedures were identical. This phase involved no more than one session for any subject.

Phase two of training decreased the density of praise statements for precurrent elements. The ratio of correct counting and marking responses per supplementary praise statement was increased from a mean of 2 to a mean of 7. By the end of phase two only a single supplementary praise statement followed the left and right components of each problem. Other procedures were identical to phase one. This phase was in effect for 2 to 4 sessions.

Phase three of training extended the removal of praise statements and the correction procedure. As in baseline, no praise was given for overt precurrent behaviors: only correct solution responses were praised and led to token reinforcement. Further, errors of overt counting and marking led to the correction procedure. This phase was in effect for 2 to 7 sessions. Throughout all training phases, solution responses were under baseline contingencies – correct solutions were reinforced and incorrect solutions were neither reinforced nor corrected.

Extinction: Noncontingent reinforcement

Extinction procedures were designed to decrease problem solving and solution accuracy. The experimenter did not praise or dispense tokens for solution responses, nor did he praise or correct precurrent behaviors. The only response the experimenter made to the child was to instruct the child to do the next problem as in other conditions. In addition, prior to each extinction session the subject was allowed to select a toy which he could take at the termination of the session, regardless of performance. This less-than-optimal procedure was in compliance with nursery school procedures. Baseline and extinction differed in two respects: (1) contingent upon correct solutions, praise and tokens were given in baseline, and (2) a noncontingent toy was selected by the child and given to the child in each extinction session.

Prohibition: Instructions not to display overt precurrent behaviors

Prohibition was designed to decrease problem solving. At the beginning of each session the child was told not to count aloud or to mark slashes on the problems. Then the experimenter modeled a solution as he had at the beginning of the first baseline session. Whenever a subject made any overt counting or marking response, regardless of accuracy, the experimenter stopped the child as in the training correction procedure (i.e., "Stop"), repeated the prohibition in a neutral manner, and asked the child to begin the problem again. Two subjects (S-2 and S-5) continued to count aloud in their first session of prohibition despite the repeated reminders. They were allowed to "count quietly" during this session. In subsequent sessions the normal procedures were followed without overt counting and without incident. Throughout prohibition each correct solution response was reinforced with praise and token reinforcement and incorrect solutions were under extinction-just as in baseline and training.

Results

The percentage of correct solutions (accuracy) and the presence of overt marking (precurrent responses) were analyzed for each subject in line with a modified ABAB design.

Baseline, training, and return to baseline. Figure 2 through 6 show data for solution accuracy for the five subjects. Summary data on the presence vs. absence of precurrent marking responses are presented in Table 1. All subject's mean solution accuracies were low in the first baseline (mean = 50.4%; SD = 9.6%) and there was no apparent trend of improvement.

Table 1. Presence vs. Absence of Overt Symbol-Marking Responses

Experimental Condition	*Presence vs. Absence*	*Comments*
Baseline(pre-training)	Absent All Subjects	
Training(phases 1 & 2)	Present All Subjects	Determined by Procedures
Training(phase 3)	Present All Subjects	
Baselines(post-training)	Present All Subjects	
Extinction	Present All Subjects	S-3 did not experience
Prohibition	Absent All Subjects	Determined by Procedures

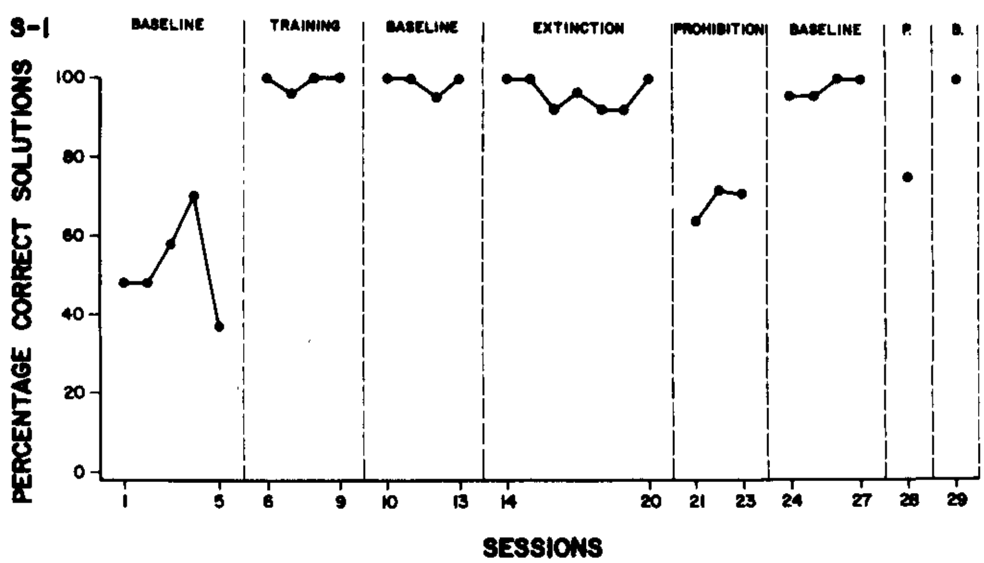

Figure 2. Accuracy of solution responses for S-1 under conditions of baseline, training, baseline, extinction, prohibition, baseline, prohibition (P), and baseline (B).

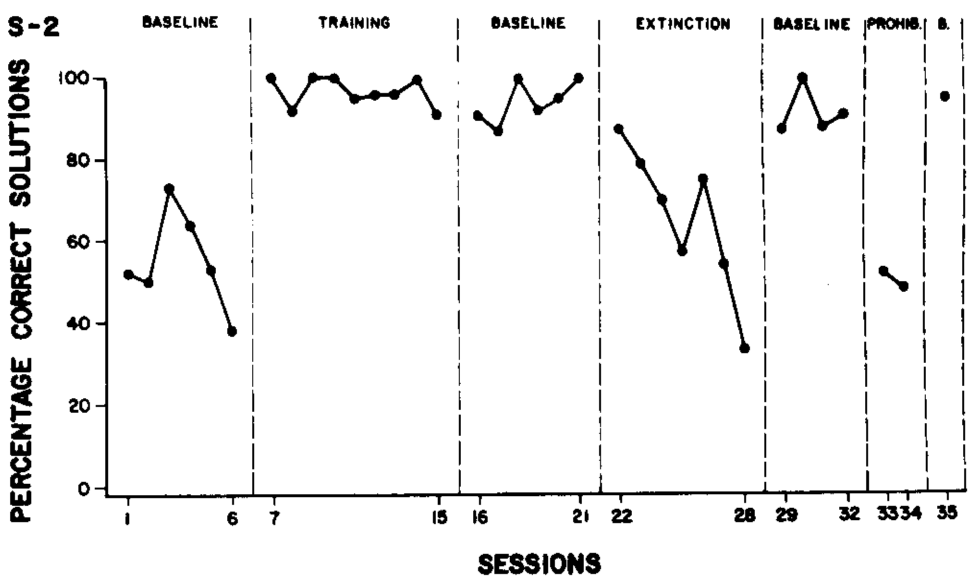

Figure 3. Accuracy of solution responses for S-2 under conditions of baseline, training, baseline, extinction, baseline, prohibition (Prohib), and baseline (B).

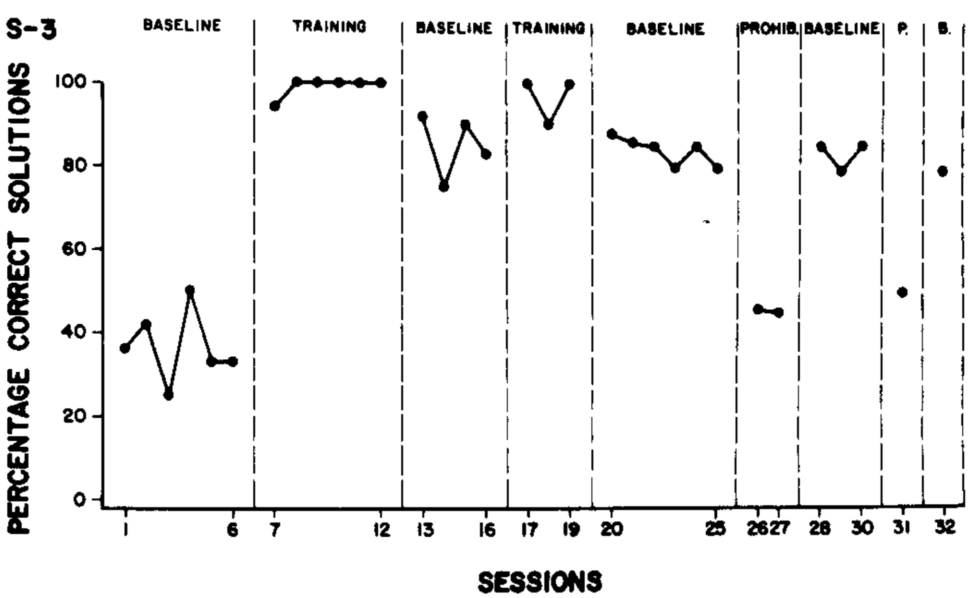

Figure 4. Accuracy of solution responses for S-3 under conditions of baseline, training, baseline, training, baseline, prohibition (Prohib), baseline, prohibition (P), and baseline (B).

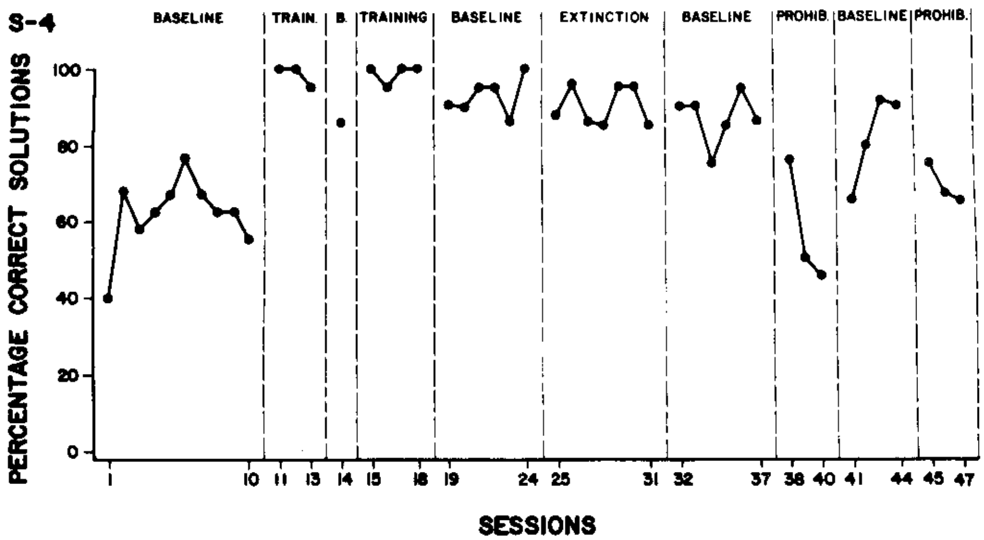

Figure 5. Accuracy of solution responses for S-4 under conditions of baseline, training (Train), baseline (B), training, baseline, extinction, baseline, prohibition (Prohib), baseline, and prohibition (Prohib).

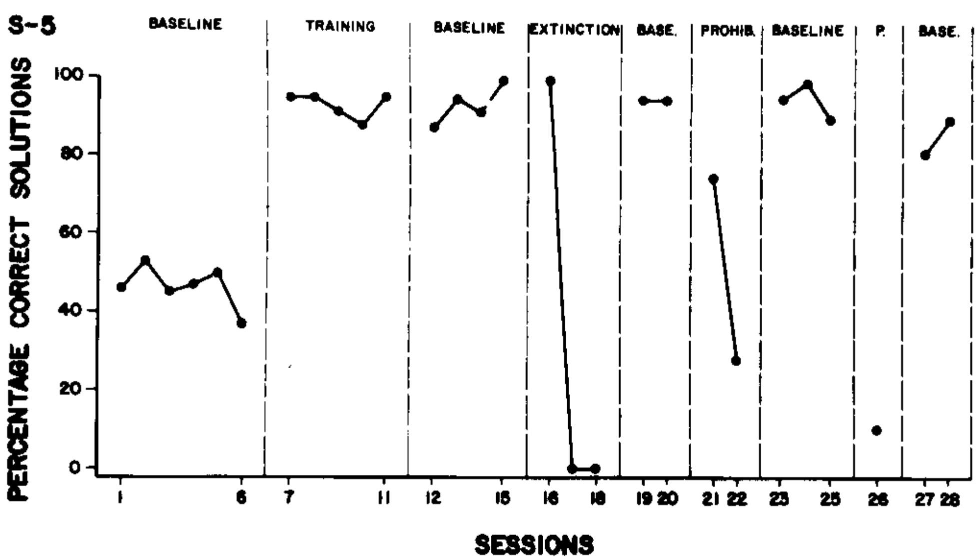

Figure 6. Accuracy of solution responses for S-5 under conditions of baseline, training, baseline, extinction, baseline (Base), prohibition (Prohib), baseline, prohibition (P), and baseline (Base).

Under contingencies of continuous differential reinforcement for correct solutions (baseline) subjects failed to develop either precurrent behaviors or reliable solution responses.

Training procedures effected immediate gains in solution accuracy for all subjects (mean = 97.2%; SD = 2.5%) and these increases were reliable when analyzed with the *t*-statistic for related means[3] ($t = 10.80$, $df = 4$, $p < 0.001$). More important, following the completion of training, when subjects were returned to baseline, accuracy remained high for all subjects as compared to their original baseline data. Mean accuracy of solutions in the baseline following training was 92.6% (SD = 5.5%), a reliable improvement over the initial baseline ($t = 13.06$, $df = 4$, $p < 0.001$).

The additional training and baseline sessions for S-3 and S-4 indicated in Figures 4 and 5 deserve comment. Training for S-4 was interrupted midway through phase two. A probe baseline session was conducted to assess whether the initial portion of the training sequence was sufficient to maintain high performance when returned to baseline conditions. When compared to the first baseline, probe data for S-4 indicated an increase in accuracy of 23.7%. Training was completed (phases 2 and 3) and S-4 was returned to baseline. After completion of training, accuracy was 30.8% higher than the first baseline. Subject 3 received extended training (three additional sessions of phase 3). Following these sessions, baseline performance indicated no further improvement in solution accuracy.

For all subjects, precurrent marking responses conditioned during training were maintained (overt) during the subsequent baseline condition when no longer required (via correction) or directly reinforced.

Extinction and return to baseline. Extinction procedures were conducted for S-1, S-2, S-4, and S-5. Both S-2 and S-5 indicated anticipated decrements in solution accuracies (mean = 49.2%; SD = 15.9%). Performance of S-2 decreased in accuracy an average of 29.1% from the preceding baseline to a low of 33%. Performance of S-5 dropped in accuracy to zero. When baseline conditions were reinstated, both subjects showed immediate increases in accuracy to previous, post-training baseline levels (mean = 89.2%; SD = 2.4%). Both subjects continued to emit precurrent marking responses during their decline in solution accuracies, but their responses were not reliable (i.e., occasionally marking too many or too few symbols). Extinction not only decreased accuracies of solutions but also the number of problems attempted (rate), making further analysis of precurrent errors unjustified. For example, in their last session of extinction, S-2 attempted only three problems and S-5 attempted only one problem. Accuracies of solutions and problems attempted by S-1 and S-4 were not affected by the extinction procedures (mean = 92.9%; SD = 3.1%).

Prohibition and return to baseline. The effects of prohibition were consistent across subjects. Instructions not to emit overt counting and marking

[3] Means of subject's solution accuracies were used for computation of the statistic due to unequal numbers of sessions.

responses reduced solution accuracies to levels observed during the initial baseline, prior to training (mean = 54.7%; SD = 9.2%). Compared to the prior baseline, mean performance decreased reliably during the prohibition sessions ($t = 11.60, df = 4, p < 0.001$).

In the first session of prohibition for S-4 and S-5, the children continued to count aloud, although marking responses were not explicit. When counting occurred, accuracy decreased only slightly for both subjects.[4] Subsequently, when counting and marking were absent, accuracy decreased substantially for both subjects.

All subjects were returned to baseline conditions following prohibition. With the exception of S-4, subjects showed immediate recovery of post-training baseline levels of precurrent behaviors and solution accuracies. That is, precurrent counting and marking and solution accuracies increased to previous levels without retraining (mean = 90.5%; SD = 7.8%). Unlike other subjects, S-4's accuracy was "low" (72.1%) in the first session of baseline following prohibition. It was noted that S-4 was not reliably counting aloud even though the prohibition was no longer being given at the beginning of the session. Since accuracy could be low due to inadequate counting, S-4 was instructed prior to sessions 43 and 44 that he could count aloud. With these instructions overt precurrent counting became reliable and accuracy increased to a mean of 91.3%.

Subject S-1, S-3, and S-5 each received a replication of the prohibition and baseline conditions. Again, prohibition of overt precurrent responses decreased these behaviors as well as solution accuracies (mean = 51.0%; SD = 29.3%), and subsequent return to baseline affected immediate recovery of performance (mean = 88.3%; SD = 10.7%).

Discussion

In the initial baseline condition children were under reinforcement contingencies frequently considered as "optimal" for the development of academic behaviors, continuous differential reinforcement. In fact, the same contingencies have been applied as the treatment or experimental condition in many behavior modification studies (e.g., Bijou, Birnbrauer, Kidder, & Tague, 1966; Conlon et al., 1973). Thus, the baseline against which treatments were assessed in this study was stringent. Nevertheless, five children failed to show acquisition of accurate problem solving with praise plus token reinforcement contingent upon terminal solution responses.

Next, children received training in performing precurrent behaviors of counting and marking the symbols. Training procedures were effective in conditioning precurrent responses in all subjects and resulted in substantial gains in solution performance. Accuracy of solutions increased due to (1) the

[4] The reader is reminded that reliability of subjects' vocal counting responses were not able to be determined.

correction procedures which made it improbable that precurrent responses would result in incorrect solutions, and (2) the presumed improved stimulus control (chaining) made possible by the presence of overt functional precurrent behaviors. Correction procedures alone would account for the increases in performance observed in training sessions; but, data from subsequent baseline sessions lend support to the position that training altered the stimulus control of solution responses by building a problem solving chain (see Grimm et al., 1973). Clearly, all subjects showed increases in accuracy from the initial baseline to the baseline following training. We may conclude that the conditioning of precurrent responses during training improved problem solving performance and the effects were maintained by the solution-contingent reinforcement provided for solution responses. This finding is consistent with a functional analysis of problem solving and in agreement with previous research on precurrent interactions (Eckerman et al., 1968; Grimm et al., 1973).

The effects of extinction varied. Subjects S-2 and S-5 showed marked effects —accuracy and rate of solutions decreased. Empirically based principles of chaining and conditioned reinforcement suggest that the absence of terminal reinforcement of an operant chain would reduce the behavior in the chain (Kelleher, 1966). Since it is often assumed that the intra-chain stimuli develop their discriminative and reinforcing functions due to the presence of the terminal reinforcing event, continued behavior in the absence of reinforcement would return the function of intra-chain stimuli to their pre-conditioned status (Ferster & Skinner, 1957).

For S-1 and S-4 the effects of extinction were minimal within the time limits imposed upon the study. It is not at all clear what conditions led to the persistence of problem solving, but two possible interactions deserve comment. First, it is possible that uncontrolled reinforcers were functioning during extinction sessions. In the current study children were allowed to pick up their pre-selected "noncontingent" toy, escape from the nonreactive experimenter, and return to the classroom all possible yet undocumented contingencies. Second, the absence of extinction effects may be related to the presence of social setting conditions functioning to augment subjects' compliance with the experimenter's requests to complete the problems (i.e., the "Go ahead" prompt given prior to each problem). Such control has been demonstrated with children elsewhere (e.g., Meddock, Parsons, & Hill, 1971; Peterson & Whitehurst, 1971; Winston & Redd, 1973).

The effects of verbal prohibition of overt mediation were consistent for all subjects. Accuracy of solutions showed substantial decreases under the prohibition as compared to baseline sessions prior to and following the prohibition condition. These decrements in accuracy are comparable to the increases from initial baseline effected by the training procedures which conditioned the "prohibited" precurrent responses.

The fact that solution accuracy under prohibition returned to near pre-training baseline levels suggests the procedures were effective in disrupting precurrent responses. Although initial low baseline performance was not recovered in the baseline following training (an apparent irreversibility due to the development of the problem solving chain), the prohibition data supply evidence that the training procedures and the subsequent increase in problem solving performance were functionally related (see Goss, 1961).

In the case of prohibition, we would expect immediate decreases in problem solving, and that when the prohibition was removed there would be no need to recondition the chain. That is, precurrent behaviors should exist in the child's repertoire at a strength equal to that before the prohibition instruction and should be completely reversible. In the case of extinction, however, if the chain is emitted without reinforcement, problem solving behavior should decrease in probability as it did for half of the subjects. For these subjects, reconditioning of the chain should require a "rebuilding" process, where links of the chain are again brought under stimulus control. This would only be the case, however, when extinction disrupts the stimulus control between all links of the chain (Skinner, 1934). It is possible for the two subjects "successfully extinguished" in this study, that extinction served to disrupt the interaction between solution responses and terminal reinforcement, but other links in the chain were not affected as suggested by Sidman (1960). Then again, it remains a possibility that sequences of behavior seen in problem solving do not conform to a rigid chaining analysis.

Regardless of the theoretical ramifications of the chaining analysis, the practical implications for the procedures involved in this study are straightforward. Initial acquisition of a majority of cognitive behaviors involve the strengthening of a response sequence. Often, early components of the sequence are left unidentified because they are considered to be mental activiy or hypothetical covert interactions (e.g., mediation, selfcontrol, attention, problem solving). So viewed, cognitive interactions are studied by inference, failure for solutions to develop are attributed to the child's production (Flavell, Beach, & Chinksy, 1966) or mediational deficiencies (Reese, 1962), and the teaching of cognitive behaviors is conducted by a process described by Skinner (1968) as "intellectual muscle building". Referring to the plight of the teacher, Skinner writes,

> Possessing no clear-cut description of the behavior he is to set up and having no apparent access to the controlling variables, he is forced back to the notion of exercise. He sets problems to be solved and reinforces the student when he solves them or punishes him when he does not... The method does not teach; it simply selects those who learn without being taught... Special reinforcers must be made contingent upon the topography of the behavior rather than its outcome. Only under rare circumstances will the ultimate advantages of thinking teach a student to think (1968; pp. 118-119).

The current study demonstrates that contingencies of reinforcement directed to the precurrent elements of a response sequence can lead to rapid conditioning of problem solving skills. Teachers may wish to require overt precurrent behaviors. This would make practical the direct monitoring of precurrent interactions and the arrangement of special contingencies of reinforcement upon the formal and functional characteristics of the target behavior.

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