DOCUMENT RESUME

ED 058 969 | 24 | PS 005 442

AUTHOR Caruso, John L.; Resnick, Lauren B.
TITLE Task Sequence and Overtraining in Children's Learning and Transfer of Double Classification Skills.
INSTITUTION Pittsburgh Univ., Pa. Learning Research and Development Center.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
BUREAU NO BR-5-0253
PUB DATE 71
CONTRACT OEC-4-10-158(010)
NOTE 34p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS *Children; Classification; Complexity Level; Evaluation; Hypothesis Testing; Kindergarten Children; *Learning Activities; Organization; Skill Development; *Task Performance; Time Factors (Learning); *Training; *Transfer of Training
IDENTIFIERS *Piaget (Jean)

ABSTRACT

This paper reports on an experiment which attempted to: (1) empirically validate a hypothesized hierarchical sequence of three double classification tasks; (2) investigate transfer to an untrained Piagetian double classification task; and (3) assess the effects of overtraining a relatively easy task on the learning of a more difficult task, as compared with learning a related task of intermediate difficulty. Fifty-five kindergarten children, who were shown by pretesting to possess negligible double classification skills, were trained over a period of two months on matrix tasks involving color and shape dimensions. The subjects were divided into four groups and were either: (a) trained on three matrix tasks in the hypothesized optimal sequence (simplest to most complex); (b) trained on the same three tasks in the reverse sequence; (c) given overtraining on the simplest task followed immediately by training on the most complex task. The results strongly supported the existence of a hierarchical relationship among the three tasks. More subjects learned the most complex task, and they learned it in fewer trials, when taught in the optimal order. No subject learned a higher-level task without also having learned the lower-level one. High, though not complete positive transfer to a different double classification task was also demonstrated for those subjects who learned the most complex task in the hierarchy. (Author)

TASK SEQUENCE AND OVERTRAINING IN CHILDREN'S LEARNING AND TRANSFER OF DOUBLE CLASSIFICATION SKILLS

John L. Caruso and Lauren B. Resnick

Learning Research and Development Center
University of Pittsburgh

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The research reported herein was supported by a grant from the Ford Foundation and by the Learning Research and Development Center supported in part as a research and development center by funds from the United States Office of Education, Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position or policy of either organization and no official endorsement should be inferred.

ACKNOWLEDGMENTS

The authors would like to thank Shellie Williams for typing the manuscript and Donna Rottman for preparing the figures.

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Fifty-five kindergarten children, who were shown by pretesting to possess negligible double classification skills, were trained over a period of two months on matrix tasks involving color and shape dimensions. The subjects were divided into four groups and were either: a) trained on three matrix tasks in the hypothesized optimal sequence (simplest to most complex); b) trained on the same three tasks in the reverse sequence; c) given overtraining on the simplest task followed immediately by training on the most complex task; or d) trained to criterion (without overtraining) on the simplest task followed immediately by training on the most complex task.

The results strongly supported the existence of a hierarchical relationship among the three tasks. More subjects learned the most complex task, and they learned it in fewer trials, when taught in the optimal order. No subject learned a higher-level task without also having learned the lower-level one. High, though not complete, positive transfer to a different double classification task was also demonstrated for

those subjects who learned the most complex task in the hierarchy. Subjects who proceeded directly from the simplest to the most complex task without overtraining (group d) learned the most complex task as quickly as subjects who had training on a task of intermediate difficulty (group a) or overtraining on the simplest task (group c).

This paper will be of interest to psychologists interested in learning and instruction or cognitive development, and to instructional designers interested in the generation and validation of learning hierarchies.

TASK SEQUENCE AND OVERTRAINING IN CHILDREN'S LEARNING AND TRANSFER OF DOUBLE CLASSIFICATION SKILLS[1]

John L. Caruso and Lauren B. Resnick

University of Pittsburgh

The present study extends work begun by Resnick, Siegel and Kresh (1971) on the transfer relationships among hierarchically related early learning tasks. The tasks under study are variants of a matrix classification task commonly accepted as providing evidence that children are capable of classifying objects simultaneously on two dimensions, one of the abilities associated with the stage of concrete operations (Inhelder & Piaget, 1964). Resnick et al. used two relatively simple matrix tasks, one of which included all of the behavioral components of the other plus some additional ones. They showed that learning the simpler task first provided positive transfer in learning the more complex task, and concomitantly that individuals who were able to learn the more complex task first had in the process acquired the ability to perform the simpler one as well.

Two limitations of the Resnick et al. study prompted the further investigation reported here. First, the more difficult task used was sufficiently easy to learn even when presented first that the positive transfer effects of learning the simpler task first were only weakly demonstrated. Second, the tasks studied were not exactly analogous to the matrix tasks used by Piaget and others (e.g., Smedslund, 1967a, 1967b; Lovell, Mitchell & Everett, 1962) as a test of concrete operations, and thus

[1]This report is based on a Master's thesis written by the first author under the direction of the second.

no conclusions concerning the "trainability" of classification skills as commonly understood could be drawn. The present study used both a more complex terminal training task and a transfer task drawn directly from the Piagetian research. In addition, it extended the study of hierarchical sequence relationships by using a sequence of three rather than only two training tasks; and it investigated the effects of overtraining on transfer within a hierarchy.

The format for the three training tasks studied is illustrated in Figure 1. The requirement for each task was to choose, from an array of objects, the one which correctly filled each empty cell of the matrix. This involves inferring the attributes for the empty cell on the basis of information provided by the objects already in place. Thus the tasks are called Inferring Tasks. Each task involved a different type of empty cell, corresponding to the cells labelled 1, 2 and 3 in the Figure. Behavioral components for performing the task were hypothesized to be different in certain respects for cells of type 1, 2 and 3. The analysis leading to this prediction is shown in the flow chart in Figure 2.

In order to solve cell type 1 (i.e., an empty cell whose row <u>and</u> column each have two already filled cells), the <u>S</u> would have to be able to perform the following behaviors (corresponding to the left hand branch of Figure 2): 1) Given an empty cell in a column (row) with two or more objects, name the common column attribute, e.g., "triangle" or "red" (boxes A and B; note that this sequence is performed twice for cell type 1); 2) given the names of a common column and a common row attribute, describe an object in terms of the two attributes, e.g., "red triangle" (box D); 3) given a description of an object in terms of two attributes and given an assortment of objects, select the object described (boxes E-F-G-H-I). The most complex task in the Resnick et al.

study included empty cells of this type.

For cell type 2 (i.e., two filled cells in one direction--row or column--but only one in the other direction), the solution process is more complex, because S cannot directly name a common row (or column) attribute. Therefore, he must answer "no" to the question in box A (Figure 2) and proceed once through the right hand branch of the diagram. This branch requires that, in addition to all behaviors for cell 1, the S must be able to: 1) given a row with only one object in it, find another row that has at least two objects in it (box J); 2) given a row with two or more objects in it, identify the common attribute (box K; note equivalence to box B); 3) given the common attribute, identify the dimension of which the attribute is a specific example, e.g., "color" (box L); 4) given the relevant dimension, return to the original row and identify a specific attribute of the object in the row that is an example of that dimension, e.g., "white" (boxes M-N-O).

Cell 3 in Figure 1 is still more difficult to solve because neither attribute can be directly determined from objects already in the row or column. S must answer "no" twice to the question in box A, thus requiring him to proceed through the more complex right hand branch twice.

Hypotheses

Hierarchical relationships. On the basis of the analysis just described, it was hypothesized that tasks involving empty cells of the three types shown would form a learning hierarchy, with cells of type 1 (Inferring_1) at the simplest level, cells of type 3 (Inferring_3) at the most complex level and cells of type 2 (Inferring_2) intermediate. Such a hierarchical relationship among the tasks would be supported if the following specific predictions were verified:

(1) Concerning Inferring $_3$, Ss who learn the three tasks in the "optimal" order suggested by the hierarchy (i. e., Inferring $_1$, then Inferring $_2$, then Inferring $_3$) will learn Task 3 more easily than Ss who learn the three tasks in the reverse order. Specifically, more optimal order Ss will learn Inferring $_3$, and they will learn it in fewer trials than reverse order Ss.

(2) Concerning Inferring $_2$, (a) Ss in the reverse order group who do succeed in learning Inferring $_3$ will reach criterion performance on Inferring $_2$ in a minimal number of trials, since they would have acquired all components of Inferring $_2$ in the process of learning Inferring $_3$. These Ss will, therefore, learn Inferring $_2$ in fewer trials than optimal order Ss, who have some new components to learn when they reach Inferring $_2$. (b) However, reverse order Ss who fail to learn Inferring $_3$ will take longer and show more failures in learning Inferring $_2$ than will optimal order Ss. If the Inferring $_3$ task proves very difficult to learn, this should have the effect of making Inferring $_2$ more difficult for the reverse order group than for the optimal order group.

(3) Concerning Inferring $_1$, (a) reverse order Ss who succeed in learning Inferring $_2$ should demonstrate almost immediate performance of Inferring $_1$ and thus need fewer trials than optimal order Ss. (b) There should be no difference on Inferring $_1$ between reverse order Ss who did not learn Inferring $_2$ and optimal order Ss.

Transfer to a Piagetian task. The matrix task used by Inhelder and Piaget (1964) and the subsequent researchers exploring their conceptions of multiple classification skills is a 2 x 2 matrix, with three cells filled and one cell (typically the bottom right cell) empty. The solution strategy for such a matrix is, according to our analysis, exactly the same as for Inferring $_3$, since in each case the empty cell is in a row <u>and</u> column with only one other filled cell.

In order to test the adequacy of this analysis, and to permit generalization to the Piagetian task, the 2 x 2 matrix task was included as a transfer task in the present experiment.

The specific hypothesis concerning transfer was:

(4) Ss who learn Inferring $_3$ (whatever sequence) should perform better on the 2 x 2 transfer task than Ss who fail to learn Inferring $_3$.

Overtraining. Overtraining on discrimination tasks is known to facilitate reversal shifts (see Hale, 1969; Lovejoy, 1966; Mackintosh, 1965) presumably by emphasizing the relevant dimensions. With respect to more complex tasks, Clark and Cooper (1966) showed that overtraining on a task which required sorting of geometric shapes facilitated sorting pictures into five conceptual categories. Transfer was related both to the complexity of the training task and to the degree of its overlearning. These studies suggest that, by sharpening basic matrix skills, overtraining on the simplest task in a three-step hierarchy might facilitate learning the most complex task as much as learning the intermediate task. To explore this possibility the present experiment included a group which proceeded directly to Inferring $_3$ after overtraining on Inferring $_1$, together with a control group that proceeded from Inferring $_1$ to Inferring $_3$ without either overtraining or experience on the intermediate task. Predictions concerning overtraining were that:

(5) The group receiving overtraining on Inferring $_1$ would learn Inferring $_3$ as easily as the group proceeding through the three tasks in the optimal sequence without

overtraining.

(6) Both the overtraining and optimal sequence groups would learn Inferring $_3$ more easily than the control group proceeding directly to Inferring $_3$.

METHOD

Subjects

A sample consisting of 29 boys and 26 girls, from an urban public school kindergarten, was selected on the basis of pretesting and pretraining results. None of the final Ss were initially capable of solving the double classification problems used in the study, and all successfully learned a pretraining task. The Ss were predominantly Black and came from families whose socioeconomic status was widely distributed but heavily weighted at the lower end of the scale.

Description of Tasks

Seven different double classification matrix tasks employing color (red, yellow, blue, green, orange, and purple) and shape (square, circle, cross, star, triangle, apple and heart) were used in the experiment. The seven included two "familiarization" tasks, one pretraining task, three training tasks and one transfer task.

The familiarization tasks were designed to acquaint Ss with the general nature of matrix boards; responses from the Ss on these two tasks were not recorded. The pretraining task was administered to all Ss immediately prior to the training phase of the experiment. Data from this task were used to equate the four experimental groups. The three training tasks were the Inferring tasks described above. They were presented twice: first in a pretest form and then again under training conditions.

Finally, the transfer task was a 2 x 2 matrix task on which no training was given, but transfer was measured. It also was presented twice; first in the pretest and again after the training phase of the experiment as a posttest.

All matrices were made from white construction paper with 3-inch squares marked off in black magic marker. Appropriate cells were filled with 2-inch gummed colored paper shapes. The tasks and their administration are described in detail below.

Familiarization task 1. S was presented with one 3 x 3 matrix with attribute cells at the head of each row and column, each defining the relevant common attribute. The interior cells were filled, but covered. E pointed to the attribute at the beginning of the first row and said, "That tells you that everything in this row has to be (red)." E continued in a like manner for the rest of the rows and columns, and then said, "O.K., now let's see if we played this game correctly," and removed the covers from all the interior cells, exposing a correctly completed matrix. E then said, "See, everything in this row is red," (E pointed to first row). He continued similarly for the remainder of the rows and columns, with the S completing the sentence which E began, "Everything in this row (column) is...." On rare occasions when S did not respond, E completed the sentence for him.

Familiarization task 2. E placed an empty 3 x 3 matrix board before S and said, "Watch what I do." Then E proceeded to fill in all the interior cells with nine shapes so that all the objects within any row were of the same color and all within any column were the same shape. E then said, "See, everything in this row is (red)," and continued for the remainder of the rows and columns. E then said, "Now, I'm going to take away one of these pieces and I want you to watch me very carefully because then

I'm going to ask you to tell me exactly what piece I took away." E then removed a piece from one interior cell and said, "O.K., what piece did I take away?" If S responded with the name of only one relevant attribute, e.g., "a triangle," E said, "That's right, it was a triangle, but what color was it? Remember, you have to tell me exactly what piece I took away." E then replaced the piece, said, "Let's try another one," and continued in a similar manner until S named four consecutive pieces correctly, i.e., naming the two relevant attributes, one from the color and one from the shape dimension, for each piece removed.

Pretraining task. S was presented with a 3 x 3 matrix with filled attribute cells and empty interior cells. This task was the simpler one in the hierarchy tested by Resnick et al. and was thus known to facilitate learning of the easiest of the three training tasks. E held the set of four objects which belonged in the four cells in the second and third rows and columns, and said to S, "I'm going to give you an object. You put it where it belongs." E then handed S each of the four objects in turn and S was required to place it in the appropriate cell. After S placed each object, E recorded its placement and then removed it from the matrix board; nine empty cells were thus left in which S could choose to place the next object.

If S responded correctly, E removed the object and handed S the next object. If S responded incorrectly, E said, "No, that is not right." E then put the object in the correct cell and pointed to the correct row and column attribute, saying "Everything in this row is red, and everything in this column is a triangle (emphasizing the intersection of the row and column by bringing his fingers together at the point of intersection in the appropriate cell) so this is where the red triangle belongs." This procedure was repeated until the S reached a criterion of nine out of ten consecutive correct responses.

Training task 1 (Inferring $_1$). S was presented with a partially filled 3 x 3 matrix without attribute cells. A response array, consisting of the nine response choices representing the nine interior cells of the matrix, was pasted in a circular pattern and placed next to the incomplete matrix. E said, "In this game, someone has already taken away some of the pieces. I want you to point to the piece over here (E pointed to response choice array) that belongs here (E pointed to the missing cell)."

In the pretest, all cells were filled except the middle cell, which was empty. E pointed in turn to the empty center cell in each of four matrices. S was scored as passing the task if he responded correctly on at least three of the four Inferring$_1$ matrices presented him. There was no feedback to the S as to the correctness of his choice.

In the training phase, only two cells in each row and column, or six cells in all, were filled. E pointed in turn to each of three empty cells per matrix and recorded S's response choice. If S responded correctly, E moved on to the next cell or matrix. If S responded incorrectly, E said, "No, that is not right. Everything in this row (E ran his finger across the row of which the empty cell was a part) is red and everything in this column is a triangle (E ran his finger along the column of which the empty cell was a part). So here (E pointed to the empty cell) you need something that is red and a triangle." This procedure was repeated until S reached a criterion of nine out of ten consecutive correct responses.

Training task 2 (Inferring $_2$). S was presented with a partially filled 3 x 3 matrix without attribute cells, and a response array from which to make his choices. In the pretest, the middle cell and one other cell in the center row or column were empty and all the rest of the cells were correctly filled. In the training phase, four empty cells were arranged so that there were always two filled cells in the appropriate column but only one filled cell in the appropriate row (or vice versa) for any empty cell E pointed to. All other details of procedure were the same as for the Inferring_1 task, with the exception of the correction procedure in the training phase, which was amended to fit the Inferring_2 solution procedure.

Thus, if S responded incorrectly, E held his finger on the empty cell in question. If its row had only one cell filled, E pointed to a different row and said, "Everything in this row is blue, so everything in this row (E pointed to original row) must be red. And everything in this column (E ran his finger along the appropriate column, i.e., the original column that had two objects in it) is a triangle, so you need something that is red and a triangle. Point to the piece over here (in the response array) that is a red triangle."

<u>Training task 3 (Inferring_3)</u>. S was presented with a partially filled 3 x 3 matrix without attribute cells and a response array from which to make his choices. In the pretest, three objects were missing from the matrix, one from the center cell, one from the center row and one other from the center column. In the training phase, five empty cells were arranged so that there was always only one filled cell in both the row and column for any empty cell pointed to by E. All other details of procedure were the same as for the Inferring_1 task, with the exception of the correction procedure in the training phase which was amended to fit the Inferring_3 solution procedure.

Transfer task (2 x 2). S was presented with a 2 x 2 matrix without attribute cells in which three of the four cells were filled and one was empty, and a response array. The response array consisted of the four objects that completed the entire matrix and five objects which maintained at least one relevant attribute. E said, "Only one piece is missing from this game. Can you point to the piece over here (E pointed to response array) that is missing from, or belongs here (E pointed to empty cell)?" E recorded S's response and said, "O.K., let's try another one." This task was not used in the training phase, and no feedback was given. In the pretest four matrices were presented and a criterion of at least three correct was established for a passing score. In the posttest, each S was presented with 10 matrices. The number of correct out of a possible 10 was recorded for each S.

Design and Procedure

There were five phases in the experiment: familiarization, pretest, pretraining, training and transfer.

Familiarization. All Ss were first asked to name all the relevant colors and shapes. Ss who could not name the colors and shapes to be used in the experiment were immediately dropped. Remaining Ss were then acquainted with the general nature of the tasks to be used by working through the two familiarization tasks. They then proceeded to the pretest stage.

Pretest. All Ss were given the Inferring $_1$, Inferring $_2$, Inferring $_3$, and 2 x 2 pretests in that order. Only Ss who failed all four tasks were included in the experimental sample.

Pretraining. All remaining Ss were then trained to a criterion of nine out of ten consecutive correct responses on the pretraining task and rank-ordered in terms of number of trials to criterion. They were then assigned to four treatment groups matched so as to produce equivalent group means and standard deviations.

Training. Four training groups were designed to provide information concerning the effects of presentation sequence and overtraining on the acquisition of Inferring $_3$, hypothesized to be the most difficult Inferring task. Each of the four experimental groups received a different sequence of training tasks, as follows:

Group I received training on the three Inferring tasks in the hypothesized optimal sequence; namely, Inferring $_1$, Inferring $_2$, Inferring $_3$.

Group II was presented with the reverse sequence of Inferring tasks; namely, Inferring $_3$, Inferring $_2$, Inferring $_1$.

Group III was first trained on Inferring $_1$, then received overtraining (OT) on Inferring $_1$ before being trained on Inferring $_3$. In order to equate Group I and Group III Ss in terms of the number of intervening trials between Inferring $_1$ and Inferring $_3$, a yoked control technique was used. Ss in Groups I and III were rank-ordered within their groups and then paired as closely as possible in terms of trials to criterion on Inferring $_1$. Each S in Group III then received as many OT trials on Inferring $_1$ as his matched pair in Group I received training trials on Inferring $_2$. The range of OT trials extended from 10 to 77 with a mean of 34.44.

Group IV did not receive any intervening training between Inferring $_1$ and Inferring $_3$, which were presented in that order.

Besides the verbal feedback as to correctness of choice in the training phase, Ss were allowed to move a bead on a counter when they were correct, but not allowed to move a bead if they were incorrect. On each task Ss were trained to criterion, until a total of 90 trials had elapsed, or until three 15-20 minute training sessions had elapsed, whichever came first. At the end of the third training session on any given task, Ss who had not completed 90 trials and who had not reached criterion were assigned a score of 90 and moved to the next task. By the end of the third training session, however, all Ss had either reached criterion or made at least 45 responses.

Transfer. When each S completed his training sessions, the 2 x 2 transfer task was administered. The number of correct responses on 10 different 2 x 2 matrices using the same relevant dimensions, color and shape, was recorded. No feedback was given to the Ss.

All Ss were tested and trained individually by the same (white male) E in the hallway outside S's classroom. From pretest to posttest, approximately 10 weeks elapsed. Pretesting took one week to complete, followed by two weeks during which the Ss were on vacation from school prior to initiation of the pretraining phase of the experiment. All Ss were taught the pretraining task in less than a week and then began their training sessions. Ss were given a minimum of two and a maximum of nine 15-20 minute training sessions, depending on what group they were in (whether they were given two or three tasks to learn) and how many sessions it took them to reach criterion. The average S was seen about twice a week for three weeks. The transfer test was given in the session immediately after the S completed the training phase.

RESULTS

Familiarization and Pretest Phases

All 94 kindergarten children who were present in school during the week of pretesting were included in this stage. Of these, 13 failed to give ready verbal labels to the shapes and colors to be used and were immediately dropped from the sample. The remaining 81 were administered the four double classification pretests, and the 62 who failed all the pretests were allowed to proceed to the pretraining stage of the experiment.

Pretraining Phase

Of the 62 Ss who were trained on the pretraining task, four failed to reach criterion at the end of one 15-20 minute session and were dropped from the sample. The remaining 58 Ss were rank-ordered in terms of the number of trials to criterion on the pretraining task and divided into four equal groups. During the course of training, three additional Ss were dropped, two from Group I and one from Group II, because they either moved from the school district or were excessively absent. Analysis of variance confirmed that even after dropping these three Ss no differences existed among the groups in terms of trials to criterion on the pretraining task ($F < 1.00$).

Training Phase

Table 1 presents the number of Ss reaching criterion on the training tasks for each of the experimental groups. Table 2 presents the mean number of trials to criterion and related standard deviations on the training tasks for each of the experimental groups, considering all 55 experimental Ss. Table 3 presents the same information considering for each task only those Ss who had reached criterion on the immediately preceding task. The portions of these data relevant to each of the experimental hypotheses are discussed below.

Hierarchical hypotheses. Tests of the hierarchical hypotheses required comparison between the groups which received the tasks in the optimal order (Group I) and the reverse sequence (Group II).

Number of Ss reaching criterion (Table 1): In accord with the hypotheses, Fisher's exact probability test revealed that Inferring $_3$ was learned by a significantly greater number of Ss in Group I than in Group II ($p < .05$, one-tailed).[2] The optimal sequence was also more successful than the reverse sequence in teaching Ss Inferring $_2$ ($p < .05$, two-tailed). However, on Inferring $_1$ there was no significant difference between the groups ($p > .10$, two-tailed).

Trials to criterion: t-tests between Group I and II, considering all Ss (Table 2), confirmed the prediction that Inferring $_3$ would be learned more quickly by Group I than by Group II Ss ($t=1.86$, $df=24$, $p < .05$, one-tailed), and also confirmed the superiority, noted above, of the optimal sequence for Inferring $_2$ ($t=4.12$, $df=24$, $p < .005$, two-tailed). No difference between the two groups existed on Inferring $_1$ ($t=.02$, $df=24$, $p > .10$, two-tailed).

When only Ss who reached criterion on the preceding task are considered (Table 3), the differences in trials to criterion on Inferring $_3$ are heightened (comparing Groups I and II, $t=2.14$, $df=21$, $p < .025$, one-tailed). This heightening of effect is as expected since mastery of the simpler task, rather than mere exposure to it, should produce

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[2] One-tailed tests were used whenever specific predictions concerning differences between the groups had been made. Two-tailed tests were used in all other cases.

greater transfer to the more complex task. Each of the above findings is in accord with the predictions concerning the general effects of reverse versus optimal order training (Hypotheses 1, 2b, and 3b).

The data in Table 3 also reveal that the one S in Group II who succeeded in learning Inferring $_3$ (in 43 trials) then learned Inferring $_2$ in only 19 trials, considerably faster than the mean number of trials to criterion on Inferring $_2$ taken by Group I Ss who had previously learned Inferring $_1$. Further, the three Ss in Group II who learned Inferring $_2$, when then given Inferring $_1$ to learn, reached criterion in an average of only 11.33 trials. This was significantly faster than the mean number of trials to criterion on Inferring $_1$ taken by Group I Ss who learned the preceding (pre-training) task ($t=4.87$, $df=14$, $p<.005$, one-tailed). These data, although based on very few subjects, support the predictions made in Hypotheses 2a and 3a concerning reverse order Ss who succeeded in learning the more complex tasks.

The 12 Ss in Group II who did not reach criterion on Inferring $_3$ (mean trials on Inferring $_2$ =86.5, s.d.=9.02) were compared with Group I Ss on Inferring $_2$. As predicted (Hypothesis 2b), Group I Ss had significantly fewer trials to criterion ($t=7.61$, $df=21$, $p<.005$, one-tailed). Finally, the 10 Ss in Group II who did not reach criterion on Inferring 2 (mean trials on Inferring $_1$ =59.5, s.d.=33.43) were compared with Group I Ss on Inferring $_1$. Group I Ss reached criterion significantly faster ($t=2.21$, $df=19$, $p<.025$, one-tailed), contrary to the prediction made in Hypothesis 3b. This finding suggests that for Group II Ss, experience with a difficult task that they were unable to learn interfered with ability to learn the simpler task.

In summary, all but one of the predictions made in Hypotheses 1-3 were strongly supported. The optimal sequence was more successful in teaching the terminal task, Inferring $_3$, which proved to be very difficult to learn. The rate of learning the intermediate task depended on whether all Ss or only Ss learning the preceding tasks were considered. When the data from all Ss were analyzed, the optimal sequence was superior; when the data from Ss mastering the preceding task were analyzed, the reverse sequence was superior. For the latter Ss, learning the intermediate task first also led to significantly faster learning of the easiest task. Each of these findings indicates that the elements of the simpler task had been acquired in the course of learning the more complex task.

Additional evidence supporting the hypothesized hierarchy comes from examination of the learn-no learn contingencies for all Ss on the three double classification tasks. As would be predicted, no S learned a more difficult task without also learning the easier one to criterion.

Overtraining hypotheses. A test of the effects of overtraining required that comparisons of performance on Inferring $_3$ be made between the group learning the three tasks in optimal sequence (Group I), the group given overtraining on Inferring $_1$ prior to Inferring $_3$ (Group III), and the group given no intervening training between Inferring $_1$ and Inferring $_3$ (Group IV). These groups were shown to be equal in performance on Inferring $_1$, in terms of both number of Ss reaching criterion (Table 1) (χ^2=.53, df=2) and trials to criterion (Table 2) ($F < 1.00$).

Analysis by chi-square revealed that no significant differences (χ^2=.96, df=2) existed between the three groups in terms of the number of Ss reaching criterion on Inferring $_3$ (Table 1). Further, analysis of variance showed no differences among the groups on trials to criterion (F< 1.00). This was true both when all Ss (Table 2) and when only Ss learning the preceding task (Table 3) were compared. Thus, while Hypothesis 5 was supported, Hypothesis 6 was not.

Transfer Phase

Table 4 shows the mean number of correct responses on the transfer task for Ss learning and for Ss not learning Inferring $_3$. There were no significant differences in transfer scores between the four treatment groups for either the learning or the non-learning Ss. The data for the four groups were, therefore, combined and a comparison made of those who had learned (n=16) and those who had not learned (n=39) Inferring $_3$. As predicted (Hypothesis 4), Ss who reached criterion on Inferring $_3$ had significantly higher transfer scores than Ss who did not reach criterion ($t=4.42$, $df=53$, $p<.005$, one-tailed). Transfer was less than absolute, however, as Ss learning Inferring $_3$ averaged a score of only 6.44 out of a possible 10 on the 2 x 2 transfer task. A comparison of transfer scores for Ss (across all groups) who had and Ss who had not reached criterion on Inferring $_1$ only (and not on Inferring $_3$) showed no significant difference. Thus, the difference in transfer scores shown in Table 4 must be due to having learned Inferring $_3$, rather than to differences in general learning ability between the groups.

DISCUSSION

In terms of the number of Ss learning the terminal and intermediate tasks, the number of trials to criterion and the pass-fail patterns for the three training tasks, the predictions stemming from the hierarchical hypotheses were strongly supported. The intermediate and terminal tasks proved very difficult to learn for reverse sequence

Ss, and the hypothesized optimal sequence was thus clearly shown to facilitate learning. However, those reverse sequence Ss who did manage to learn the more difficult tasks then learned the simpler tasks faster than the optimal sequence Ss. This finding supports the behavior analysis which suggested that all the elements necessary to perform the easy task were present in the intermediate task, and all the elements necessary to perform the intermediate task were present in the terminal task.

The results for overtraining are more difficult to interpret since the group receiving neither overtraining nor exposure to the intermediate task did as well on the terminal task as the overtraining and optimal sequence groups. This seems to suggest that the basic matrix skills were quite well developed by the time Ss had reached criterion on the primary Inferring $_1$ task. Overtraining, or practice on the intermediate task, then, could only slightly improve these skills.

Clark and Cooper (1966) explained analogous data in which a group given training on an easy task did not do as well on a transfer task as another group which was given no training whatsoever in terms of Helson's (1959) adaptation level theory: i.e., a number of practice trials on the very easy task made it harder for those children given practice to adapt to the demands of the difficult task than for those children who had experienced no specific training of any kind. If one assumes that in the present study the intermediate task was more similar to the primary than to the difficult task, then Ss given practice on the intermediate task, like those given overtraining on the primary task, may have found it more difficult to adapt to the demands of the difficult terminal task.

This interpretation calls into question the adequacy of the behavior analysis for Inferring $_2$, which suggested that a major new set of components--identical to the ones required for Inferring $_3$--first came into play in the intermediate task. The data on this point are unclear, however. While only one of the optimal sequence Ss who learned the easy task failed to learn the intermediate task (Table 3), the mean number of trials to criterion on the intermediate task was still quite high. In addition, Inferring $_2$ was clearly very difficult for reverse sequence Ss who had not learned Inferring $_3$ (Table 2). More direct observation or testing of the solution strategies actually used on the various training tasks is required before the overtraining data in this experiment will become interpretable.

The results confirmed the prediction of positive transfer from the terminal to the behaviorally analogous transfer task, but since transfer was less than perfect even for Ss who had reached criterion on Inferring $_3$ there is the suggestion that the behavioral analysis has not identified all critical components of the solution strategies for the two tasks. In particular, it seems likely that the 2 x 2 matrix format offers less perceptual support for verifying choices for the empty cell, but this needs to be examined empirically.

The training procedures used in the present experiment were successful in teaching about 50 percent of lower class Ss, well below the age normally associated with the acquisition of concrete operations, to solve double classification problems (see Jacobs and Vandeventer, 1969, for description of another successful training procedure for matrix skills). The present results, therefore, lend support to the findings of other investigators (e.g., Kingsley & Hall, 1967; LeFrancois, 1968; see also Gagné, 1968) concerning the use of behavioral analysis techniques in identifying sequences of learning objectives which can lead to accelerated acquisition of concrete operational behaviors.

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TABLE 1

Number of Subjects Reaching Criterion on the

Training Tasks for Each of the Experimental Groups

Group	$Inferring_1$ n	$Inferring_2$ n	$Inferring_3$ n
I (N=13)	11	10	6
II (N=13)	8	3	1
III (N=14)	11		4
IV (N=15)	11		5
Total (N=55)	41	13	16

TABLE 2

Mean Trials to Criterion on the Training Tasks for Each of the Experimental Groups Considering all Subjects

Group	Inferring$_1$		Inferring$_2$		Inferring$_3$	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
I (N=13)	48.08	26.34	40.85	29.24	69.46	30.40
II (N=13)	48.38	35.69	81.31	19.97	86.38	12.52
III (N=14)	46.21	28.77			80.57	16.14
IV (N=15)	52.42	27.80			69.80	29.66

TABLE 3

Mean Trials to Criterion on the Training Tasks for Each of the Experimental Groups Considering Only Subjects Who Reached Criterion on the Preceding Task

Group	Inferring$_1$			Inferring$_2$			Inferring$_3$		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
I	13	48.08	26.34	11	31.91	22.16	10	63.30	32.20
II	3	11.33	3.30	1	19.00	0.00	13	86.38	12.52
III	14	46.21	28.77				11	78.00	17.34
IV	15	52.42	27.80				11	62.45	31.58

TABLE 4

Mean Correct Responses on the Transfer Task for Subjects Learning $Inferring_3$ and Not Learning $Inferring_3$

Group	Learning $Inferring_3$			Not Learning $Inferring_3$		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD
I	6	6.50	3.45	7	2.57	3.02
II	1	10.00	0.00	12	2.92	2.06
III	4	4.75	1.92	10	2.90	2.95
IV	5	7.00	1.55	10	3.00	2.32
Total	16	6.44	2.78	39	2.87	2.56

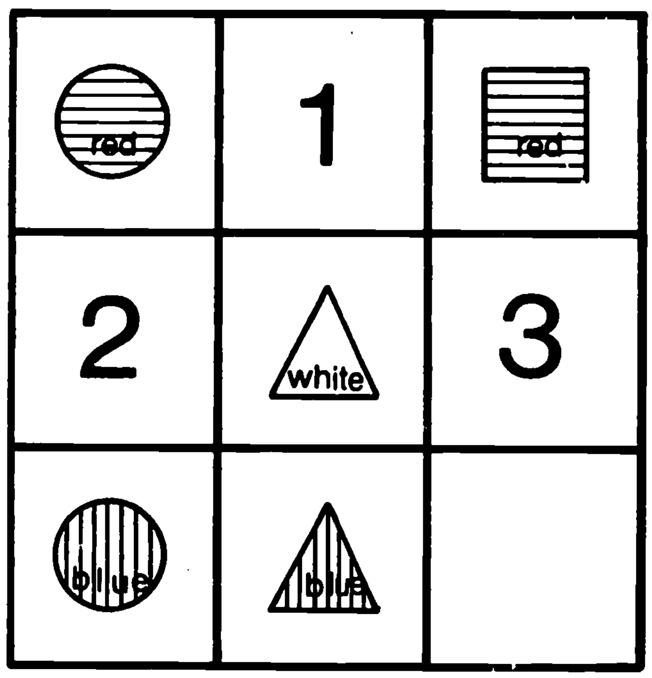

Figure 1: The Training Tasks.

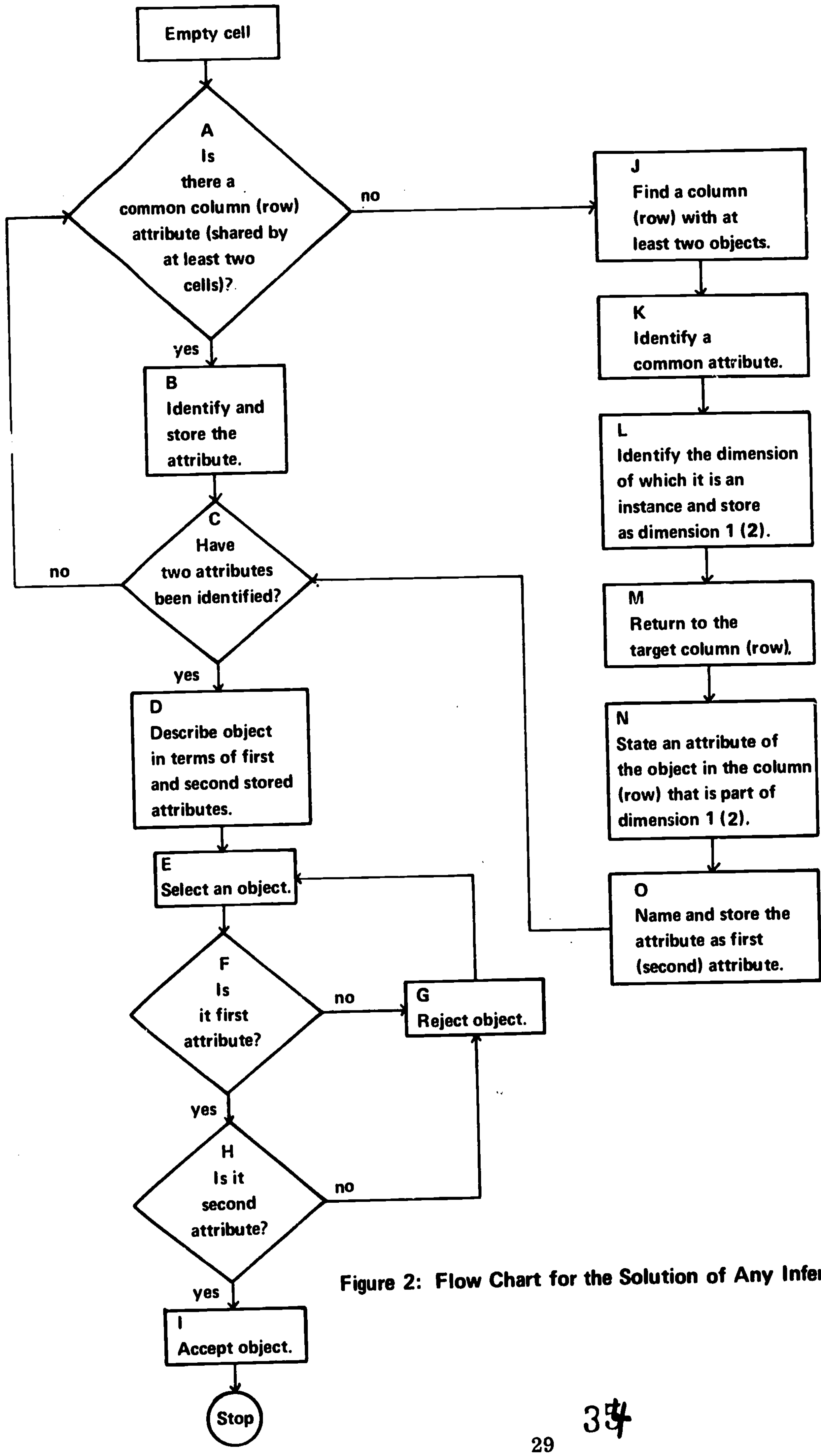

Figure 2: Flow Chart for the Solution of Any Inferring Matrix Task.