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AUTHOR Riley, Christine A.; Trabasso, Tom
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ABSTRACT

This study is based on an earlier investigation by Brant and Trabasso, in which it was demonstrated that 4-year-old children could perform transitive inferences when training forced information encoding by involving questions about two comparative dimensions of an object (long and short). The present study was designed to examine the sources of difficulty that children have in making inferences and to investigate the crucial factors in the Bryant and Trabasso procedure that contributed to its success. The following three experiments were conducted: (1) replication of Bryant and Trabasso, (2) traditional approach using only one comparative dimension (longer), and (3) both comparative questions asked across pairs rather than within each pair. Results of initial training indicated that in traditional studies failure to make transitive inferences was not necessarily due to inability to infer, but inability to encode comparative relations. Retraining with verbal and visual feedback was undertaken, and the information processing demands of each experiment were analyzed. It was concluded that children need to be cued to both dimensions to make inferences and that the information processing demands are generally the crucial determinants of children's success or failure. (DP)

LOGICAL STRUCTURE VERSUS INFORMATION PROCESSING IN MAKING INFERENCES

Christine A. Riley and Tom Trabasso
Princeton University

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A transitive inference is a logical operation of the form: if A is greater than B (A>B) and if B is greater than C (B>C), then A is greater than C (A>C). This inference requires the addition of two asymmetrical relations, A>B and B>C, which is one of the grouping structures, identified by Piaget, which is acquired at the stage of concrete operations. Preoperational children fail to make this type of inference, in Piaget's analysis, because they cannot coordinate (logically add) the two relations A>B and B>C using the middle term B. This coordination requires encoding the reversibility of the relationship between A and B (A>B and B<A) in order to use B as a middle term which is both less than A and greater than C.

Bryant and Trabasso (1971) did an experiment which demonstrated that preoperational children (ranging in age from four to six years) could perform such inferences about length with a high degree of success. Their experiment also resolved several problems which were disputed in the earlier literature by:

(1) Using symbols (colors) to represent lengths, eliminating any solution using perceptual differences between sticks,

(2) controlling for response bias (success achieved by labelling "A is long" and generalizing this label to answer the AC question) by using five sticks and basing the critical test on the center three sticks, and

(3) ensuring memory for the original information by training (in this case the relations of AB, BC, CD and DE) and measuring memory for the original information during test trials.

Table I describes the procedure used by Bryant and Trabasso. Colored sticks were placed in a box with holes countersunk so that a stick when placed appropriately would protrude exactly one inch. Two sticks at a time were presented and the experimenter asked "Which sitck is longer (shorter)?" In the first training phase each of the four pairs was trained separately to a criterion of eight out of ten correct responses. In the second phase of training the pairs were randomized and subjects were trained to a criterion of six consecutive correct responses on each pair. In both phases subjects were given visual feedback by showing them the sticks, or verbal feedback by telling them the relationship. In testing subjects were presented with each of the ten possible pairs from the five sticks four times. The forty questions were randomized and no feedback was given.

Table II shows the results from Bryant and Trabasso with visual feedback on four year old subjects. The pairs on the diagonal are the training pairs, and the proportion correct is a measure of memory for the original information. Response bias is possible on pairs on the top and right margins. We call them "end-anchored" pairs because they involve the longest and shortest stick in the five stick array. The center pair is the critical test pair.

The purpose of the present experiments is to examine the sources of difficulty children have in making inferences and to examine what factors in the Bryant and Trabasso procedure contributed to their success. An examination of the Bryant and Trabasso task indicated that they departed from traditional procedures in the way in which they asked questions, as well as by their use of training to ensure memory. Their training procedure made explicit the reversible relation of the sticks in each training pair by requiring the subjects to answer both longer and shorter questions, and thus forced the children to encode the relationships in this manner in order to reach memory criterion.

We asked what would happen if this encoding was not forced. That is, the logical structure of the information used in the experiment was exactly the same, but the task demands were varied. Table III shows the design of our three experiments. In Experiment 1 we replicated Bryant and Trabasso with verbal feedback. In Experiment 2 we used a more "traditional" procedure by using only one comparative question (either longer or shorter) throughout to see if the use of both comparatives was a critical factor. In Experiment 3, both questions were asked but across pairs rather than within a pair. This tests whether a subject needs to be forced to encode the reversible relationship by using both comparatives within each pair, or whether he only needs to be cued to use both forms by using both in the training, but across pairs.

Table IV shows a summary of the training data. The same trends are observed for both the number of subjects reaching criterion and the number of trials necessary to reach criterion for those subjects who did succeed. Both the Bryant and Trabasso replication and inferential conditions gave subjects little difficulty (with the inferential appearing somewhat simpler); however, in the traditional condition, where only one comparative question was asked there was a high rate of failure and even for those subjects who learned, the task was much more difficult.

Therefore, in earlier traditional studies, failure to make a transitive inference was not necessarily because of an inability to infer, but rather because of an inability to encode the comparative relation of the original pairs of ordinal relations. This failure is consistent with Piaget's observation that preoperational children will reduce ordered relations to classifications, i.e. use the comparative as a label. This reasoning produces: if A is longer than B, then A is long and B is not long, and if B is longer than C, then B is long and C is not long, which places B in two mutually exclusive classes and causes considerable confusion.

Table V shows test data following training with verbal feedback. Test questions are counterbalanced for longer and shorter in all three experiments. Table VI shows the test data for the same subjects who were retrained using visual feedback.

The Bryant and Trabasso replcation group performed much better than the other two. Of greatest interest are their memory for initial pairs (shown on the diagonal) and their performance on the critical test pair. The histograms on the right show the number of subjects making zero to four correct responses on the BD questions. There is some improvement in all groups following retraining with visual feedback, but this improvement is most striking for the Bryant and Trabasso replication study, where there is a very high success rate on the critical inferential question.

The main conclusions to be drawn from the data in Tables V and VI are:

1. When feedback was <u>verbal</u>, the Bryant and Trabasso replication subjects were above chance on the critical BD test. Although the traditional proportion is as high, it is not above chance becuase of the small number of subjects who had succeeded in training. Also, the overall performance of the Bryant and Trabasso group was superior.

2. When subjects were retrained with <u>visual</u> feedback, subjects in the Bryant and Trabasso replication experiment show substantial improvement on the inferential pair (about 20 percent), whereas traditional subjects show no improvement on the inferential pair.

Turning to the individual subject data, we reach the same conclusions. In particular, the percent of subjects who answer <u>all</u> critical test correctly rose from 35 percent to 70 percent in the Bryant and Trabasso experiment.

Even though the inferential subjects reached criterion easily during training, their performance is within the chance interval for all pairs. This puzzling result lead us to look for another possible strategy which subjects might be using. Going back to Table III, note that in Experiment 3 subjects can answer training questions by using simple response rules: for one group "choose A, C or E" and for the other group "choose B or D" for any pair presented. Further analysis of the test data shows that subjects continue to apply these rules during testing. When presented with any pair including one of the "right answer" sticks, subjects tended to choose that stick without regard to whether the question asked for the longer or shorter stick. For example, when given the pair AD a subject in the first group would choose A regardless of question. Subjects gave the inferentially correct answer on appropriate questions (in this case longer) more than on inappropriate questions (in this case shorter) (sign test, $p<.0001$). On pairs containing two or none of the sticks chosen by the response rules, subjects gave no diffenential performance on longer versus shorter questions; all they appear to do is guess.

The conclusion here is that the double form of the comparative is necessary for success in making inferences. The question of forced versus cued double encoding cannot be examined, because the subjects discovered a simple solution to the inferential task, which the authors had not anticipated. The few traditional subjects who could be tested showed somewhat intermediate performance. The small N does not allow any conclusions about the strategy they used; however, there appears to be some mixture of encoding strategies used by these subjects.

These results lead us to examine what the information processing demands on the subjects are in each experiment. Three factors arise. First, can the subject be successful in training by using a simple response rule. Second, what is the memory lead placed upon the subject. Finally, must the subject listen to the form of the question asked by the experimenter, and how much information does the question give about appropriate encoding of the information.

Referring back to Table I, we can see that in phase one both the traditional and inferential groups can succeed by using a simple response rule, becuase only one question is asked for each pair. Therefore, there is only one right answer per pair, and attending to the form of the questions is not critical for learning the correct response. For the Bryant and Trabasso subjects, however, two different responses per pair are required and the form of the question indicated the appropriate response. Thus the subject must encode the reversible relationship in order to consistently give the correct response.

In phase two inferential subjects can continue to use the response rules learned in phase one, because the response holds across pairs and the randomization presents no furhter problem. The traditional group, however, cannot continue to use simple response rules. They must begin again and encode either conditional rules (i.e. A is the answer when AB is presented, B is the answer when BC is presented, etc.) or encode the length relationship in order to reach criterion. If the conditional rules are used there is no concrete way to integrate the information adn reduce the memory load.

Bryant and Trabasso subjects, like the inferential, can continue to use the strategy employed in phase one. In addition, when learning all pairs simultaneously, they can coordinate the series and encode one ordering from longest to shortest, and thus reduce their memory load.

Success on the test questions was determined not only by the ability to learn the required pairs in training, but was also largely determined by wherther or not the pairs were encoded appropriately in terms of length relationships.

Thus successful performance on a task with the logical structure of the addition of four asymmetrical relations has been demonstrated; however, the information processing demands on the subjects are the critical factors involved in the success or failure of four-year-old children.

REFERENCE: Bryant, P.E. and Trabasso, T. Transitive inferences and memory in young children. Nature, 1971, 232, 456-458.

TABLE I. DESCRIPTION OF BRYANT AND TRABASSO (1971) PROCEDURE

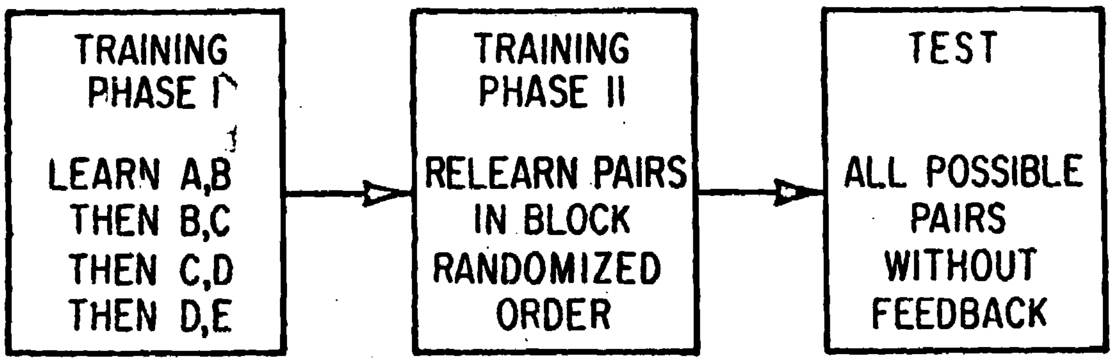


TABLE II PROPORTION OF CORRECT CHOICES FOR TRANSITIVITY AND RETENTION

TEST DATA FROM BRYANT AND TRABASSO (1971)

4 YEAR OLD SUBJECTS, FOLLOWING VISUAL FEEDBACK

	B	C	D	E
A	.96 (underlined)	.96 (circled)	.93 (circled)	.98 (circled)
B		.92 (underlined)	.78 (boxed)	.92 (circled)
C			.90 (underlined)	.94 (circled)
D				.91 (underlined)

Underline — TRAINING PAIR

Circle — END-ANCHORED PAIR

Square — CRUCIAL TRANSITIVITY PAIR

TABLE III. DESIGN OF THE EXPERIMENTS TO BE PRESENTED

EXPERIMENT I	EXPERIMENT II		EXPERIMENT III	
BRYANT AND TRABASSO REPLICATION	TRADITIONAL		INFERENTIAL	
A>B & B<A	A > B	B < A	A > B	B < A
B>C & C<B	B > C	C < B	C < B	B > C
C>D & D<C	C > D	D < C	C > D	D < C
D>E & E<D	D > E	E < D	E < D	D > E
N=20	N=10	N=10	N=20	N=20

A > B READS "WHICH STICK IS LONGER, THE A (B) STICK OR THE B (A) STICK?"

B < A READS "WHICH STICK IS SHORTER, THE A (B) STICK OR THE B (A) STICK?"

TABLE IV. TRAINING DATA

EXPERIMENT	NUMBER OF SUBJECTS REACHING CRITERION
BRYANT-TRABASSO REPLICATION	20/23
TRADITIONAL	7/20
INFERENTIAL	40/40

PHASE II

CONDITIONAL MEAN ERRORS WITH VERBAL FEEDBACK

EXPERIMENT	AB	BC	CD	DE	TOTAL
BRYANT-TRABASSO REPLICATION	2.55	5.35	4.10	3.10	3.78
TRADITIONAL	7.78	12.29	8.57	3.43	7.89
INFERENTIAL	2.60	3.53	3.83	3.05	3.25

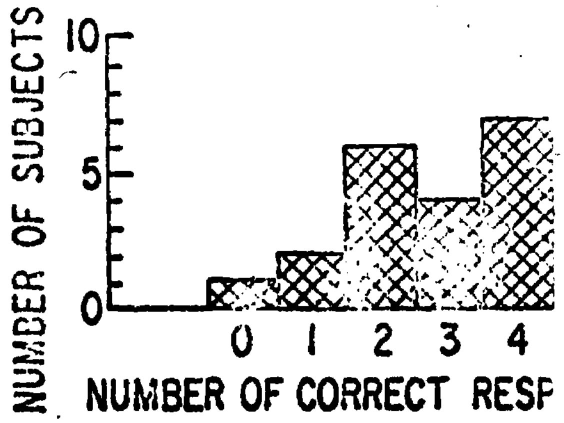
TABLE V. TEST DATA FOLLOWING TRAINING WITH VERBAL ''EEDBACK

1. BRYANT-TRABASSO REPLICATION

N=20

	B	C	D	E
A	.96	.81	.75	.86
B		.66	.68	.80
C			.79	.76
D				.85

Overall = .79

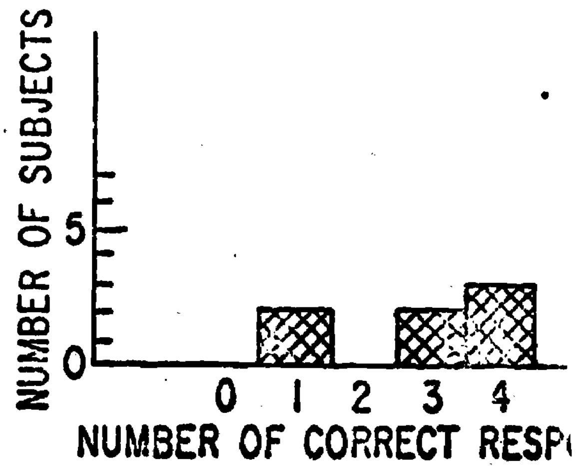


2. TRADITIONAL

N=7

	B	C	D	E
A	.75	.71	.61	.57
B		.54	.71	.61
C			.57	.79
D				.75

Overall = .66



3. INFERENTIAL

N=40

	B	C	D	E
A	.61	.50	.59	.59
B		.54	.56	.56
C			.53	.61
D				.60

Overall = .60

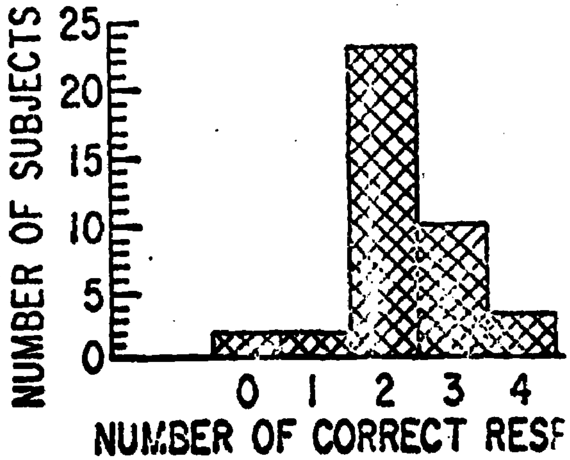


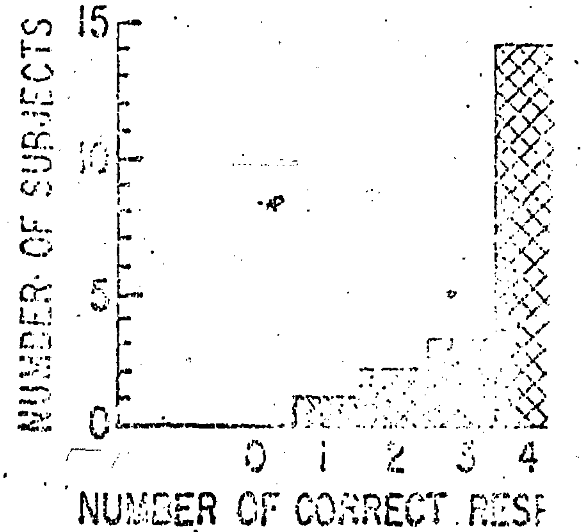
TABLE VI. TEST DATA FOLLOWING RETRAINING WITH VISUAL FEEDBACK

1. BRYANT-TRABASSO REPLICATION

N=20

	B	C	D	E
A	.99	.90	.91	.93
B		.81	.88	.88
C			.91	.90
D				.98

Overall = .91

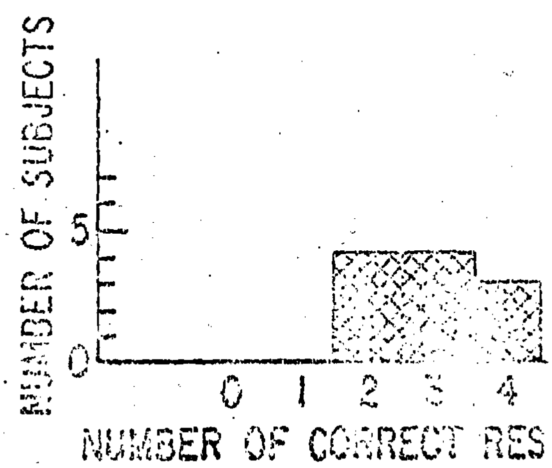


2. TRADITIONAL

N=11

	B	C	D	E
A	.82	.82	.77	.77
B		.59	.73	.75
C			.68	.64
D				.64

Overall = .72



3. INFERENTIAL

N=40

	B	C	D	E
A	.69	.63	.72	.65
B		.56	.61	.60
C			.61	.68
D				.69

Overall = .64