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Effects of Strategy Modeling and Age Upon Information-Processing Efficiency Among Elementary-School Children

by

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ABSTRACT

Effects of Strategy Modeling and Age Upon Information-Processing Efficiency Among Elementary-School Children

by

Shanna Richman

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Using the blank-trial, hypothesis-testing paradigm, second- and sixth-grade children were exposed to a ten-minute videotape on which one of two strategies for solving four-dimensional, discrimination-learning problems was modeled with rule provision. A third videotape, the control tape, did not provide the rule for any strategy, but illustrated the precurser processes that were analyzed that are essential to generating any strategy, e.g., maintaining a single hypothesis through the four, no feedback trials that constitute a blank-trial probe, maintaining a confirmed hypothesis, changing a disconfirmed hypothesis, and sampling from the positive stimulus array after negative feedback. Measures of problem solution and the hypothesis-sampling systems (strategies, stereotypes, and unsystematic sequences of hypotheses) employed by the subjects were also analyzed.

Previous research without modeling had indicated that elementary-school children did not manifest the most efficient strategy (focusing), while a less efficient strategy (dimension checking) was manifested in approximately 50% of the problems presented. Other hypothesis-sampling systems observed included a still less efficient strategy (hypothesis checking), sequences of hypotheses that did not confirm to any delineated strategy (unsystematic patterns), and sequences in which the manifested hypothesis was insensitive to feedback (stereotypes).

Analysis of the percentages of problems solved indicated that sixth-grade children performed better than second-grade children after exposure to each of the tapes. Only after exposure to the dimension-checking tape did the performance of the second graders approach that of the sixth graders. Dimension checking is the strategy most often manifested by elementary-school children of all ages without modeling. The second graders' performance was markedly below that of the sixth graders after exposure to the focusing and control tapes. Similar findings obtained on the precurser process measures in that second graders exposed to the dimension-checking tape generally performed as well as the sixth graders. The sixth graders did not differ on the precurser process measures as a function of tape exposure. Among the second graders, performance was best after exposure to the dimension-checking tape, depressed after exposure to the focusing tape, and usually intermediate after exposure to the control tape.

Without modeling, no differences in strategy production were previously found among elementary-school children. Modeling established clear age differences. The maximally efficient strategy was elicited in 55% of the problems presented to the sixth graders exposed to the focusing tape. The second graders did not manifest focusing under any experimental conditions. After exposure to the dimension-checking tape, both second- and sixth-grade children manifested this strategy in 65% of the problems presented. The sixth-grade children exposed to the control tape manifested focusing (40%) or dimension checking (45%). The second graders exposed to the control tape manifested 45% dimension checking, 30% hypothesis checking, 10%

stereotypes, and 15% unsystematic hypothesis sequences. After exposure to the same tape, the sixth graders manifested no hypothesis checking or stereotypes and 10% unsystematic sequences.

Eighty percent of the problems presented to the sixth graders under all experimental conditions and 80% of the problems presented to the second graders after exposure to the dimension-checking tape resulted in sequences of hypotheses that were categorizeable (primarily strategies). However, only 43% of the problems presented to the second graders exposed to the focusing tape and 53% of the problems presented to the second graders exposed to the control tape resulted in manifestation of any hypothesis-sampling system.

The hypothesis is advanced, therefore, that sixth-grade children have the information-processing capacity to manifest the maximally efficient focusing strategy, most successfully when the rule is provided. Focusing can also be elicited when sixth graders are exposed to a tape that models only precurser processes but gives them 10 minutes to organize their own thinking while watching a model make silent choices.

The obtained age differences in hypothesis-sampling systems are interpreted from both a Piagetian view (concrete vs. formal operational) and a developmental learning theory perspective (age differences in attention, coding, logical inference, and memory).

In Memory of my Father,

George J. Richman

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Introduction

The purpose of this study was to examine the effects of modeling information-processing strategies on the problem-solving behavior of elementary-school children. Assuming that such behavior consists of learning appropriate response rules, it becomes important to understand how these rules are learned.

There is little doubt that the probability of a desired response can be increased above baseline by reinforcing the response when it occurs. Even concepts and response rules can be learned if the appropriate behavior is selectively reinforced (Hilgard & Bower, 1966).

Recent evidence indicates, however, that a great deal of learning is probably accomplished through the observing of models. Even when it is possible to produce learning through other means, modeling can often shorten the acquisition process (Bandura, 1971).

Modeling studies have been reported under various rubrics: imitation, observational learning, identification, internalization, introjection, incorporation, copying, social facilitation, contagion, and role taking. Although distinctions among the various labels have been proposed, Bandura (1971) suggests that there is no theoretical reason for doing so.

The term modeling usually refers to a two-stage process: in the first stage the subject watches the model perform the desired behavior (the modeling *per se*), and in the second stage the subject attempts to perform the modeled behavior (imitative behavior). There are wide variations in modeling procedures, e.g., model and subject taking turns (e.g., Odom, Hill & Huff, 1969), modeling with the subject verbalizing as he watches (e.g., Zimmerman & Bell, 1972), and most important, in view of this study, modeling as silent behavioral demonstration versus modeling with verbalization, especially with direct rule provision (e.g., Zimmerman & Rosenthal, 1972). However, in all these cases, the modeling phase may be thought of as occurring without direct reinforcement to the subject. The subject is, however, reinforced during the imitative phase, usually by knowledge of results.

Bandura's current social-learning theory views the modeling process as operating primarily by providing information for the subjects (observers) who acquire symbolic codings of the modeled events. The degree to which modeling affects subsequent performance depends upon a number of subprocesses. These include (a) attention -- the subject must attend to, recognize, and differentiate the distinctive features of the stimuli and the model's responses; (b) retention -- since in most modeling studies, the subject does not perform the required responses at the same time that he is observing the modeling, he must retain the observational inputs in some symbolic form (imaginal, verbal, or both). Bandura believes that verbal codes facilitate observational learning and retention because a great deal of information is carried in easily stored form; (c) motoric reproduction -- the subject must understand the motoric responses required and be physically able to perform them; (d) motivation -- the subject must be willing to participate in demonstrating that he has learned what is being modeled.

Deficiencies in any of the subprocesses may result in failure to demonstrate that observational learning has occurred. Bandura's theory views the subject as an active agent who attends, remembers, classifies, and organizes the modeled behavior, rather than as a passive observer who simply records whatever is presented and reproduces it when the appropriate conditions are aroused.

A large number of modeling studies have concentrated on the effects of modeling interpersonal variables such as behavioral contagion (particularly aggression). The role of variables that can change the effectiveness of modeling has also been investigated. These include antecedent characteristics of the model (including status, control of resources valuable to the subject, nurturance, sex, and degree of realism of the model's performance), the affective relationship between the model and the subject, and antecedent characteristics of the subject (see Flanders, 1968, for a review of this literature).

Investigations of modeling have not dealt exclusively with social behavior, however. The relationship between modeling and more specific rule learning has also been studied. Odom, Liebert, and Hill (1968) found that second-grade children who were exposed to an unfamiliar prepositional phrase (e.g., The goat was the door at) spontaneously reconstruct the phrases so that they conform to Standard English sentences (e.g., The goat was at the door). Liebert, Odom, Hill, and Huff (1969) later suggested that the subjects may be employing one of several possible strategies. The strategy which involved the use of a previously learned language rule (sic) apparently prevailed over an alternative one which would have led to the "correct" solution. They offered two alternative predictions: (1) If reordering into "correct" English constructions is due to previous familiarity with the language, then with increasing age, the children should be <u>less able</u> to repeat and spontaneously produce deviant sentences. (2) If the reordering strategy represents an inability to abstract the rule from brief modeling training, and one assumes this ability increases with age, then the ability to abstract and use an unfamiliar construction strategy should increase with age. The subjects were middle-class children of three median ages: 5.8 years, 8.4 years, and 14.1 years. The experimenter and model were both adult females. After baseline training, during which the subjects simply produced sentences with given nouns, the experimenter said that he liked some sentences better than others. Each subject was given 20 nouns and asked to produce 20 sentences. The model produced 30 sentences. Praise was given to both the subject and the model for producing the relevant constructions in both the familiar English-rule sentence groups and the new-rule sentence groups (comparable to the unfamiliar constructions in the previous study). Their results indicated that, as in the earlier study, the children in the English-rule groups continued to do well and performance improved with age. The youngest children in this study performed as they had in the earlier one, transforming new-rule sentences into Standard English. However, in the new-rule condition, the two older groups showed a mean decrease in grammatically correct sentences and a corresponding increase in spontaneous production of the new-rule sentences. This improvement in new-rule production increased with age so that among the children in the oldest group, the new-rule children performed as well as the children of the same age exposed to the Standard English rule. This leads to the conclusion that language learning and performance may be viewed as a problem-solving situation in which the accurate processing of novel information increases with age.

Liebert and Swenson (1972) examined the performance of first-grade children in abstracting, using, and transfering a modeled underlying rule. The children observed an adult female silently choosing from stimuli presented on slides and exhibiting either a preference for one item or two items equal in value to a single item (e.g., one large ball as opposed to two small balls) or inconsistently choosing one or two items. The subjects were required first to recall the model's choices from the same set of stimuli and then to guess what the model would have chosen with a different set of stimuli. Results indicated that children who were exposed to a model making consistent choices (i.e., either one item or two items) had shorter response latencies, reliably better recall of the model's choices, and consistently better prediction of what the model's choices would be on a set of new items than did those subjects exposed to a model who showed inconsistent preferences. It appears, then, that young children can abstract the common feature from a number of discrete response examples and use this information for prediction. "Additionally, the data provided strong corroboration for the more general assumption that the behavioral phenomena associated with observational learning may be fruitfully viewed within the heuristic framework of an information-processing approach to imitative behavior" (Liebert & Swenson, 1972, p. 503).

There have been a number of studies that evaluated the effects of children verbalizing as they were exposed to a modeling situation (e.g., Bandura, Grusec, & Menlove, 1966; Coates & Hartup, 1969; Zimmerman & Bell, 1972). In general, the results indicate that a subject's unstructured verbalizations during observation of a model did not enhance performance over the situation in which the subject passively watched the model without verbalizing.

Some research has been directed at the effect of the model's verbalizations on the child's information processing. The most relevant study was by Zimmerman and Rosenthal (1972). They studied rule provision, with and without modeling. Their subjects were four groups of third-grade children: (1) No model control. (2) No model, rule provision, in which the rule was verbally provided before the game was played, i.e., "Now before your next turn, let me give you a good rule for playing the game. The arrow moves like a backward clock and tells you how many spools to pick. When the arrow is up, you need just one spool; when the arrow is left you need two spools; when the arrow is down you need three spools; and when the arrow is right you need four spools. The color of the arrow tells you which color of spools to pick to be correct." (3) A modeling group, in which the subjects observed an adult male correctly performing the task silently; no feedback or praise was administered to the model. (4) A modeling group with rule provision was given the same rule as the subjects in group 2 after they had watched the model silently performing, but before they were tested for either imitation or generalization. The results confirmed previous findings in that (a) all groups, except the controls, learned the concept; (b) the silent modeling subjects outperformed the controls; (c) the rule provision, no model group performed better than the silent model group; and, most important for the present study, (d) the model plus rule group showed the greatest concept attainment both in imitation and in generalization. The authors concluded, therefore, that "empirically, modeling and rule-provision were not redundant operations. . . . The results further suggested that children acquired and stored a mnemonic paradigm or cognitive rubric, rather than discrete links to particular physical stimuli. . . ." (Zimmerman & Rosenthal, 1972, p. 148).

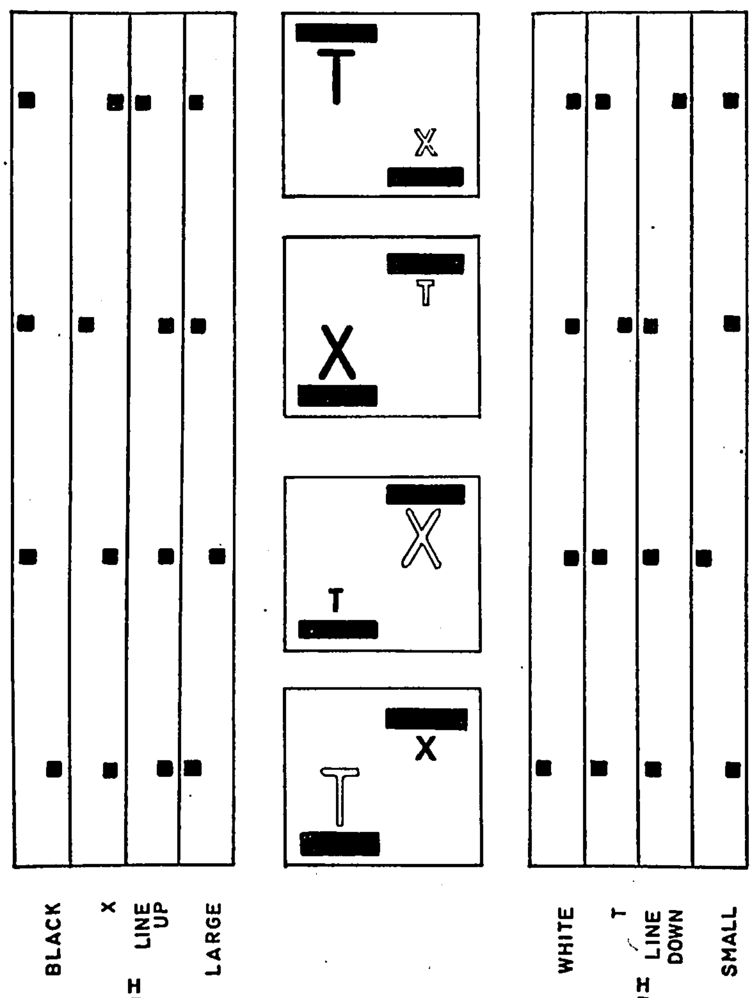
Viewing a strategy as an information-processing plan, Mosher and Hornsby (1966) distinguished two types of strategies that could be employed in playing Twenty Questions. The more efficient of these strategies was termed constraint seeking. Here the information value of each question is maximized so that when all possibilities are equally likely, the first question could eliminate half the possibilities. One such question might be, "Is it living?" The opposite strategy is called hypotheses scanning (or seeking). A player using this strategy asks a question that eliminates one specific possibility (or hypothesis), without regard to the questions that have been previously asked. An example would be, "Is it a car?" when there is only one car. Using kindergarteners, first, and second graders, the author presented pictures of two classes of objects (four types of toys and four types of animals). In an ordered array, a row consisted of one animal or toy and a column consisted of all drawings in one of three colors (red, yellow, or blue). In the unordered array, the colors and classes of objects were presented in random order. The children were allowed to ask any questions that could be answered "yes" or "no." For half the subjects in each group, the eliminated alternatives were removed from the array; for the other half they were not. Results indicated that the youngest children did not impose any order on a perceptually disordered array. They used the hypothesis scanning (or essentially guessing) strategy, but did somewhat better when the array was ordered. The older children showed much more constraint-seeking behavior. But even these children did not use the maximally efficient constraint-seeking strategy, i.e., a question that would have divided the array in half, such as, "Is it a toy (or an animal)?" They used constraints, e.g., "Is it red?" that eliminated some of the alternatives in a systematic way. Removal of eliminated alternatives had no effect on strategies, but the game was a simple one which imposed little strain on memory. Establishing constraints on the random array helped the children formulate informative questions, at least among the six- and seven-year-olds.

The previous study attempted only to elicit the strategy produced by children under different conditions of stimulus organization. Denny (1972) used videotape to model three different types of strategies: (a) hypothesis-seeking questions, e.g., "Is it a zebra?" (b) perceptually-based constraint-seeking questions, e.g., "Does it have stripes?" (c) functionally-based constraint-seeking questions, e.g., "Does it walk on four legs?" On each card the model asked two or three questions and then chose the correct picture. The six-, eight-, and ten-year-olds who served as subjects were scored on the number of questions they asked and whether the questions were hypothesis-seeking, constraint-seeking, or pseudoconstraint-seeking (questions with the same syntactic structure as a constraint-seeking question but referring to only one picture, e.g., "Does it have a sail," when only one picture has a sail). The results indicated that the percentage of hypothesis-seeking questions decreased with increasing age, while the percentage of constraint-seeking questions increased. The percentage of pseudoconstraint-seeking questions increased from six- to eight-year-olds and then decreased. The number of questions asked of each card also decreased with age, indicating that increased efficiency accompanied the increased percentage of constraint-seeking questions. No significant modeling effects were found for six year olds. Eight year olds exposed to the hypothesis-scanning model showed a significant decrease in constraint-seeking questions while those exposed to the perceptual constraint-seeking model increased their percentage of constraint-seeking questions. The eight year olds exposed to the functional constraint-seeking model did not produce more constraint seeking than the controls but the ten year olds exposed to the same model did.

The results indicated that children of different age levels were differentially responsive to various conceptual strategy models. The younger children were more responsive to less sophisticated conceptual-strategy models (i.e., the hypothesis-scanning approach was initially used by six-year-olds and not changed by any modeling condition), while the older children responded to more sophisticated conceptual-strategy models. They did reduce their constraint-seeking when exposed to an hypothesis-scanning model, although they increased their constraint-seeking more when exposed to a constraint-seeking model. Denny concluded that modeling probably was not effective with the six year olds because they did not have constraint-seeking behavior in their repertoire. He suggested that the results favored an eliciting rather than a learning effect of exposure to modeling. The assumption here is that the subject must already have the strategy in his repertoire, or, minimally, have the cognitive elements of the strategy in his repertoire before modeling can be effective. Modeling per se is not presumed effective in teaching anything to anyone. The subject must be in some sense "ready" to respond to the modeled material.

Denny and Ziobrowski (1973) did, however, induce constraint-seeking questions in six-year-olds by having the subject and model take turns asking the questions. The model asked only constraint-seeking questions and described her strategy. Eliminating items from the array on the basis of constraint-seeking questions resulted in improved scores. The authors suggested that the combination of the model verbalizing her strategy (instead of merely exemplifying it) along with the graphic illustration of the efficiency of constraint-seeking questions (by removal of eliminated items) induced the strategy in the six-year-old children.

The types of strategies studied by Denny and his coworkers are in some respects similar to the type of strategies delineated by Gholson, et al. (1972) within the context of hypothesis theory (Levine, 1966, 1969, 1971; Restle, 1962; Trabasso & Bower, 1968). According to this theory, at the beginning of, for example, a bi-valued four-dimensional, discrimination-learning problem, a subject selects one hypothesis from the universe of possible hypotheses and responds on the basis of the hypothesis selected. Figure 1 presents an example of the stimuli used in a four-dimensional problem. If the subject selects large as his hypothesis, he will continue to choose the stimulus array containing large, regardless of its color, form, or position. If the subject is told that the stimulus array that contains large is correct, he will continue to choose the array that contains large. If, however, he is told that the stimulus array containing his hypothesis is incorrect, he will abandon his hypothesis and choose a new one. The subject will continue to choose and abandon hypotheses as the result of feedback until he selects the one that always leads to feedback that confirms his hypothesis.



Each of the four cards in the center consists of two stimulus arrays, each containing one of the two cues of each of the four dimensions. The entire set of four cards constitutes a blank-trial (no feedback) probe. On either side are the eight patterns of right and left choices made to the stimulus arrays that correspond to the eight different hypotheses that can be manifest during a blank-trial probe.

Figure 1

The subject's hypothesis is inferred from a series of four, no feedback trials that constitute a blank-trial probe. A verbal statement is not required. Figure 1 presents the patterns of three responses to one side and one response to the other during the four-card, blank-trial probe for each of the eight simple hypotheses in a bi-valued four-dimensional problem.

Levine's (1969) data from adult subjects indicated that hypotheses appeared in 90% to 95% of the blank-trial probes, showing that the behavior of adults is strongly systematic. Positive and negative feedback are defined as "correct" and "wrong," respectively. When a subject received positive feedback he maintained his hypothesis about 95% of the time, but following negative feedback, he changed hypotheses about 98% of the time.

Using second-, fourth-, and sixth-grade children and college students, Gholson, Levine, and Phillips (1972) presented four-dimensional problems. The stimuli appeared on two adjacent screens. On feedback trials, after the subject pushed one of the two screens, a red light lit over the correct stimulus and remained lit, with the stimuli still in view, for three seconds. The subjects were pretrained to familiarize them with the stimuli and task requirements; they then received a series of six problems with feedback presented on every fifth trial. Hypotheses were manifested during 88.4, 89.3, 92.4, and 92.8 percent of the blank-trial probes for grades two, four, six, and adults, respectively. Subjects of all ages tended to retain their hypothesis when feedback was positive and to switch to another hypothesis when feedback was negative.

If a subject was behaving in a locally consistent manner

(Erickson, 1968), he would, following a trial on which he received negative feedback, resample from among the hypotheses consistent with the stimulus that was positive and manifest one of these during the next blank-trial probe. For grades two, four, six, and adults, the percentages of locally consistent hypotheses were 89.3, 87.9, 91.4, and 94.6, respectively. Age differences therefore did not result in large differences in local consistency.

Since hypothesis theory views the subject as actively processing information in an effort to achieve the solution, the hypothesis can be viewed as a prediction by the subjects about the behavior that will lead to solution. The fact that subjects manifested locally consistent hypotheses most of the time and yet the number of problems solved increased with age (i.e., 64.5% for second graders, 70.3% for fourth graders, 80.5% for sixth graders, and 96.2% for adults) led Gholson et al. (1972) to distinguish two distinct categories of hypothesis-sampling systems: stereotypes and strategies.

Just as an hypothesis is inferred from a sequence of responses during a blank-trial probe, the subject's hypothesis-sampling system is inferred from the sequence of hypotheses manifested. Stereotypes involve sequences of hypotheses that are insensitive to disconfirmation. Three different stereotype systems have been delineated. In the first, Stimulus Preference, the subject manifests an hypothesis corresponding to a stimulus cue, but the same hypothesis is manifested during each blank-trial probe (e.g., large) despite its disconfirmation. A subject using a Position Alternation system alternates left and right positions during each blank-trial probe, independent of confirmation or disconfirmation. Thus they generate left-right, left-right or right-left, right-left patterns that do not correspond to any hypothesis. A third stereotype, like the Position Alternation system, also involves a position-oriented response set. When a subject shows a Position Perserveration system, he responds on the basis of a single position (e.g., left-left-left-left) throughout a series of blank-trial probes, independent of feedback. Of the three stereotypes, stimulus preference is the only one from which an hypothesis can be inferred that corresponds to a stimulus cue. Position Alternation and Position Perserveration, although they involve stereotype systems of response, appear to be independent of the stimuli. Stereotypes are observed predominantly in very young children (i.e., kindergarteners); they also appear occasionally in older children, but never in adults. By the second grade the only stereotype that occurs with any frequency is stimulus preference. Stereotypes do not lead to solution since hypotheses are not responsive to feedback. The inclusion of stereotypes can help explain the age differences in percentages of problems solved.

Three different strategy systems have been delineated also. A strategy is defined as an hypothesis-sampling system which, if followed perfectly, leads eventually to solution. The most efficient strategy, equivalent to the maximally efficient constraint-seeking strategy which can be used in Twenty Questions, is termed Focusing. A subject manifesting the focusing strategy, presented with a four-dimensional problem (with orthogonal stimuli, see below), starts with all eight hypotheses, eliminates four at feedback one, two more at feedback two, and the final incorrect hypothesis at feedback three, leaving only the correct hypothesis. For the focusing subject each hypothesis will be consistent with the feedback information preceding it (local consistency) and with the feedback information on all previous feedback trials (global consistency, Gregg & Simon, 1967). "For this subject, hypothesis one will be consistent with the feedback information at feedback one; hypothesis two will be different from hypothesis one (given negative feedback at feedback two) and will be consistent with the information at both feedback one and feedback two; and hypothesis three will again be different (given negative feedback) and the correct hypothesis. When this pattern appears in the data, one infers a focusing system" (Gholson, et al., 1972, p. 436).

At the other extreme, and equivalent to hypothesis scanning, is the system called Hypothesis Checking. The assumption here is that a subject checks one hypothesis on a dimension, then its complement, and then goes on to do the same with another dimension, etc. It is further assumed that all hypotheses are sampled according to a local-consistency but not global consistency rule.

Between the two extremes lies the Dimension-Checking system. The subject employing dimension checking proceeds through the dimensions one at a time, but recognizes that if one value on a dimension is confirmed at any time, the other value cannot logically be correct and need never be tried. The subject manifests local consistency but not global consistency and goes through the dimensions one at a time, testing only one hypothesis per dimension.

Finally, subjects sometimes manifest unsystematic sequences of hypotheses. A problem is categorized as unsystematic when the sequence of hypotheses manifested is, at least at times, sensitive to feedback but does not follow any identifiable plan. The unsystematic category will be discussed further in the results section of this paper.

An analysis of the hypothesis-sampling systems employed by subjects was performed on the data in the Gholson et al. (1972) study. The results indicated that adults manifested about 45% focusing, 45% dimension checking, less than 10% hypothesis checking, and no stereotypes. Sixth graders showed about 13% focusing, 55% dimension checking, 15% hypothesis checking, and 17% stereotypes. Second and fourth graders showed less than 5% focusing, between 50% and 60% dimension checking, 15% hypothesis checking, and the remainder stereotypes.

A second experiment reported in the Gholson et al. (1972) paper attempted to differentiate the behavior of kindergarten children from second graders. Results indicated that while second graders manifested consistent hypothesis patterns on 80% of the blank-trial probes, the kindergarten children generated only 42% consistent hypotheses, which was significantly below chance expectation (50%). Examining the hypothesis-sampling systems analysis, the percentage of strategies and stereotypes varies from study to study, depending upon factors such as age and laboratory manipulation (Gholson & Danziger, in press; Gholson & McConville, 1974; Gholson, Phillips, & Levine, 1973), but, in general, the analysis of hypothesis-sampling systems has proved to be a useful way of looking at developmental changes in information-processing performance.

The present study represents an attempt to assess the effects of modeling on the information-processing strategies used by elementary-school children in solving problems of the type used by Levine and Gholson. Children rarely use the focusing strategy but manifest dimension checking on approximately 50% of the problems presented. Elementary-school children do not differ significantly among themselves in the type and percentages of strategies employed (Gholson et al., 1972). In the present study focusing was modeled for second and sixth graders to test the assumption that this sophisticated information-processing strategy could be elicited from elementary-school children. Dimension checking was modeled for both the second- and sixth-grade children in order to see whether modeling would increase the amount of that strategy and also to see if and how the hypothesis-sampling system distributions would be differentially effected by exposure to the modal nonmodeling strategy.

In addition, the interaction of tape-exposure condition and age was investigated with respect to the "precurser processes." Precursers are those processes essential to the generation of any strategy, e.g., manifestation of an hypothesis, sensitivity to positive and negative feedback, and local consistency. If, as expected, children of different ages responded differently to the two modeling conditions, the precurser processes might also be differentially effected.

Finally, groups of both second and sixth graders were exposed to a minimal-information "control" tape on which there was no verbal rule provision to determine if rule provision was the critical variable in eliciting focusing and/or increasing the percentage of dimension checking.

Method

Subjects

The subjects were 72 second-grade ($\bar{X}$ age = 7.8) and 72 sixth-grade ($\bar{X}$ age = 11.9) children. Approximately two thirds of the subjects in each age group were students in New York City Public Schools. The remaining children were from the Ramapoe Country Day Camp in New Jersey. The children were predominantly middle class and all were fluent in the English language. There were 24 subjects (12 boys and 12 girls) assigned to each of the three tape-exposure conditions at each grade level. Subjects were randomly assigned to the focusing, dimension-checking, and minimal-information, control-tape exposure conditions. There were no significant age differences among the subjects in the three tape-exposure conditions at either grade level.

Stimulus Materials and Equipment

Each subject was individually presented with a series of simultaneous discrimination-learning problems, as illustrated in Figure 1. Stimuli in each problem consisted of two cues on each of four dimensions: alphabet letter (e.g., X vs. T), color (e.g., red vs. green), size (large vs. small), and line position (line on the top vs. line on the bottom of the letter). The line positions and sizes remained the same from problem to problem while the letter combinations and color combinations changed on each problem. The specific colors and letters used for the pretraining, modeling, and experimental problems are listed in the first two columns of Table 1.

The stimuli for each problem were presented on white 5-in. by 8-in. cards held together on one side by three rings. Except for a

Table 1

Summary of Colors, Alphabetic Letters, and Feedback Sequences Used in All Problems Presented to Subjects

Color	Alphabetic Letters	Feedback Sequences
		Pretraining
pink & brown	H & Z	feedback in terms of predetermined solution: large for ½ subjects, small for other ½
orange & green	K & G	feedback in terms of predetermined solution: orange for ½ subjects, green for other ½
green & purple	U & E	feedback in terms of predetermined solution: U for ½ subjects, E for other ½
brown & blue	P & L	feedback in terms of predetermined solution: line up for ½ subjects, line down for other ½
		Modeling
black & white	G & Z	+,-,-: Solution: G
black & white	V & N	-,-,-: Solution: line on the top
black & white	S & K	-,+,-: Solution: white
black & white	X & H	+,-,-: Solution: small
		Testing
blue & green	S & X	+,+,-
purple & pink	P & V	-,+,-
red & green	T & X	+,-,-
tourquoise & brown	N & L	+,+,-
red & tourquoise	T & V	+,-,-
green & orange	S & J	+,-,-
purple & orange	R & J	-,-,-

Note: + indicates that whichever stimulus array the subject chose, he was told, "Correct."
- indicates that whichever stimulus array the subject chose, he was told, "Wrong."

half-in. border on the left for the rings, the stimuli were centered on each half of the card and a line was drawn down the middle. The small letters were 3/4 in. high and the large letters were 1-1/2 in. high. The line above or below the letter was centered 3/8 in. above or below the letter.

The subjects were pretrained (see Pretraining), then exposed to one of three ten-minute, black-and-white videotapes which modeled either focusing or dimension checking with rule provision or the minimal-information control tape (see Modeling Procedure, below). After exposure to the modeling, each subject was presented with seven different experimental problems. Each problem contained eight feedback trials and seven blank-trial probes.

Pretraining

The subjects were pretrained to familiarize them with the stimuli and the task requirements (i.e., continuing to respond during blank-trial probes and the idea that the solution was always a single cue from a single dimension).

Each child was tested individually. The experimenter, sitting across a table from the child, presented the first pretraining stimulus card and said:

> I would like you to help me with some puzzles that I have here. What will happen is that you will see pictures like these. As you can see, there are two pictures. This picture (pointing) is small and this one is large. This picture is pink and this one is brown; this picture has a line on the bottom and this one has a line on the top. This picture has an H and this one has a Z.

The order in which the dimensions were described was varied from subject to subject, but the cues were always described dimensionally, i.e., either large, then small; or small, then large.

> One of the two pictures contains the correct answer; the other picture is wrong. I want you to choose one of the two pictures by pointing at it. If you choose the picture that contains the correct answer, I'll tell you "yes." If you choose the picture that doesn't contain the correct answer, I'll tell you "no" and point to the picture with the correct answer. I'd like you to try to be correct as often as you can. When you figure it out, you can always choose the picture that contains the correct answer. Okay, let's try this first puzzle just to get the idea. Remember, the answer could be line on the top or line on the bottom or Z or H or brown or pink or large or small. The answer is always a simple one. It's always just one of those things. Your job is to figure out which of those things is the answer and then to always choose the picture that contains the correct answer. You choose one picture to start with.

Blank trials were introduced during the third pretraining problem. The first and second contained only 16 feedback trials each. When blank trials were introduced, during the third pretraining problem, the subject was told:

> This time something will be different. From now on I won't always tell you what the correct picture is. Sometimes I'll tell you which picture is correct and sometimes I won't, but I know because I have it on my sheet, so you always try to be correct, even when I don't tell you which picture contains the correct answer. So you choose one picture to start with.

The third pretraining problem also contained 16 feedback trials with eight blank trials interspersed in sets of two among the feedback trials (after feedback trials 3, 6, 9, and 12). The fourth pretraining problem contained seven feedback trials with 24 blank trials interspersed in sets of four. The solution to each pretraining problem was randomly selected from a different dimension.

After the child completed each pretraining problem, he was asked to verbalize the solution. If he did not do so, the problem was presented again, following a hint, e.g., "This time why don't you see if the answer is either large or small." If he did not solve during the second presentation, the next problem was presented. Any child who did not solve at least two of the four pretraining problems by the second presentation was dropped from the study. Solution was determined by correct verbalization. No sixth graders but three second graders were dropped after pretraining because of failure to meet the criterion.

Experimental Problems

The stimuli for the modeling and experimental problems were arranged in an internally orthogonal manner (Levine, 1966). That is, each cue of each of the four dimensions was exactly counterbalanced with each cue of every other dimension. There are eight ways the two cues on each of the four dimensions can be combined without repetition; these were divided in two sets of four stimulus cards, each of which contained two stimulus arrays consisting of opposing pairs from each of the four dimensions. One set of four stimulus cards was used to construct the blank-trial probes. A blank-trial probe consists of four, no feedback stimulus cards. These were constructed so that each of the eight hypotheses yielded a pattern of three responses to one side (e.g., the left) and one response to the other side (e.g., the right). The patterns of right and left choices resulting in the eight hypotheses for a sample blank-trial probe can be seen in Figure 1. The other set of stimulus pairs was used for feedback trials. These were randomly ordered under the restriction that any series of three consecutive feedback trials logically defined the solution.

Modeling Procedure

After the child completed the pretraining problems, he was told:

> Now we're going to look at a movie. The child in the movie learns how to solve the puzzles very well. You watch and listen carefully because after the movie is over you will get another chance to do some more puzzles. I want to see if you can do them the same way that the child does. If you do, you can always be correct once you've figured out the answer. The child in the movie does very well and if you pay careful attention and always try to be correct, you can do just as well. Okay, let's watch the movie together. Remember, pay very careful attention so you can learn the way to solve the puzzles and you can do as well as the child in the movie.

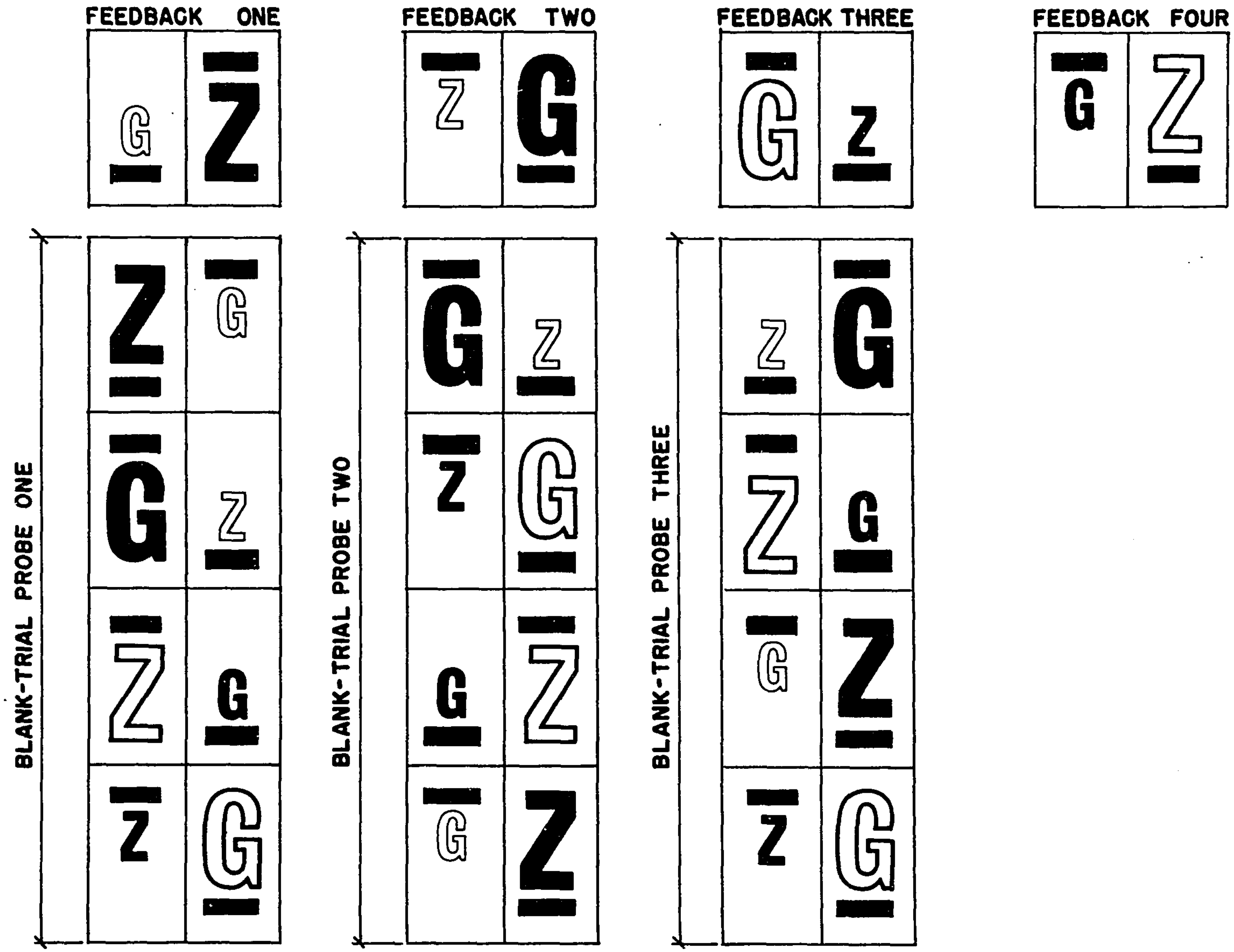
The child and the experimenter watched a ten-minute, black-and-white videotape presented on a nine-in. television screen (measured diagonally). The child sat about two feet away from the screen. Four problems, each illustrating a solution from a different dimension, were presented to an unseen subject (a 15-year-old girl). The stimulus cards and the experimenter's and subject's hands were all that were visible on the screen. On the modeling tapes the colors were always black and white; the alphabetic letter pairs were different from both the pretraining and experimental sets; the sizes and line positions maintained the same proportions as in the pretraining and testing problems. One group of subjects at each age level viewed a tape on which the problems were solved by a model verbalizing the use of the focusing strategy. A second group of subjects at each age level saw the same videotape but the soundtrack provided the means for solution using the dimension-checking strategy. The third (control) group of subjects was shown the same videotape but with a third soundtrack. This audio track provided the same introduction, hypothesis selection by the subject, the solution hypothesis, and the same predetermined feedback sequences but did not verbally present any strategy for solution.

Description of Strategies

Figure 2 presents one complete problem as it was presented on videotape to subjects. The script that follows includes both the subject's and the experimenter's responses. The problem was solved by focusing and exemplifies the strategy used in solving any problem using the focusing strategy, i.e., remembering all four cues that were correct in the first stimulus array, the two that were correct in the first and second stimulus arrays, and elimination of one of those two on the third feedback, leaving only the solution hypothesis to be manifested during the third blank-trial probe.

Card One: S: pointing to small, white, G, line down.
E: (Feedback one): Yes, the answer is in that picture.
S: Then the answer could be small or G or white or line on the bottom. It could be any of the four choices, so I have to remember all of them. I'll keep remembering that the answer could be G or white or line on the bottom or small, but I'll just try one.
Cards 2,3,4,5 (blank-trial probe one): S: I'll try small.
Card 6 (Feedback two): S: Pointing to small, white, Z, line up.
E: No, the answer is in this picture (pointing to large, black, G, line down).
S: That means that the answer must be either G or line on the bottom. I'm narrowing down the answer and only G and line on the bottom are both in the pictures you told me were correct. So I'll remember G and line on the bottom but I'll try just one.
Cards 7,8,9,10 (blank-trial probe two): S: I'll keep trying line on the bottom until you tell me which picture is correct.
Card 11 (Feedback three): S: Points to small, black, Z, line down.

Figure 2



STIMULI FOR ONE MODELING PROBLEM INCLUDING FEEDBACK TRIALS AND BLANK-TRIAL PROBES

E: No, the answer is in this picture (pointing to large, white, G, line up).
S: Then the answer must be G, since I had only two choices left, G or line on the bottom, and it isn't line on the bottom. I'll just make sure.
Cards 12, 13, 14, 15 (blank-trial probe three): S chooses G on each card.
Card 16 (Feedback four): S: points to small, black, G, line up.
E: Yes, the answer is in that picture (pointing), and it's G. You did very well.

The same visual stimuli and feedback sequences were used to model dimension checking. When a subject manifests dimension checking, he goes through the dimensions one at a time, checking only one cue on each dimension and logically eliminating the other cue.

Card one: S: pointing to small, white, G, line down.
E: Yes, the answer is in that picture.
S: Well, if I want to try one of the sizes, large or small, to see if one of them is the right answer, I'll have to try small because that's in the correct picture. So, to check out the sizes, I'll try small.
Cards 2, 3, 4, 5 (blank-trial probe one): S silently chooses small on each.
Card 6 (Feedback two): S: points to the small, white, Z, line up.
E: No, the answer is in this picture (pointing to large, black, G, line down).
S: That eliminates the sizes. So I'll have to try something else. The correct answer might be the position of the line. The correct picture has the line on the bottom, so I'll try that. I'll keep trying line on the bottom until you tell me which picture is correct.
Cards 7, 8, 9, 10 (blank-trial probe two): S silently chooses line down on each.
Card 11 (Feedback three): S points to the small, black, Z, line down.
E: No, the answer is in this picture (pointing to the large, white, G, line up).
S: That means the answer isn't the position of the line, so I'll check the letters. If it's one of the letters, it has to be G, because that's in the correct picture, so I'll try G.
Cards 12, 13, 14, 15 (blank-trial probe three): S chooses G.

E: Yes, the answer is in that picture (pointing), and it's G. You did very well.

The control tape used the same visual stimuli and the same feedback sequences, and the subject stated hypotheses but no verbal explanation for choices was given by either the subject or the experimenter. Therefore, no strategy was verbally modeled.

Preprogramming

Since a strategy can be inferred only in problems in which the subject receives negative feedback at feedback trial three, feedback was "preprogrammed" during the modeling and experimental problems to maximize efficiency in data collection. The strategy the subject manifests is inferred from his choice responses on each of the first three feedback trials and the hypothesis following each.

A different feedback pattern was used on each of the four modeling problems and may be seen in column three of Table 1. Positive feedback is represented as + and negative feedback as -.

Experimental Procedure

After the child viewed the videotape, he was told, "I'll bet you can do the puzzles the same way that the child in the movie did. Now it's your turn to do some more puzzles."

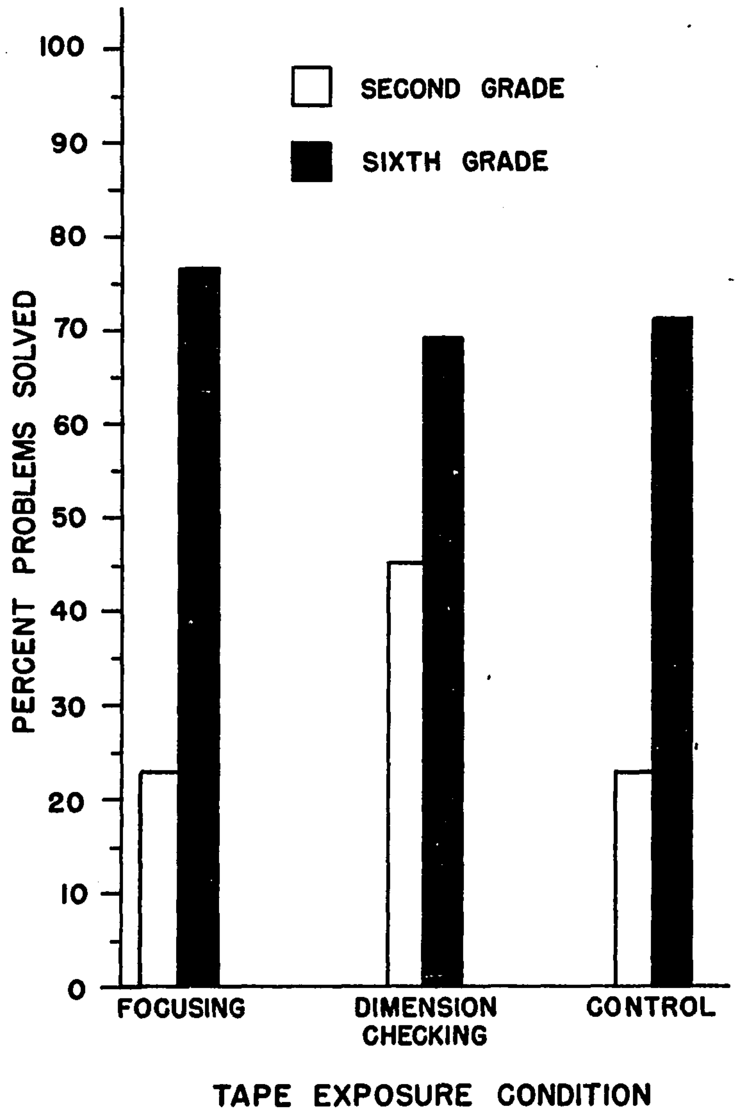
Each subject was then presented with seven experimental problems. Problem order was randomized independently for each subject. Each problem contained eight feedback trials with seven blank-trial probes interspersed. The solution was logically defined by the subject's choices and the preprogrammed feedback sequence on the first three feedback trials. From feedback three on, the subject was given feedback in terms of the logically defined solution. After testing, the child was praised, thanked, asked not to tell the other children what the game was about, and returned to the classroom or activity.

Results

Seven dependent measures were statistically analyzed: the percentages of problems solved, the percentages of hypotheses manifested during probes, the percentages of confirmed hypotheses that were maintained, the percentages of disconfirmed hypotheses that were maintained, the percentages of locally consistent sampling, the percentages of problems categorizeable as systems, and the distribution of problems in the various hypothesis-sampling system categories. The first six measures were analyzed by a fixed, three-way analysis of variance performed on percentages normalized by arcsin transformations (Guilford, 1954). Tests of independence were performed upon the relative frequencies of occurrence of problems in the various hypothesis-sampling system categories (i.e., strategies, stereotypes, and unsystematic hypothesis sequences). The analysis of variance summary tables may be found in Appendix B. Results are reported as significant if the probability of a type I error is .05 or less. Where significant differences in the analyses of variance were found, *post hoc* comparisons, following the S-method suggested by Scheffé (Edwards, 1969) were made and reported at the .95 confidence level.

The Percentage of Solution

The solution criterion adopted was a correct response on feedback trials five, six, seven, and eight and manifestation of the correct hypothesis during blank-trial probes five, six, and seven. The main effect for age was significant, $F(1,132) = 90.93$, as was the age by tape interaction, $F(2,132) = 5.23$. The sixth graders solved a mean of 72.56% of the problems presented while the second graders solved only 30.34%. Figure 3 shows the percentages of problems solved for second- and sixth-grade children after exposure to each of the modeling tapes. Scheffé tests showed that the sixth graders solved significantly more problems than did the second graders after exposure to each of the tapes. There were no significant differences in the percentages of problems solved by the sixth graders as a result of tape exposure condition. The second-grade subjects exposed to the dimension-checking tape solved significantly more problems than did the second graders exposed to either the focusing or control tapes. Second graders exposed to the dimension-checking tape solved 45.14% of the problems presented, while second graders exposed to the focusing and control tapes solved 23.16% and 22.72%, respectively. These last two percentages did not differ significantly.



THE PERCENTAGE OF PROBLEMS SOLVED AFTER EXPOSURE TO EACH TAPE

Figure 3

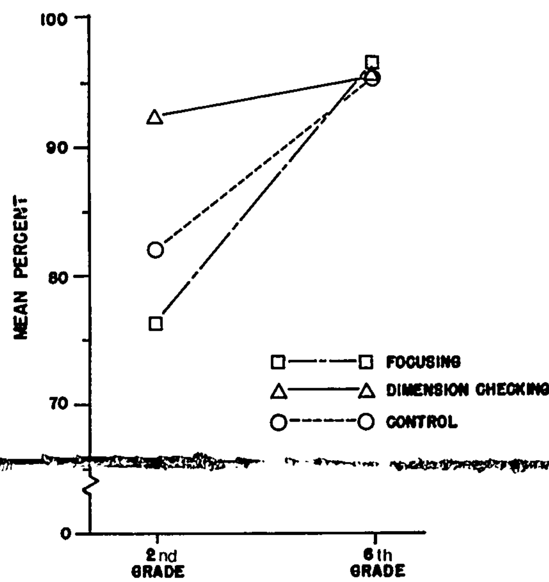
Information-Processing Data

Blank-Trial Data

In order to infer which, if any, hypothesis was held, it was necessary for the child to choose the stimulus array that contained that cue on each of the four stimulus cards that constituted a blank-trial probe (see Figure 1). Sixth graders manifested a mean of 96.17% hypotheses during blank-trial probes, while second graders manifested a mean of 83.63%.

Significant main effects were found for tape, $\underline{F}(2,132) = 3.61$, and age, $\underline{F}(1,132) = 44.98$, and significant interactions were found for tape by age, $\underline{F}(2,132) = 4.19$, and tape by age by sex, $\underline{F}(2,132) = 3.32$.

Figure 4 presents the percentages of hypotheses manifested by second- and sixth-grade children after exposure to each of the modeling tapes. Scheffé tests indicated that there were no differences among sixth graders as a result of tape-exposure condition. Second graders manifested significantly fewer hypotheses than sixth graders after exposure to the focusing and control tapes but they did not differ from the sixth graders after exposure to the dimension-checking tape. Those second grade children exposed to the dimension-checking tape produced significantly more hypotheses (92.47%) than did those exposed to the focusing tape (76.34%). The percentage of hypotheses manifested by second graders exposed to the control tape (82.23%) fell between those exposed to the focusing and dimension-checking tapes, but did not differ significantly from either.



THE PERCENTAGE OF HYPOTHESES MANIFESTED BY SECOND-AND SIXTH-GRADE SUBJECTS AFTER EXPOSURE TO EACH TAPE

Figure 4

Scheffé tests showed that the significant tape by age by sex interaction was attributable to the higher percentage of hypotheses manifested by the sixth-grade males exposed to the focusing tape ($\overline{X}$ = 97.52%) and the sixth-grade females exposed to all three tapes ($\overline{X}$ = 96.88%), as compared with the second-grade males ($\overline{X}$ = 71.40%) exposed to the focusing tape (Table 2).

Effects of Feedback

Three measures of the effect of feedback were analyzed: (1) the percentage of blank-trial probes in which a confirmed hypothesis was maintained, (2) the percentage of probes in which a disconfirmed hypothesis was maintained, and (3) the percentage of locally consistent sampling (i.e., after negative feedback, the next hypothesis was chosen from the positive stimulus array).

In general, in response to confirmation or disconfirmation of their hypotheses, sixth graders were highly sensitive to feedback, maintaining confirmed hypotheses 95% of the time, and changing disconfirmed hypotheses 99% of the time. They also resampled in a locally consistent manner, following negative feedback, approximately 97% of the time. Tape exposure condition did not effect these measures. The mean percentages of blank-trial probes on which second and sixth graders maintained confirmed and disconfirmed hypotheses and manifested locally consistent hypotheses may be seen in Table 3.

Second graders maintained confirmed hypotheses slightly but not significantly less frequently than did sixth graders after exposure to the dimension-checking tape (93% vs. 96%) and control tape (79% vs. 96%). They rejected a disconfirmed hypothesis 95% of

Table 2

Mean Percentages of Hypothesis Manifested by Second- and Sixth-Grade Males and Females After Exposure to the Focusing, Dimension-Checking, and Control Tapes

Tape Exposure Condition	Grade Level			
	2nd		6th	
	Males	Females	Males	Females
Focusing	71.40	81.27	97.52	95.57
Dimension Checking	90.48	94.45	94.21	97.86
Control	88.62	75.84	94.65	97.21

Table 3

Mean Percentage of Blank Trial Probes on Which Second and Sixth Graders Maintained Confirmed and Disconfirmed Hypotheses, and Locally Consistent Sampling After Exposure to Each Modeling Tape

	Tape Exposure Condition			
	2nd Grade		6th Grade	
Percent Maintained Confirmed Hypotheses	Focusing	70	Focusing	93
	Dimension Checking	93	Dimension Checking	96
	Control	79	Control	96
Percent Maintained Disconfirmed Hypotheses	Focusing	13	Focusing	01
	Dimension Checking	04	Dimension Checking	02
	Control	06	Control	01
Percent Locally Consistent Hypotheses	Focusing	72	Focusing	97
	Dimension Checking	89	Dimension Checking	97
	Control	94	Control	96

the time following exposure to the dimension checking and control tapes. They were locally consistent during 92% of the following blank-trial probes after exposure to the dimension-checking and control tapes. However, performance on all three measures declined significantly for second graders after exposure to the focusing tape.

When a subject received positive feedback after he had manifested an hypothesis, it seems reasonable for him to have maintained that hypothesis. Strictly speaking, however, it was not the hypothesis that was confirmed but the stimulus array that contained the hypothesis, i.e., the subject was told, "Yes, the answer is in that picture." It is, therefore, not surprising that subjects sometimes selected one of the other three cues in the positive stimulus array (Levine, 1969).

An analysis of variance performed on the percentage of maintained confirmed hypotheses showed significant main effects for tape, $\underline{F}(2,132) = 5.84$, and age, $\underline{F}(1,132) = 26.84$. The tape by sex interaction, $\underline{F}(2,132) = 4.10$, and the tape by age by sex interaction, $\underline{F}(2,132) = 5.52$, were also significant.

Table 4 shows the mean percentage of blank-trial probes on which second- and sixth-grade males and females maintained an hypothesis during two consecutive blank-trial probes when the intervening feedback was positive.

There were no significant differences among the sixth graders as a result of tape-exposure condition, age, or sex. The second-grade males and females exposed to the dimension-checking tape performed as well as the sixth graders in all three conditions. The sixth-grade males and females exposed to the focusing tape maintained a

Table 4

Mean Percentage of Blank-Trial Probes on Which Second- and Sixth-Grade Males and Females Maintained a Confirmed Hypothesis

Tape Exposure Condition	Grade Level			
	2nd		6th	
	Males	Females	Males	Females
Focusing	58.49	82.14	95.70	91.67
Dimension Checking	93.88	92.92	94.69	98.91
Control	91.03	67.04	96.36	96.42

confirmed hypothesis significantly more often than did the second-grade females. These differences did not follow an interpretable pattern and are tentatively attributed to sampling variation. However, if the means are taken of the male and female second graders exposed to the focusing ($\bar{X}$ = 70.31%) and control ($\bar{X}$ = 79.03%) tapes, it again appears that the second graders exposed to the dimension-checking tape ($\bar{X}$ = 93.40%) performed as well as the sixth graders, while second graders exposed to the control tape performed at an intermediate level. The age by tape interaction did not, however, prove significant.

An analysis of variance performed on percentages of maintained disconfirmed hypotheses indicated that sixth graders were significantly less likely ($\bar{X}$ = 1.45%) than second graders ($\bar{X}$ = 8.12%) to maintain a disconfirmed hypothesis, $\underline{F}(1,132) = 9.88$. The tape by sex interaction, $\underline{F}(2,132) = 3.64$, was also significant.

Table 5 shows the percentages of hypotheses maintained after disconfirmation for males and females at each grade level after exposure to each modeling tape. Scheffé tests reveal that the only significant comparison was that males exposed to the focusing tape were significantly more likely to maintain a disconfirmed hypothesis than were the males exposed to the control tape. Neither the main effect for tapes nor the tape by age interaction proved significant.

An analysis of variance performed on the local consistency data indicated significant effects for tape $\underline{F}(2,132) = 3.24$, age, $\underline{F}(1,132) = 36.08$, and the tape by age interaction, $\underline{F}(2,312) = 5.24$. The sixth graders performed equally well after exposure to each of

Table 5

Mean Percentage of Hypotheses Maintained Following Disconfirmation for Males and Females of Each Grade Level After Exposure to Each Modeling Tape

Tape Exposure Condition	Sex			
	Males		Females	
	2nd	6th	2nd	6th
Focusing	19.62	2.83	7.15	0.00
Dimension Checking	6.22	1.80	2.28	2.24
Control	21.51	0.00	11.94	1.83

the three modeling tapes ($\overline{X}$ = 96.84%) and the second graders performed as well as the sixth graders after exposure to the dimension-checking ($\overline{X}$ = 89.70%) and control tapes ($\overline{X}$ = 94.27%). Only those second graders exposed to the focusing tape ($\overline{X}$ = 76.15%) showed significantly poorer performance than the other groups.

The Systems Analysis

According to the hypothesis theory conception adopted here, subjects are seen as processing or attempting to process information according to some plan or hypothesis-sampling system which determines the order or sequence in which hypotheses are manifested. Two distinct types of systems have been delineated (see Introduction): stereotypes and strategies. There are three categories of stereotypes, all of which involve sequences of hypotheses that are insensitive to feedback: stimulus preference, position perseveration, and position alternation.

A strategy is an information-processing plan or system by which a subject attempts to arrive at the solution, using the stimulus information received on each feedback trial to direct his series of hypotheses. If ordered in terms of the amount of memory and logical inference required, the strategies from most to least sophisticated are: focusing, dimension checking, and hypothesis checking.

Not all of the data may be included in the analysis of hypothesis-sampling systems. In order for an hypothesis-sampling system to be inferred, the subject must be consistent in his plan of action. For example, if a stimulus preference system is to be inferred, the subject must manifest the same hypothesis (e.g., large) during each of the first three blank-trial probes and on the first three feedback trials. In order for a strategy to be inferred, the subject must minimally: (a) manifest an hypothesis during each of the first three blank-trial probes of the problem; (b) choose the stimulus array consistent with his hypothesis at each feedback trial; (c) maintain his hypothesis when it is confirmed and change it when it is disconfirmed; and (d) choose his next hypothesis from the positive stimulus array after negative feedback, i.e., show locally consistent sampling. Deviations, which may be the result of loss of attention or memory, may result in an uncategorizeable problem. The percentage of categorizeable problems for second and sixth graders after exposure to the focusing, dimension-checking, and control tapes may be seen in Table 6. The mean percentage of categorizeable problems for second- and sixth-grade children were 56.65 and 79.98, respectively. An analysis of variance performed on these data indicated significant effects for tape, $\underline{F}(2,138) = 7.53$, age, $\underline{F}(1,138) = 37.32$, and the tape by age interaction, $\underline{F}(2,138) = 7.57$. Scheffé tests indicated that the percentage of categorizeable problems did not differ significantly among the sixth graders as a function of tape exposure. Tape-exposure condition did, however, produce significant differences among the second graders: these children produced significantly fewer categorizeable problems following exposure to the focusing tape than following exposure to either the dimension-checking or control tapes. The later conditions did not differ significantly from each other. After exposure to each modeling tape, the sixth

Table 6

Mean Percentage of Categorizeable Problems for Second and Sixth Graders After Exposure to Each Tape

Grade	Tape Exposure Condition		
	Focusing	Dimension Checking	Control
2nd	43.16	73.47	53.33
6th	78.19	83.73	78.04

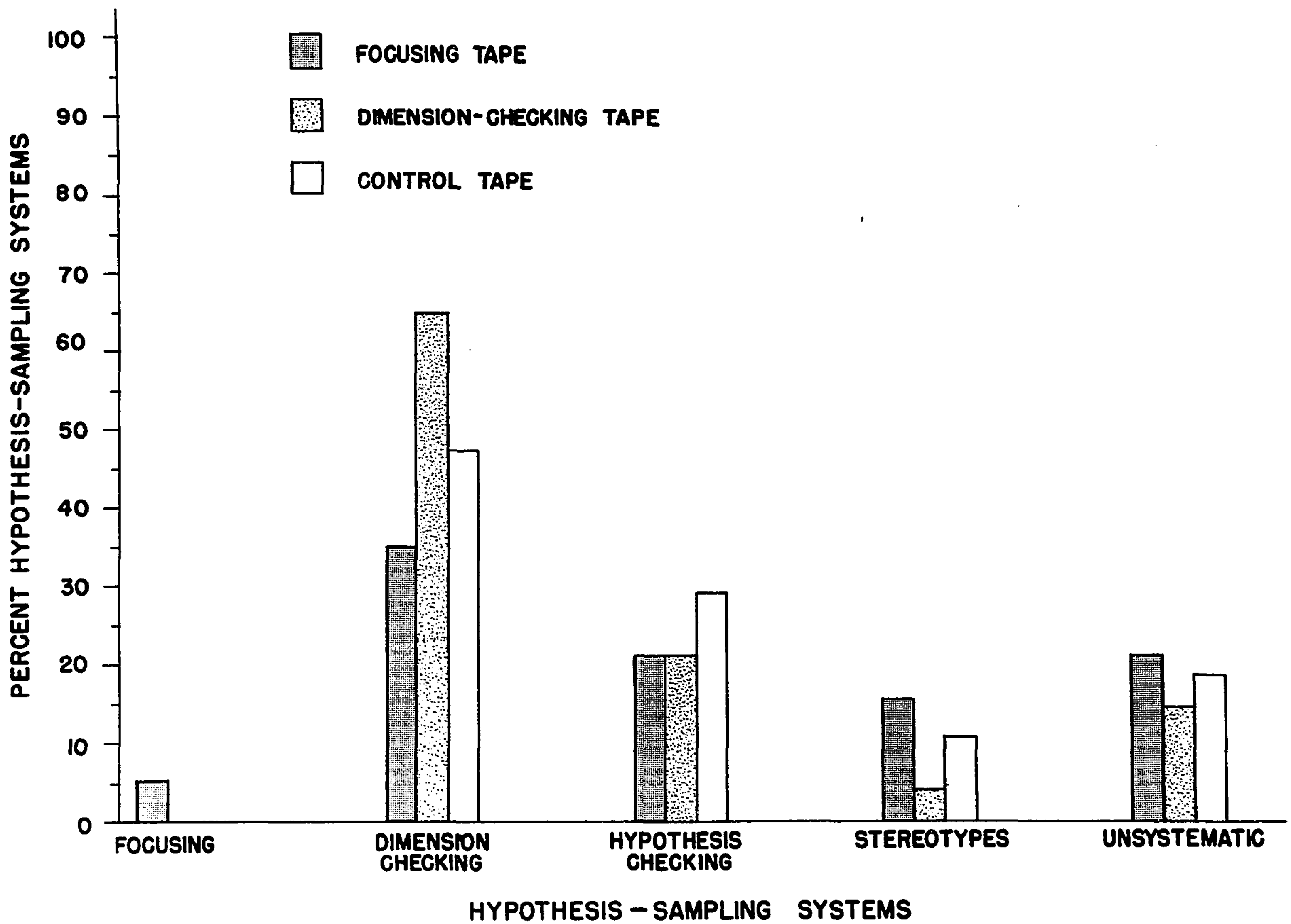
graders generated significantly more categorizeable problems than did the second graders.

Figure 5 presents the relative frequency of occurrence of each hypothesis-sampling system (focusing, dimension checking, hypothesis checking, stereotypes, and unsystematic sequences of hypotheses) among second graders after exposure to each of the modeling tapes. Second graders never manifested focusing after exposure to the dimension checking or control tapes and manifested it in less than six percent of the problems presented following exposure to the focusing tape. It is apparent from Figure 5 that second graders in all three conditions manifest more dimension checking than any other hypothesis-sampling system.

A more detailed account of how each hypothesis-sampling system pattern is derived and the appropriate statistical corrections are presented in Appendix C.

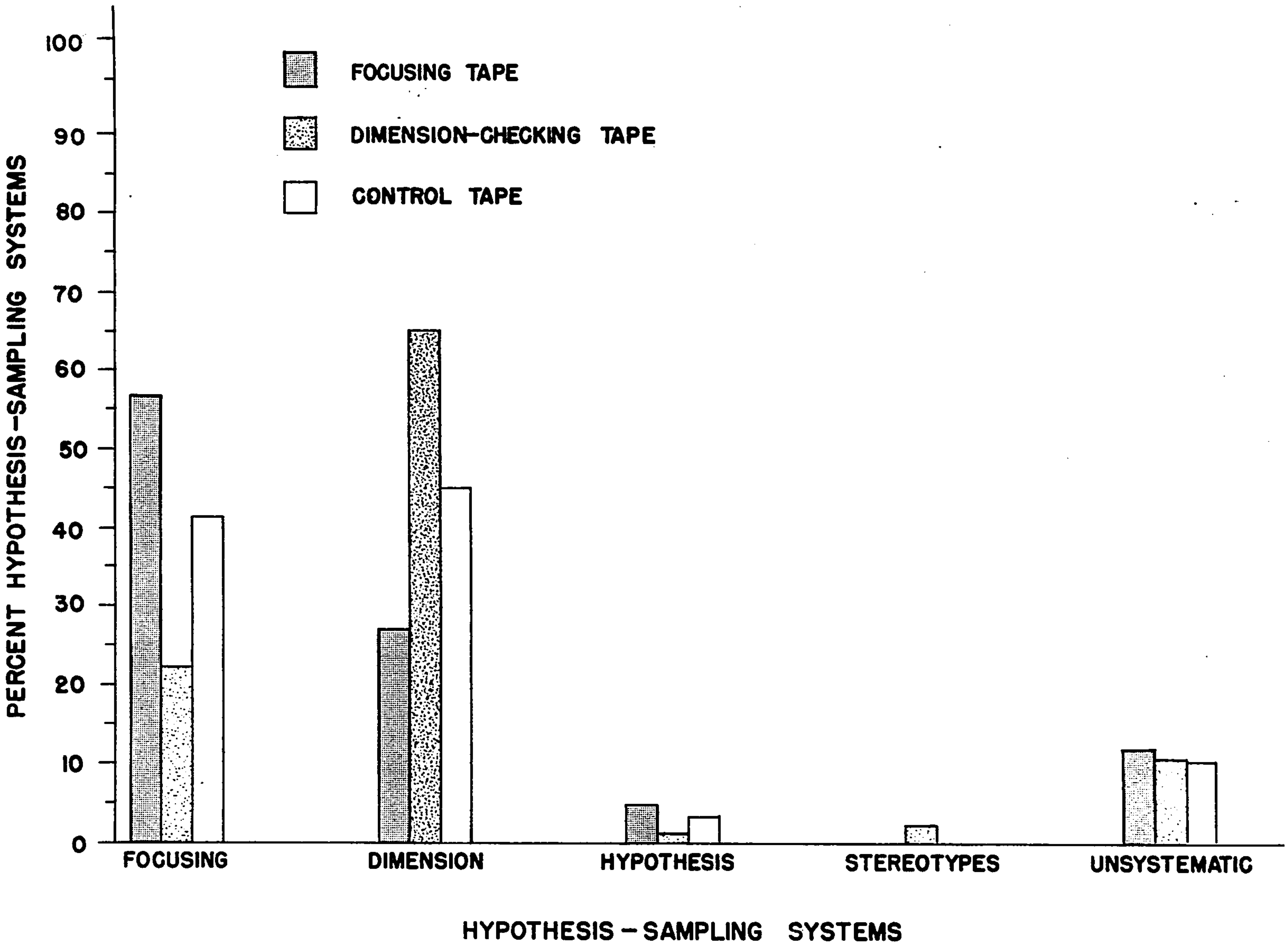
Figure 6 presents the relative frequency of occurrence of each hypothesis-sampling system among sixth graders after exposure to each of the modeling tapes. As may be seen, focusing occurs under all experimental conditions, but maximally after exposure to the focusing tape. Dimension checking is the modal strategy after exposure to the dimension-checking tape. Exposure to the control tape resulted in approximately equal percentages of focusing and dimension checking. Few hypothesis-checking and stereotype patterns were found among sixth graders but exposure to all three tapes resulted in approximately equal percentages of unsystematic patterns.

Figure 5



PERCENTAGE OF HYPOTHESIS-SAMPLING SYSTEMS AMONG SECOND GRADERS AFTER EXPOSURE TO EACH OF THE MODELING TAPES

Figure 6



PERCENTAGE OF HYPOTHESIS-SAMPLING SYSTEMS AMONG SIXTH GRADERS AFTER EXPOSURE TO EACH OF THE MODELING TAPES

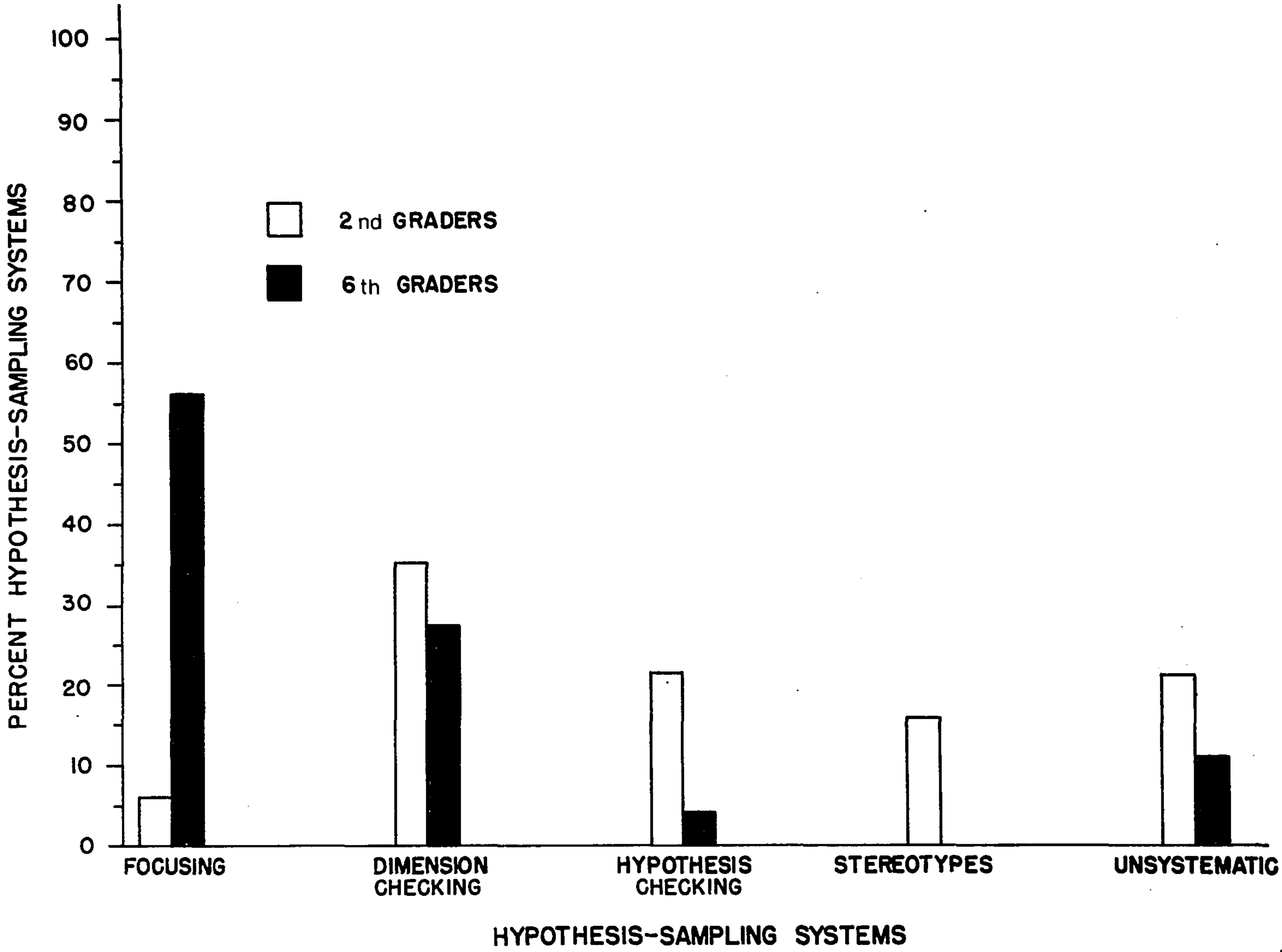
Figures 7, 8, and 9 present, for comparison, the distributions of hypothesis-sampling systems for second and sixth graders after exposure to each of the modeling tapes. As can be seen in Figure 7, the sixth-grade children show a high percentage of focusing, while the second graders manifest very little. As a consequence of this difference, the second graders show greater percentages of every other hypothesis-sampling system than do sixth graders. A test of independence applied to these two distributions indicated that they were significantly different ($\chi^2(4) = 66.66$, $\underline{p} < .05$).[2]

Figure 8 presents the distribution of systems for second and sixth graders after exposure to the dimension-checking tape. Of primary interest here is the finding that the percentages of dimension checking manifested by second and sixth-grade children are almost identical. When second graders did not manifest dimension checking, they usually manifested either hypothesis checking or unsystematic patterns, while the sixth graders manifested focusing or unsystematic patterns. The two distributions, reflecting the later finding, differed significantly ($\chi^2(4) = 55.64$, $p < .05$).

The relative frequency of each system following exposure to the control tape may be seen in Figure 9. Both second- and sixth-grade children most frequently manifested dimension checking after exposure to the control tape. The sixth graders also manifested 40% focusing, however, while the second graders manifested no focusing

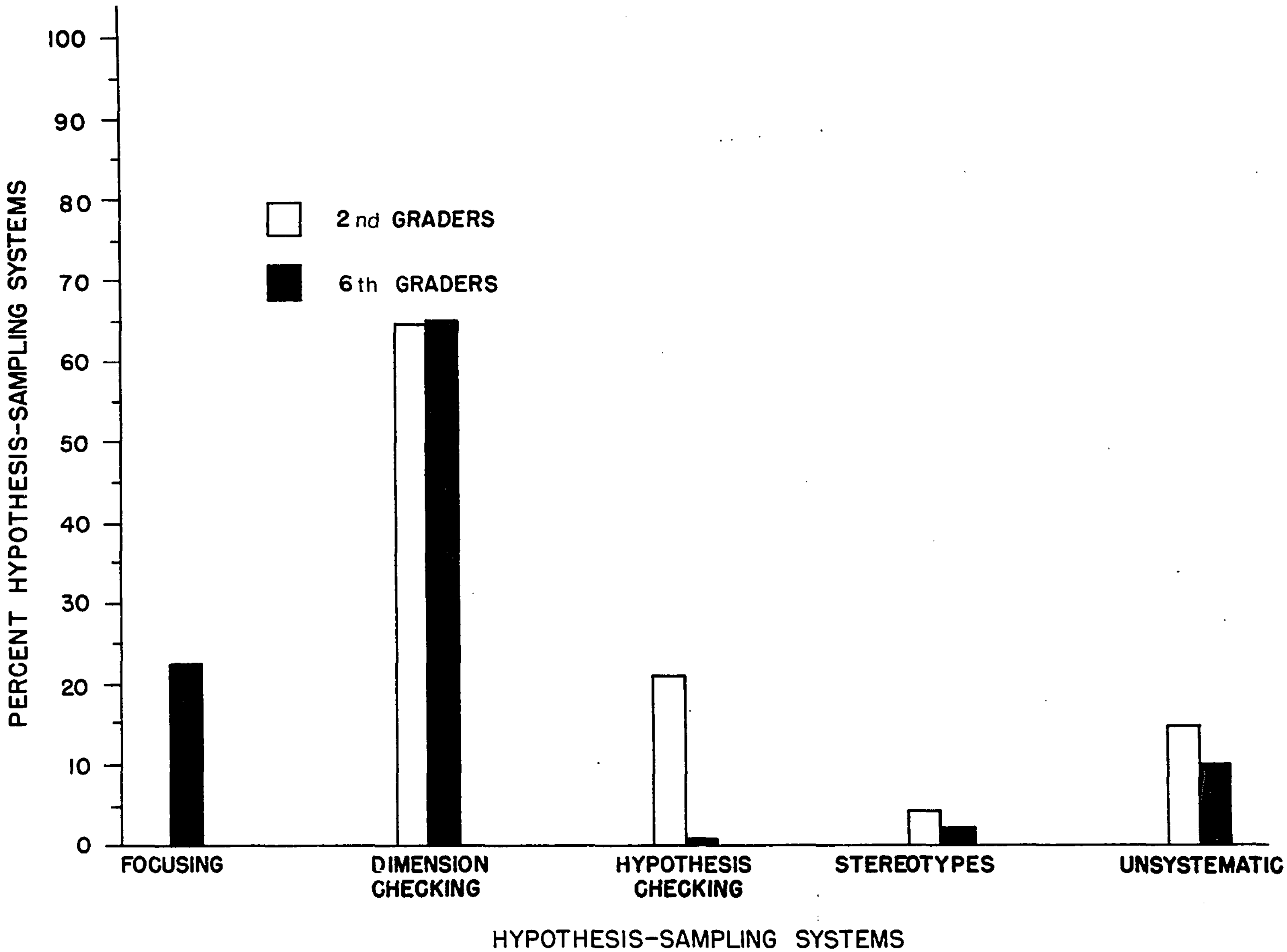
[2] Although Chi square is not a totally appropriate statistic since the frequencies of each hypothesis-sampling system are not independent, it has been used traditionally and accepted by journals.

Figure 7



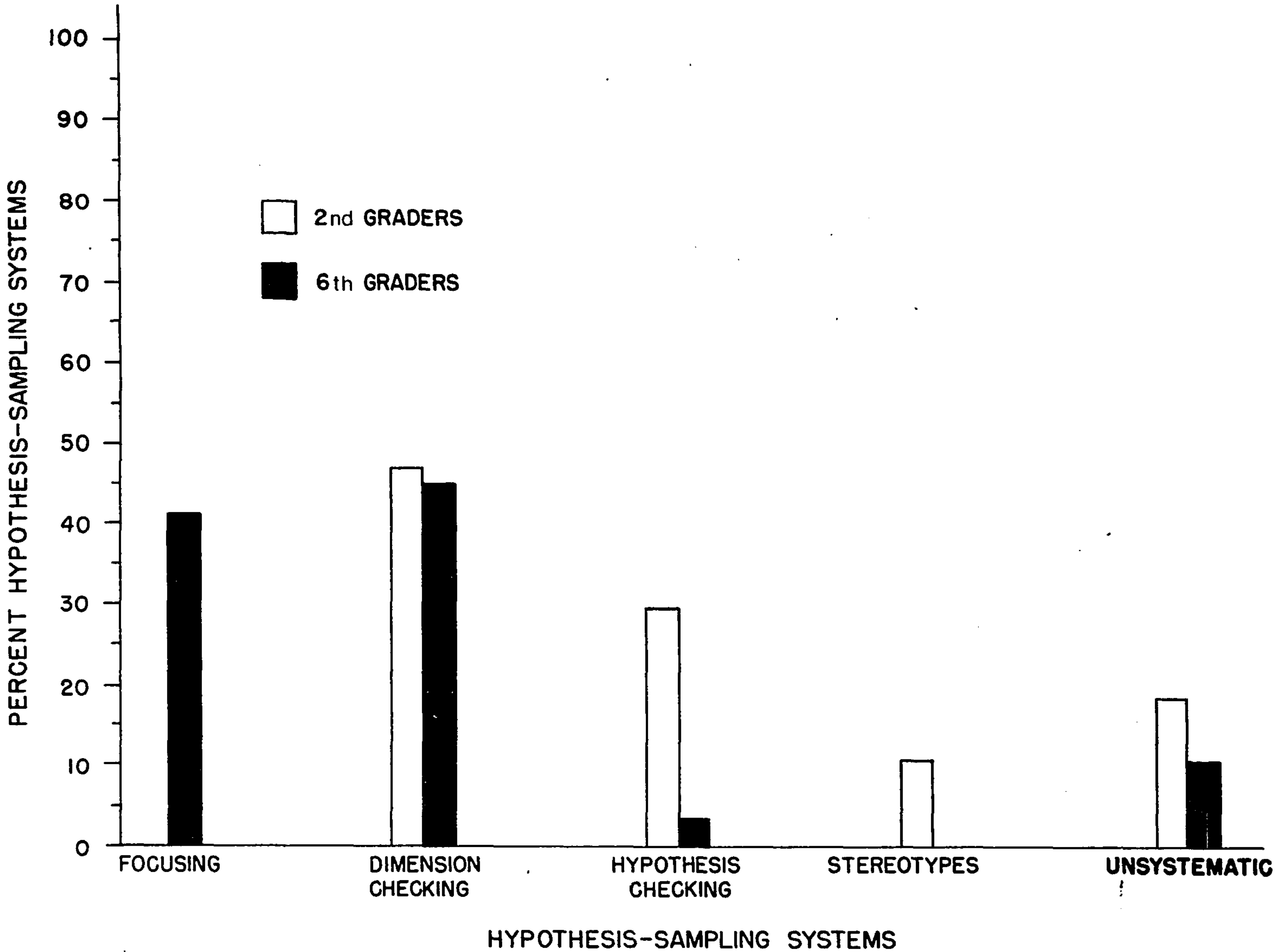
PERCENTAGES OF HYPOTHESIS-SAMPLING SYSTEMS FOR SECOND AND SIXTH GRADERS AFTER EXPOSURE TO THE FOCUSING TAPE

Figure 8



PERCENTAGES OF HYPOTHESIS-SAMPLING SYSTEMS FOR SECOND AND SIXTH GRADERS AFTER EXPOSURE TO THE DIMENSION-CHECKING TAPE

Figure 9



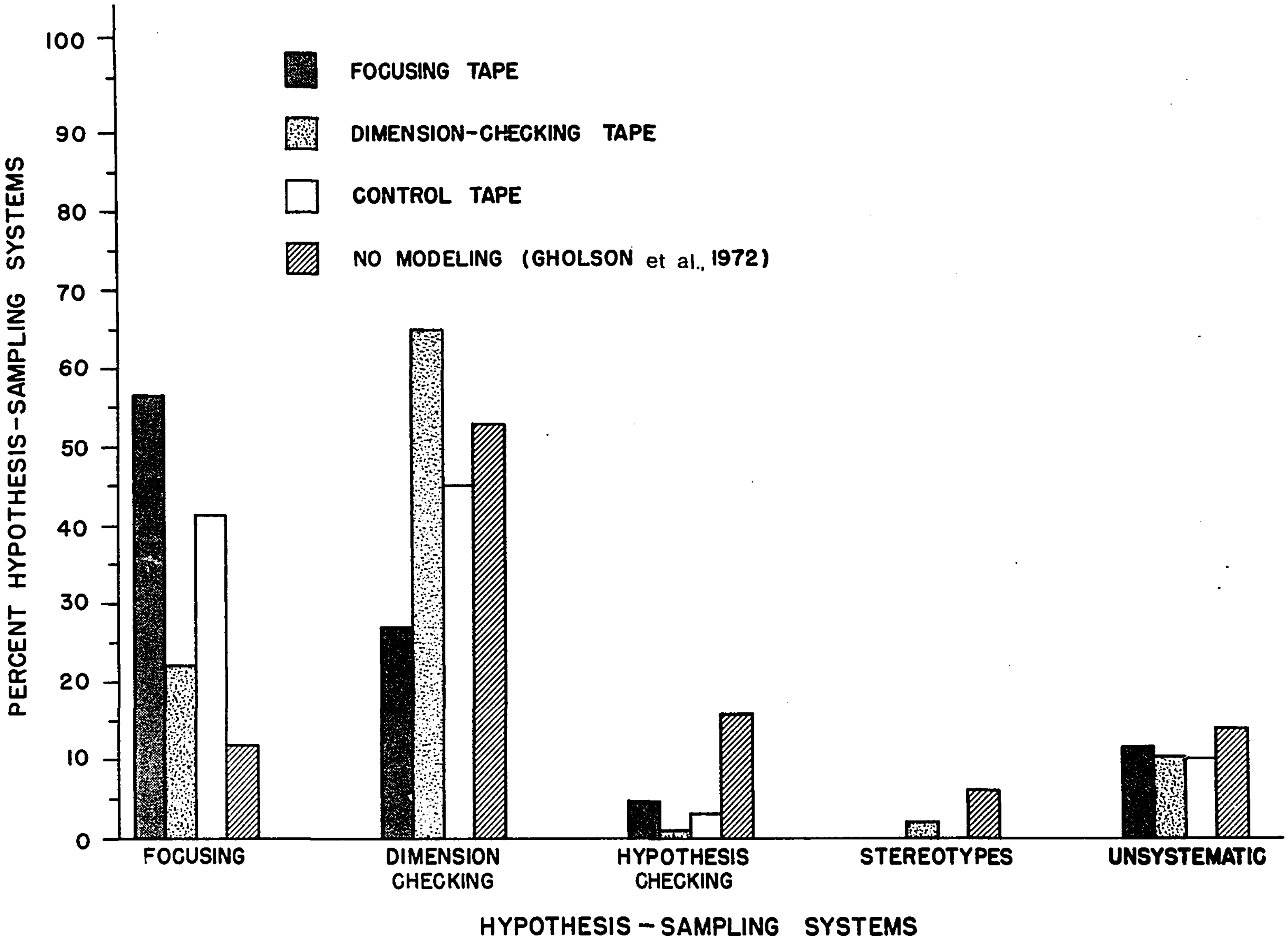
PERCENTAGES OF HYPOTHESIS-SAMPLING SYSTEMS FOR SECOND AND SIXTH GRADERS AFTER EXPOSURE TO THE CONTROL TAPE but more than 30% hypothesis checking. The second graders also showed some stereotypes and more unsystematic patterns than the sixth graders. These two distributions were also significantly different (χ^2 (4) = 76.35, $p < .05$).

Discussion

The results of this study indicate that modeling a complex, problem-solving strategy (labelled focusing) affects second- and sixth-grade children differentially. After viewing the focusing tape, sixth-grade children manifested focusing on more than 55% of the problems presented. After viewing the control tape, the sixth graders manifested focusing on more than 40% of the problems presented. Both of these percentages contrast markedly with the approximately 13% focusing obtained by Gholson _et al._ (1972) for sixth graders in a similar study without modeling (Figure 10). Therefore, both telling the subjects exactly how to solve the problems, as was done on the focusing tape, and modeling of the problem procedures without verbal rule provision, as was done on the control tape, result in high percentages of focusing as compared with no modeling. It is not clear why exposure to the modeling procedure without rule provision results in such a high percentage of focusing among the sixth graders. It is possible that sixth graders have available in their repertoire the elements and logical operations necessary to manifest focusing, and exposure to the modeling procedure was sufficient to bring these elements together.

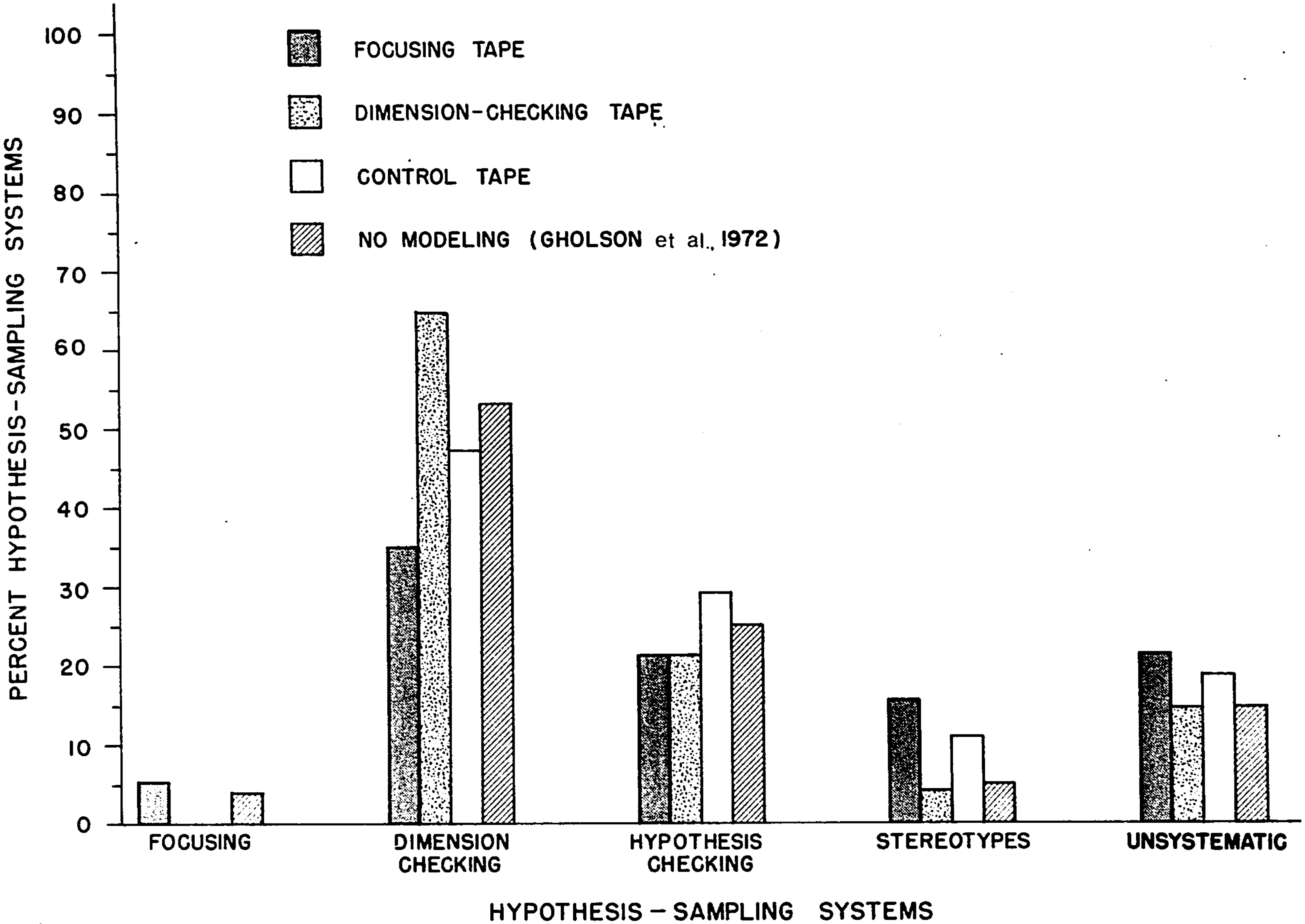
The second graders, on the other hand, manifested only six percent focusing after exposure to the focusing tape and no focusing after exposure to the control tape: results that are comparable to those found by Gholson _et al._ (1972) for second graders without modeling (Figure 11). Therefore, neither exposure to the modeling procedure nor the addition of rule provision resulted in manifestation of focusing among second graders. Moreover, as will be discussed later,

Figure 10



PERCENTAGE OF HYPOTHESIS-SAMPLING SYSTEMS AMONG SIXTH GRADERS AFTER EXPOSURE TO EACH OF THE MODELING TAPES AND COMPARISON WITH SIXTH GRADERS NOT EXPOSED TO MODELING

Figure 11



PERCENTAGE OF HYPOTHESIS-SAMPLING SYSTEMS AMONG SECOND GRADERS AFTER EXPOSURE TO EACH OF THE MODELING TAPES AND COMPARISON WITH SECOND GRADERS NOT EXPOSED TO MODELING exposure to the focusing tape apparently caused confusion among the second graders, resulting in depressed performance on all measures.

Exposure to the dimension-checking tape did not differentially affect the use of the dimension-checking strategy among children of either age level. The 65% dimension checking obtained after exposure to that tape from both second and sixth graders is somewhat higher than the approximately 50% obtained by Gholson et al. (1972) without modeling. Moreover, when the sixth graders did not manifest dimension checking, they usually manifested focusing, while the second graders did not. Focusing and dimension checking account for approximately 85% of the problems presented to the sixth graders after exposure to the dimension-checking tape. The second graders, after exposure to the dimension-checking tape, showed higher percentages of hypothesis checking and stereotypes than the sixth graders.

The sixth-grade children significantly outperformed the second-grade children on the four precurser processes considered here. These are behaviors that must be manifested if any strategy is to be inferred, e.g., manifestation of an hypothesis, maintenance of a confirmed hypothesis, changing a disconfirmed hypothesis, and locally consistent sampling. Table 7 shows the percentages obtained among the three groups at each grade level on each of the precursers along with the data from the Gholson et al. (1972) study. Inspection of this table reveals that on each of the measures the sixth graders performed equally well after viewing each of the modeling tapes, and comparable to children not exposed to modeling. Among the second graders, those subjects exposed to the dimension-checking or control tapes performed at about the same level as the sixth graders and as well as the second or

Table 7

Mean Percentage of Hypotheses, Maintained Confirmed and Disconfirmed Hypotheses, and Locally Consistent Sampling for Second and Sixth Graders After Exposure to Each Modeling Tape and Comparison with Data from a Nonmodeling Study (Gholson *et al.*, 1972)

	Tape Exposure Condition			
	2nd Grade		6th Grade	
Percent Hypotheses	Focusing	76	Focusing	96
	Dimension Checking	92	Dimension Checking	96
	Control	82	Control	95
	No Modeling	88	No Modeling	92
Percent Maintained Confirmed Hypotheses	Focusing	70	Focusing	93
	Dimension Checking	93	Dimension Checking	96
	Control	79	Control	96
	No Modeling	93	No Modeling	97
Percent Maintained Disconfirmed Hypotheses	Focusing	13	Focusing	01
	Dimension Checking	04	Dimension Checking	02
	Control	06	Control	01
	No Modeling	08	No Modeling	07
Percent Locally Consistent Hypotheses	Focusing	72	Focusing	97
	Dimension Checking	89	Dimension Checking	97
	Control	94	Control	96
	No Modeling	89	No Modeling	91

sixth graders not exposed to modeling. The most striking finding is that the poorest performance on each measure was obtained from the second-grade subjects exposed to the focusing tape.

It is clear from the data generated by both second- and sixth-grade subjects that, with and without modeling, they understand the basic concepts, i.e., that the problem is solvable and that the path to solution lies in choosing an hypothesis and maintaining or changing that hypothesis on the basis of subsequent confirmation or disconfirmation. It might be said that the performance on the precurser process measures indicates that the children understand the rules of the game, even though (as can be seen in the strategy analysis) they don't always manifest efficient ways of playing it.

Since elementary-school children (second and sixth graders) modally manifest dimension checking without any modeling, it is evident that they have the cognitive capacities and organization required to do so. Exposure to the dimension-checking tape therefore should serve simply to elucidate and perhaps consolidate a strategy already in their repertoire. Since the control tape does not verbally model any strategy, it was to be expected that each child would impose his own cognitive organization on the stimuli. As in previous studies without modeling, the modal response among second graders after viewing the control tape was dimension checking, indicating that they do impose their own strategy on the experimental problems after exposure to the control tape.

Sixth graders manifest both dimension checking and focusing after viewing the control tape. Since it may be assumed that the subjects impose their own organization on the experimental problems after exposure to the control tape, the data indicate that at least some sixth-grade children have the capacity to manifest focusing. It is not known why they do not manifest it without modeling. The major deficits may lie in the areas of logical inference and memory, both of which will be discussed below. What aspects of the control tape elicit focusing from the sixth graders is, at present, unclear. It may be that 10 minutes exposure to the modeling procedure is enough to allow the subjects to consolidate and manifest the strategy, possibly by practicing the memory demands in the presence of the stimuli. This and other possibilities are considered below.

The striking differences found on the precursers between the second and sixth graders after exposure to the focusing tape may be interpreted in terms of the congruence of the verbal rule provision on that tape with the differing cognitive levels of the two age groups. The younger subjects did not use the verbal rule provision on the focusing tape as a means of structuring and producing the focusing strategy; exposure to that tape actually led to a decrement in the previously well established (with and without modeling) precursers. Assuming that cognitive structure and organization increase with increasing age, then the data from the second graders indicate that exposure to verbal rule provision that is beyond that which can be integrated into their current cognitive level results in disruption of preexisting organization.

Since previous research (e.g., Gholson et al., 1972) has shown that elementary-school children use the dimension-checking strategy in approximately half the problems presented to them without modeling, it is evident that they are at least using simple rules and simple logical inference. If all they understood were the rules necessary to manifest hypotheses consistent with feedback, they would presumably generate hypotheses unsystematically. Since fewer than 20% of the second graders' problems and 10% of the sixth graders' problems showed unsystematic patterns, either with or without modeling, it seems clear that the subjects are using some kind of plan in their approach to the problems. Since sequences of hypotheses categorized as stereotypes are not sensitive to feedback and the percentages obtained were very low (except in the case of the second graders exposed to the focusing tape), stereotype patterns will not be considered further in the analysis of the strategic plans subjects used in the problems presented.

The simplest systematic plan is hypothesis checking. All the child has to do is organize the stimulus cues dimensionally and then systematically try each cue of each dimension sequentially, abandoning each hypothesis when it is disconfirmed until he finds the solution. This plan makes minimal memory demands since the subject need remember only which dimensions he had already eliminated, the dimension he is checking, and whether the cue he is checking at the moment is the first or second cue on that dimension. This simplest systematic plan is seen among sixth-grade children in approximately 15% of the problems presented without modeling, but all modeling conditions reduce that percentage to less than 5%. Among second graders, hypothesis checking is seen in about 20% of the problems, both with and without modeling.

If the hypothesis-sampling systems are ordered from least to most sophisticated, dimension checking is more sophisticated than hypothesis checking. Dimension checking requires that the subject logically disconfirm one cue on each dimension at the time the dimension is sampled. The remaining cue which is logically affirmed is then manifested as the hypothesis.

Focusing is the most sophisticated of the delineated strategies and no previous experiments using blank-trial probes with elementary-school children have obtained that strategy on more than approximately 10% of the categorizeable problems. Even adults manifest focusing on only about 50% of their problems. The first major difficulty in employing the focusing strategy lies in the heavy memory demand the strategy imposes. In order to focus, a subject must remember all four cues in the first correct stimulus array and hold them in memory while he selects one hypothesis which he manifests during the first blank-trial probe. At the second feedback trial, the subject must compare his memory of the four cues that were correct at the first feedback trial with the four that are correct at the second. He must then take the intersect of the two sets of cues and hold that set in memory while he tries one hypothesis during the second blank-trial probe. Since feedback in this study was preprogrammed so that the third feedback was always negative, the subject who was responsive to feedback always had to abandon the hypothesis he had held during the second blank-trial probe. The memory demands are especially heavy using blank-trial probes, since the subject must hold four and then two hypothesis in memory while he chooses on the basis of a single hypothesis on each of the four trials that constitute a probe.

The second major difficulty in manifesting focusing lies in the area of logical inference. An hypothesis-checking strategy requires that the subject eliminate only one cue at a time, while a subject using the dimension-checking strategy eliminates an entire dimension by testing only one cue and logically eliminating the other cue on that dimension, but a *focusing* strategy requires the elimination of four cues on the first feedback and two more on the second. While the disconfirmation of the four cues at the first feedback requires logical inference, all the cues are together in the incorrect stimulus array. At feedback two, however, the inference problem requires that the subject must disconfirm two cues while confirming two others in the same stimulus array.

In the present study sixth graders manifested focusing after exposure to both the focusing (55%) and control tapes (40%), while second graders did not show that strategy to any appreciable degree under any condition. The sixth graders may have generated the underlying rules very much the way that Denny (1972) found that older children generated constraint-seeking rules without exposure to a model. Focusing may be seen as a complex form of constraint seeking in that the subject maximizes the amount of information he uses at each feedback trial. If the sixth graders had generated focusing only after exposure to the focusing tape, the interpretation that they needed explicit rule provision in order to focus might be acceptable. However, since focusing was manifested in more than 40% of the problems among sixth graders exposed to the control tape, they must have generated the rules themselves. Again, in contrast, without modeling, sixth graders manifest focusing in approximately 10% of the problems presented (see Figure 10).

The performance differences between the second and sixth graders in response to the tapes may be interpreted from two different theoretical perspectives: developmental learning theory and Piagetian theory

(Gholson & McConville, 1974).

From a developmental learning theory perspective, the child may be seen as possessing a set of sequentially organized cognitive processes that develop with time and experience. Such a set might include stimulus differentiation, attention, verbal mediation or coding, visual imagery, memory storage and retrieval, and forms of logical deduction or inference. Little information is available concerning the role of each of these processes individually or their interactions in problem-solving situations.

In relation to this study, the processes of attention, coding, memory, and logical deduction seem to be most pertinent. Logical deduction has already been considered and will be taken up again in the Piagetian analysis. The earlier work of Gholson et al. (1972, 1973) has strongly indicated that by the second grade, children are easily able to discriminate the stimuli and to behave systematically. These children have no difficulty in attending to the relevant dimensions. It is possible, however, that second graders allocate their attention dimensionally or even to one cue at a time, while sixth graders may allocate their attention to all of the stimulus cues which, after exposure to the modeling tapes, allows them to manifest focusing.

The modeling tapes themselves may be thought of as directing attention to the various dimensions and the cues of each dimension, since at the beginning of each problem the experimenter pointed to and named each cue on each dimension and the modeling subject named and was seen choosing one cue during each trial of a given blank-trial probe. On the control tape no strategy was verbally provided. On the dimension-checking tape, the strategy of directing attention to one dimension at a time was verbally explicated. Only the focusing tape explicitly directed attention to more than one dimension at a time. Both the failure of the second graders to focus and the decrement in performance on the precursers after exposure to the focusing tape strongly indicate that second-grade children did not integrate the information provided. Sixth graders apparently did integrate the information which directed attention to all of the stimuli on the focusing tape.

Coding and memory appear to be intimately related and critical in determining the strategy used in discrimination-learning problems. Memory is usually divided into three components: sensory registration, which is brief and fades rapidly; short-term storage, which receives input from the sensory registrar and from long-term storage, and which lasts for up to 30 seconds without rehearsal before fading; and long-term storage, which is sometimes thought of as permanent and which holds the algorithms or strategies used in problem solving (Atkinson & Shiffrin, 1968). These authors define a coding process as "a select alteration and/or addition to the information in the short-term store as the result of a search of the long-term store" (Atkinson & Shiffrin, 1968, p. 115). It is possible that second grade children do not code information verbally as efficiently as sixth-grade children. Thus, the heavy memory and coding demands imposed by the focusing strategy may not be executed efficiently by the younger children. In addition, second graders may not rehearse the information in short-term storage

(Atkinson & Shiffrin, 1968) and may lose one or more of the four cues that must be maintained if focusing is to be manifest. Sixth graders probably do rehearse the four cues on the first correct stimulus array, thereby holding them in short-term storage until needed to be matched against the stimulus array at the second feedback.

The use of a strategy, brought into short-term storage from long-term storage by active retrieval on the subject's part, should aid coding of the stimuli because it proves a framework around which subjects can sensibly rehearse. For example, if the child can retrieve the dimension-checking strategy from long-term storage, he may rehearse according to dimensions and limit his rehearsal to one cue or at most, one dimension at a time. Alternatively, if the subject retrieves the focusing strategy, he may, as dictated by the strategy, rehearse all four of the cues in the first correct stimulus array and the two globally consistent cues in the second correct stimulus array.

Since sixth graders manifest focusing after exposure to both the focusing and control tapes, the suggestion here is that the elements of the strategy were already in their repertoire and exposure to the tapes aided consolidation so that this strategy could be manifested. The precurser and strategy data suggest that the elements (particularly memory and logical inference) of the focusing strategy may not be in the repertoire of the second graders.

As Montague points out, "Instructions (as are given on the focusing and dimension-checking tapes) to use elaborative strategies can increase both the frequencies of the reported use and correct recalls as compared with uninstructed control subjects. This result relies on the instructions to elicit more coding than subjects would do idiosyncratically in the task" (Montague, 1972, p. 291). Even the modeling control may increase coding, since in each instance an hypothesis that is sensitive to the preceeding feedback is verbalized. If sixth graders code and rehearse verbally, the information on the control tape may be sufficient to initiate an active search of long-term storage for a strategy that will aid coding (either dimension checking or focusing).

Finally, in terms of a developmental learning-theory approach, a hypothesized sequence of events leading to strategy production might be schematized, with feedback loops, as follows:

Stimulus input → attention → stimulus differentiation →

→ selection for short-term store → encoding and/or rehearsal →

→ long-term store → retrieval

Within the framework of current developmental learning theory, the child is seen as an active force directing his attention, coding, and memory processes. His thinking and information-processing capacities are seen as expanding and differentiating with time and experience, but the basic processes are assumed to be continuous and without sharp breaks. In contrast, within Piagetian theory, the child's thinking processes are viewed as qualitatively different during different periods of development (Inhelder & Piaget, 1958, 1964). There are four major stages in the development of thinking according to Piagetian theory: sensorimotor, preoperational, concrete operational, and formal operational. Given the age norms for the concrete operational (6 to 11) and formal operational (11 and up) periods and the ages of the subjects used in this study (7 to 8 and 11 to 12), only these two periods will be considered.

According to Piaget (Flavell, 1963), the concrete operational child is able to decenter, i.e., pay attention to more than one salient aspect of a stimulus situation. Therefore, he is able to differentiate the various aspects of the stimulus, i.e., the cues presented on each stimulus card, and he is then capable of forming sequential hypotheses rather than being limited to a stimulus preference stereotype. In addition, he is capable of class inclusion and descending classification (so that he can categorize the eight hypotheses into four dimensions and subdivide the dimensions into cues) and logical subtraction (so that he recognizes that when one hypothesis on a dimension is disconfirmed, the other remains). Furthermore, at this stage, the child can formulate a systematic plan and carry it through, taking feedback into consideration. Given these developmental achievements, the concrete operational child clearly has the operations necessary to manifest hypothesis checking or dimension checking.

The concrete operational child is limited to adding or subtracting single classes (in this case, hypotheses or dimensions). Focusing requires consideration of all the possible hypotheses at once and the logical subtraction of the maximum possible number (four and then two) at each feedback trial. Only the formal operational child is capable of this kind of consideration of all hypotheses at once and the logical deductions and intersection that reduce the set of working hypotheses to the minimum possible. Therefore only a formal operational child would be expected to manifest focusing.

The data from this study tend to confirm such a stage-dependent view since the second graders, who were almost certainly concrete operational, manifested primarily dimension checking and did not focus even when given explicit rule provision. The sixth graders who may have been either formal operational or transitional between concrete and formal operations did manifest focusing after exposure to both the explicit rule provision on the focusing tape and after exposure to the control tape. This latter group seems particularly interesting in terms of a Piagetian analysis since according to that theory if the child has the necessary logical operations he will formulate by himself the most efficient means of solving a problem, i.e., focusing.

Beilin (1971) directly addressed the question of the training and acquisition of logical operations. He suggested that "the early forms (of thought) are not suited to particular kinds of problem solving . . . (and) experience, whether it involves practice, reinforcement, need reduction or verbal rule learning, yields no persisting residue if it does not take place in the context of available intellectual resources" (Beilin, 1971, p. 82). Following this model, then, the second graders manifested dimension checking but not focusing because they have the logical operations available to dimension check but lack those (especially the ability to consider all possibilities at once) necessary to focus. The sixth graders, according to this analysis, must have the necessary logical operations available for focusing. Both second and sixth graders manifested dimension checking more frequently after viewing the dimension-checking tape than did subjects not exposed to modeling possibly because the language used in the rule provision served as an integrating algorithm. The same analysis may hold true for the sixth graders exposed to the focusing tape as compared with those exposed to the control tape. However, this analysis suggests that the sixth graders must have had the logical operations required for focusing in their repertoire or they would not have imposed the logical structure (i.e., the focusing rule or algorithm in the problems presented after viewing the control tape.

The current study does not differentiate between the developmental learning theory and Piagetian views since the obtained differences were age dependent. If focusing could be elicited from concrete operational children, then either the developmental learning theory view would have to be adopted, with finer grain analysis of the development and elicitation through modeling of the memory and inference requirements, or, conceiveably, the Piagetian view of the capacities of concrete operational children might have to be modified to account for the possible acquisition of stage-dependent capacities through appropriate training or modeling.

Implications for Future Research

The most provocative findings of this study seem to be that (a) second graders do not manifest focusing under any experimental conditions; (b) when exposed to the focusing tape, second graders perform less well on the precursers than they do after exposure to the dimension-checking or control tapes; and (c) the sixth graders focused after exposure to both the focusing and control tapes.

It would be interesting to explore whether the deterioration in processing and the failure to focus among second-grade children exposed to the focusing tape was a function of the heavy memory demands imposed by that strategy. Such a study might investigate the relationship between exposure to the focusing tape and providing memory aids during problem presentation, as Eimas (1970) did. Alternatively, the problem may lie in the inability of second graders to bring to bear on the experimental problems the logical operations (simultaneous consideration of all possibilities and logic involving intersection) necessary for focusing.

The Piagetian view assumes that focusing requires the kind and level of logic found only among formal operational children. Toward investigating this possibility a study is currently in progress in which sixth-grade children are being pretested for Piagetian stage and classified as concrete operational, transitional, and formal operational on the basis of pretest performance. Children of each cognitive level are exposed to either the focusing or control tapes or a no-modeling control condition. It is expected that those subjects classified as concrete operational will not profit from either the rule-provision focusing tape or the minimal information control tape and will not typically manifest focusing. Their behavior is expected to parallel that of the second graders both on the precursers and in terms of strategy production. The formal operational group is expected to manifest focusing after exposure to either the focusing or control tapes, since they are assumed to have the logical operations necessary to manifest that strategy without modeling. The most interesting group may turn out to be the transitional subjects. It is expected that they will manifest focusing after exposure to the focusing tape, which provides an algorithm which may allow them to bring the cognitive processes necessary for focusing to bear on the problems. The transitional group exposed to the control tape is not expected to focus, since presumably their logical operations are not sufficiently developed or consolidated to allow manifestation of focusing without rule provision.

Appendix A

Preamble for Tapes

I would like you to help me with some puzzles that I have here. What will happen is that you will see pictures like these. As you can see, there are two pictures. This picture is small and this one is big; this picture is white and this one is black. This picture has a line on the bottom and this picture has a line on the top. This picture has a G and this picture has a Z.

One of the two pictures contains the correct answer; the other picture is wrong. I want you to choose one of the two pictures by pointing at it. If you choose the picture that contains the correct answer, I'll tell you "yes." If you choose the picture that doesn't contain the correct answer, I'll tell you "no" and point to the picture with the correct answer. I'd like you to try to be right as often as you can. When you figure it out, you can always choose the picture that contains the correct answer. Remember the answer could be line on the top or line on the bottom, Z or G, black or white, or big or small. Your job is to figure out which of these things is the answer and then to always choose the picture that contains the correct answer. You choose one picture to start with.

Focusing Problem I. Feedback, +,-,-. Solution G

Card 1

S: point to small, white, G, line down.

E: Yes, the answer is in that picture.

S: Then the answer could be small or G or white or line on the bottom. It could be any of the four choices so I have to remember all of them. I'll keep remembering that the answer could be G or white or line on the bottom or small, but I'll just try one.

Card 2. S: I'll try small.

Cards 2,3,4,5 (probe with S silently picking small on each).

Card 6, F2

S: point to small, white, Z, line up.

E: No, the answer is in this picture (point to large, black, G, line down).

S: That means the answer must be either G or line on the bottom. I'm narrowing down what the answer could be, and only G and line on the bottom are both in the pictures you told me were correct. So I'll remember G and line on the bottom, but I'll try just one.

Card 7: S: I'll keep trying line on the bottom until you tell me which picture is correct.

Cards 7,8,9,10 (probe, picking line down on each).

Card 11, F3

S: point to small, black, Z, line down.

E: No, the answer is in this picture (point to large, white, G, line up).

S: Then the answer must be G, since I had only two choices left, G or line on the bottom, and it isn't line on the bottom. I'll just make sure.

Cards 12,13,14,15 (probe, picking G on each).

Card 16, F4

S: point to small, black, G, line up.

E: Yes, the answer is in that picture (pointing) and it's G. You did very well.

Focusing Modeling Problem 2, Feedback sequence: -,-,- Solution: line up.

E: Let's try another puzzle. This time the answer could be black or white, or small or big, or line on the bottom or line on the top, or V or N. You start by choosing one picture (Card 1, F1).

S: point to small, black, V, line down.

E: No, the answer is in this picture (point to large, white, N, line up).

S: Then the answer must be N or line on the top or white or big. I'll keep those four things in my head, but I'll just try one.

Card 2: S: I'll try big.

Cards 2,3,4,5 (probe, picking big on each card). Card 6,F2:

S: point to large, white, V, line down.

E: No, the answer is in this picture (point to small, black, N, line up).

S: Well, let's see. I started with four possible correct answers: N, line on the top, white, and big. But the only two things that have been in both the correct pictures are N and line on the top. So it must be one of those two. I've eliminated half the possibilities and now I just have to remember two: line on the top and N.

Card 7: S: I'll try N.

Cards 7,8,9,10: (probe, picking N).

Card 11: F3

S: point to large, black, N, line down.

E: No, the answer is in this picture (point to small, white, V, line up).

S: Then the answer must be line on the top. It's the one thing that has been in all the pictures you told me were correct. I'll just make sure.

Cards 12,13,14,15 (probe, picking line up).

Card 16,F4

S: point to large, black, V, line up.

E: Correct the answer is line on the top, and it's in this picture (pointing).

Focusing Modeling Problem 3. Feedback sequence: -,+,-. Solution: white.

E: We'll try another puzzle. This time the answer could be S or K or line on the bottom or line on the top or big or small or black or white. You choose one picture to start with.

S: I think I know how to do these puzzles. First I have to remember all the things in the first picture you tell me is correct. I memorize all four things and keep them in my head but I just try one, and I keep trying that until the next time you tell me which picture is correct. Then I have to remember which two things were in both the first and second correct pictures, and while I keep those two in my head, I try one. And the third time you tell me which picture is correct I can always tell what the answer is. Okay, now that I understand how to do these puzzles, I'll choose one picture to start with this time (point to small, black, K, line up).

E: No, the answer is in this picture (large, white, S, line down).

S: Then I have to memorize the four things in that picture. The answer could be line on the bottom or S or white or big. I'll remember all four while I try one.

Card 2: S: I'll try line on the bottom.

Cards 2,3,4,5 (probe, picking line down). Card 6,F2

S: point to small, white, K, line down.

E: Yes, the answer is in that picture.

S: So now I've narrowed it down to two choices. It has to be either line on the bottom or white because the other two things that were correct in the first correct picture are not in this correct picture. So, of the two choices: line on the bottom or white. I'll try one.

Card 7: S: I'll try line on the bottom again.

Cards 7,8,9,10 (probe, picking line down). Card 11, F3

S: point to large, black, K, line down.

E: No, the answer is in this picture (point to small, white, S, line up.

S: That means the answer must be white since I've eliminated everything except white that was in the first picture. I'll try it to be sure.

Cards 12,13,14,15 (probe, picking white)

Card 16, F4

S: point to large, white, K, line up.

E: Very good. The answer is in that picture, and it's white.

Focusing Modeling 4. Feedback sequence +,-,- Solution: small

E: Let's try one last puzzle. In this one, the answer could be line on the top or line on the bottom or big or small or white or black or X or H. You choose one to start with.

Card 1, F1

S: point to small, black, H, line down.

E: Yes, the answer is in that picture.

S: Okay, the way you do this is to remember all the things that are in this first correct picture, even though I'm only going to try one. So, it could be small or black or H or line on the bottom.

Card 2: S: I'll keep them all in my head, but I'll try black.

Cards 2,3,4,5 (probe, picking black) Card 6, F2

S: point to large black, X, line down.

E: No, the answer is in this picture (point to small, white, H, line up).

S: Now I only have to remember two things, the two that are in this correct picture that were also in the first correct picture. Let's see. Those were small and H. Of the four things that were correct in the first picture, only H and small are in the picture you just told me was correct. So I'll eliminate one of those by trying it.

Card 7: S: I'll try H.

Cards 7,8,9,10 (probe, picking H) Card 11, F3

S: Point to large, black, H, line up.

E? No, the answer is in this picture (point to small, white, X, line down).

S: Then I know the answer must be small. The last time you told me the correct picture, I only had to remember two things, H and small, and I just found out it isn't H, so it has to be small. I'm sure, but I'll try it anyway.

Cards 12,13,14,15 (probe, picking small). Card 16, F4

S: point to small, black, X, line up.

E: Yes, that's correct. You've done very well. The answer is small and it's in that picture.

Dimension Checking Problem 1. Feedback +,-,-. Solution: G

S: point to small, white, G, line down.

E: Yes, the answer is in that picture.

S: Well, if I want to try one of the sizes, big or small, to see if one of them is the right answer, I'll have to try small because that's in the correct picture. So, to check out the sizes, I'll try small.

Cards 2,3,4,5 (probe, with S silently picking small on each).

Card 6, F2

S: point to small, white, Z, line up.

E: No, the answer is in this picture (point to large, black, G, line down).

S: That eliminates the sizes. So I'll have to try something else. The correct answer might be the position of the line. The correct picture has the line on the bottom, so I'll try that. I'll keep trying line on the bottom until you tell me which picture is correct.

Cards 7,8,9,10 (probe picking line down on each).

Card 11, F3

S: point to small, black, Z, line down.

E: No, the answer is in this picture (point to large, white, G, line up).

S: That means the answer isn't the position of the line, so I'll check the letters. If it's one of the letters, it has to be G because that's in the correct picture, so I'll try G.

Cards 12,13,14,15 (probe, picking G). Card 16, F4

S: point to small, black, G, line up.

E: Yes, the answer is in that picture (pointing), and it's G. You did very well.

Dimension Checking Problem 2. Feedback -,-,-. Solution: line up

E: Let's try another puzzle. This time the answer could be black or white or small or big or line on the bottom or line on the top or V or N. You start by choosing one picture.

S: point to small, black, V, line down.

E: No, the answer is in this picture (point to large, white, N, line up).

S: Well, let's see. The answer could be any of the four things in this picture. It could be white or N or line on the top or big. I'll try size first, and since big is in the correct picture, I'll try big.

Cards 2,3,4,5 (probe, picking big). Card 6, F2

S: point to large, white, V, line down.

E: No, the answer is in this picture (point to small, black, N, line up).

S: Now I'm sure the answer isn't either of the sizes, big or small. So it must be something else. I think I'll try the letters next. If it's one of the letters, it has to be the N, because that's in this correct picture. Yes, I'll try the N.

Cards 7,8,9,10 (probe, picking N). Card 11, F3

S: point to large, black, N, line down.

E: No, the answer is in this picture (point to small, white, V, line up).

S: Okay, now I know it isn't one of the letters, either. Well, the answer could still be line on the top. It can't be line on the bottom because that picture is wrong this time. But I'll try line on the top.

Cards 12,13,14,15 (probe, picking line up). Card 16, F4

S: point to large, black, V, line up.

E: Correct, the answer is line on the top, and it's in this picture.

Dimension Checking Problem 3. Feedback -,+,-. Solution: white

E: We'll try another puzzle. This time the answer could be S or K or line on the bottom or line on the top or white or black or big or small. You start by choosing one picture.

S: I think I know how to do these puzzles. I only have to try one of each pair of things, like big or small, and I always choose the one of each pair that's in the picture you just told me was correct. Then if that's wrong, I've eliminated both the sizes, big and small, and I just pick something else, like the letter that's in the correct picture, and try that. I just check one of each pair of things -- the one that's in the picture you just told me was correct -- until I find the answer. I know I only have to check one of each pair because once you've told me, for example, that the picture with the big letter is correct, the small letter has to be in the wrong picture, so I never need to check that. And I can do that for each pair of things -- just check the one that's in the correct picture. That way I can always find the answer. So I'll start with one picture (point to small, black, K, line up).

Dimension Checking Problem 3. Feedback -,+,-. Solution: white.

S: point to small, black, K, line up.

E: No, the answer is in this picture (point to large, white, S, line down).

S: I think I'll start by checking to see if the answer might be the position of the line. If it is, it has to be line on the bottom, because that's in the correct picture. I'll try it and see. I'll try line on the bottom until the next time you tell me which picture is correct.

Cards 2,3,4,5 (probe, picking line down). Card 6, F2.

S: point to small, white, K, line down.

E: Yes, the answer is in that picture.

S: Oh, that's good. That means the answer could still be line on the bottom, since that's still in the correct picture. It might be something else, but I can't tell yet since line on the bottom is still in the correct picture, so I'll try line on the bottom again.

Cards 7,8,9,10 (probe, picking line down). Card 11, F3

S: point to large, black, K, line down.

E: No, the answer is in this picture (point to small, white, S, line up).

S: Well, that means the answer isn't the position of the line. I'll try something else. I'll try the colors. If the answer is one of the colors, it has to be white, because that's in the correct picture. I'll try white.

Cards 12,13,14,15 (probe, picking white). Card 16, F4

S: point to large, white, K, line up.

E: Very good. The answer is in that picture, and it's white.

Dimension Checking Problem 4. Feedback sequence +,-,-. Solution: small.

E: let's try one last puzzle. In this one, the answer could be line on the top or line on the bottom or big or small or white or black or X or H. You choose one to start with.

S: point to small, black, H, line down.

E: Yes, the answer is in that picture.

S: I think I'll check the colors, black or white, first. If the answer is one of the colors, it has to be black, because that's the color in the picture you just told me was correct. I'll try it and see.

Cards 2,3,4,5 (probe, picking black). Card 6, F2

S: point to large, black, X, line down.

E: No, the answer is in this picture (point to small, white, H, line up).

S: Well, that means the answer isn't one of the colors, since I was trying black and that was correct in the first picture. So I have to try something else. I think this time I'll try the letters, and if the answer is one of the letters, it has to be H, because that's the letter in the correct picture. So I'll try H.

Cards 7,8,9,10 (probe, picking H). Card 11, F3

S: point to large, black, H, line up.

E: No, the answer is in this picture (point to small, white, X, line up).

S: That means the answer isn't one of the letters, either. Let's see. I haven't tried the sizes. The correct picture this time is small, so small could be the answer. I'll try it.

Cards 12,13,14,15 (probe, picking small). Card 16, F4.

S: point to small, black, X, line up.

E: Yes, that's correct. You've done very well. The answer is small and its in that picture. Thank you.

Control Problem I: Feedback sequence +,-,-. Solution: G

S: point to small, white, G, line down.

E: Yes, the answer is in that picture.

S: I'll try one thing. I'll try small.

Cards 2,3,4,5 (probe, picking small). Card 6, F2.

S: point to small, white, Z, line up.

E: No, the answer is in this picture (point to large, black, G, line down).

S: I'll try line on the bottom.

Cards 7,8,9,10 (probe, picking line down). Card 11, F3.

S: Point to small, black, Z, line down.

E: No, the answer is in this picture (point to large, white, G, line up).

S: I'll keep trying G until you tell me which picture is correct.

Cards 12,13,14,15 (probe, picking G). Card 16, F4.

S: Point to small, black, G, line up.

E: Yes, the answer is in that picture and it's G. You did very well.

Control Problem 2. Feedback Sequence: -,-,-. Solution: line up.

E: Let's try another puzzle. This time the answer could be black or white or small or big or line on the bottom or line on the top or V or N. You start by choosing one picture.

S: Point to small, black, V, line down.

E: No, the answer is in this picture (point to large, white, N, line up).

S: Well, I'll try big.

Cards 2,3,4,5 (probe, picking big on each card). Card 6, F2

S: Point to large, white, V, line down.

E: No, the answer is in this picture (point to small, black, N, line up).

S: I'll keep trying N until you tell me which picture is correct.

Cards 7,8,9,10 (probe, picking N). Card 11, F3

S: Point to large, black, N, line down.

E: No, the answer is in this picture (point to small, white, V, line up).

S: I'll try line on the top.

Cards 12,13,14,15 (probe, picking line up). Card 16, F3

S: Point to large, black, V, line up.

E: Correct, the answer is line on the top and it's in this picture.

Control Problem 3. Feedback sequence: -,+,-. Solution: white

E: We'll try another puzzle. This time the answer could be S or K or line on the bottom or line on the top or white or black or big or small. You start by choosing one picture.

S: Point to small, black, K, line up.

E: No, the answer is in this picture (large, white, S, line down).

S: I'll try line on the bottom.

Cards 2,3,4,5 (probe, picking line down). Card 11, F3.

S: Point to large, black, K, line down.

E: No, the answer is in this picture (point to small, white, S, line up).

S: I'll try white.

Cards 12,13,14,15 (probe, picking white). Card 16, F4

S: Point to large, white, K, line up.

E: Very good. The answer is in that picture and it's white.

Control Problem 4. Feedback sequence: -,-,-. Solution: small.

E: Let's try one last puzzle. In this one, the answer could be line on the top or line on the bottom or big or small or white or black or X or H. You choose one to start with.

S: Point to small, black, H, line down.

E: Yes, the answer is in that picture.

S: I think I'll try black first.

Cards 2,3,4,5 (probe, picking black). Card 6, F2

S: Point to large, black, X, line down.

E: No, the answer is in this picture (point to small, white, H, line up).

S: I'll try H.

Cards 7,8,9,10 (probe, picking H). Card 11, F3

S: Point to large, black, H, line up.

E: No, the answer is in this picture (point to small, white, X, line down).

S: I'll keep trying small until you tell me which picture is correct.

Cards 12,13,14,15 (probe, picking small). Card 16, F4

S: Point to small, black, X, line up.

E: Yes, that's correct. You've done very well. The answer is small and it's in that picture.

Appendix B

Analysis of Variance for the Probability that Subjects Chose the Correct Stimulus Array on Feedback Trials Five, Six, Seven, and Eight and Held the Correct Hypothesis on Blank-Trial Probes Five, Six, and Seven.

Source	S.S.	df	M.S.	F
Tape	1140.22	2	570.11	1.34
Age	38448.67	1	38448.67	90.93***
Sex	98.34	1	98.34	0.23
Tape X Age	4426.38	2	2213.19	5.23***
Tape X Sex	1152.38	2	575.19	1.36
Age X Sex	.84	1	.84	0.00
Tape X Age X Sex	496.88	2	248.44	0.58
Residual	55810.08	132	422.80	

*$p < .05$

**$p < .01$

***$p < .001$

Analysis of Variance for the Probability that Subjects Manifested Simple Hypotheses on Each Blank-Trial Probe

Source	S.S.	df	M.S.	F
Tape	799.59	2	399.79	3.61*
Age	4970.25	1	4970.25	44.98***
Sex	42.25	1	42.25	0.38
Tape X Age	926.04	2	463.02	4.19**
Tape X Sex	334.04	2	167.02	1.51
Age X Sex	34.02	1	34.02	0.30
Tape X Age X Sex	735.09	2	367.54	3.32*
Residual	14584.00	132	110.48	

*$p < .05$

**$p < .01$

***$p < .001$

Analysis of Variance Table for the Probability that Subjects Maintained the Same Hypothesis on Successive Blank-Trial Probes When the Intervening Feedback was Positive

Source	S.S.	df	M.S.	F
Tape	3651.51	2	1825.75	5.84**
Age	8387.50	1	8387.50	26.84***
Sex	112.00	1	112.00	0.35
Tape X Age	1496.18	2	748.09	2.39
Tape X Sex	2562.68	2	1281.34	4.10*
Age X Sex	108.50	1	108.50	0.34
Tape X Age X Sex	3451.68	2	1725.84	5.52*
Residual	41245.08	132	312.46	

*$p < .05$

**$p < .01$

***$p < .001$

The Analysis of Variance Summary Table for the Probability That Subjects Maintained a Disconfirmed Hypothesis

Source	S.S.	df	M.S.	F
Tape	444.50	2	222.25	1.56
Age	1406.25	1	1406.25	9.88***
Sex	2.77	1	2.77	0.00
Tape X Age	553.16	2	276.58	1.94
Tape X Sex	1034.72	2	517.86	3.64*
Age X Sex	6.25	1	6.25	0.04
Tape X Age X Sex	129.50	2	64.75	0.45
Residual	18776.33	132	142.22	

*$p < .05$

**$p < .01$

*** $p < .001$

The Analysis of Variance Summary Table for the Probability of Locally Consistent Sampling

Source	S.S.	df	M.S.	F
Tape	943.93	2	471.96	3.24*
Age	5244.41	1	5244.41	36.08***
Sex	2.50	1	2.50	0.01
Tape X Age	1524.43	2	762.21	5.24**
Tape X Sex	568.34	2	284.17	1.95
Age X Sex	2.00	1	2.00	0.01
Tape X Age X Sex	193.18	2	96.59	0.66
Residual	19185.91	132	145.34	

*$p < .05$

** $p < .01$

*** $p < .001$

Analysis of Variance for the Percentage of Categorizeable Problems

Source	S.S.	df	M.S.	F
Tape	4,250.73	2	2,125.36	7.53***
Age	10,532.74	1	10,532.74	37.32***
Tape X Age	4,277.07	2	2,137.03	7.57***
Residual	38,947.02	138	282.22	

*$p < .05$

**$p < .01$

***$p < .001$

Appendix C

(From Gholson & Levine, 1972)

The technique for analyzing a set of protocols into the various systems will be demonstrated here.

The general conception: It is assumed that a subject begins a problem with some system that dictates his mode of sampling hypotheses. Each system is manifested in one of a small subset of hypothesis sequences. For example, the Stimulus Preference System is manifested when the same hypothesis is continually repeated after each of a series of disconfirmations. There is a small subset of these hypothesis sequences since the particular hypothesis is not specified -- a subject might perserverate on "large size," or on "black," etc.

A second assumption is that this system is maintained at least until the fourth feedback trial, i.e., the hypotheses observed after each of the first three feedback trials are dictated by a single system.

The third assumption concerns the subjects' manner of resampling for hypotheses after a disconfirmation. The hypotheses are divided into two classes: Response-set hypotheses (defined as the subject's preference, or bias, causing him to produce long strings of stereotypic responses) and Prediction hypotheses (defined as the subject's prediction concerning the solution). Correspondingly, the systems are divided into two classes: Stereotypes (e.g., Stimulus Preference), in which the subject persists in the same hypothesis despite repeated disconfirmations, and Strategies, in which the subject follows some plan which, in principle, leads to solution. During Strategies an hypothesis is genuinely tested, i.e., is rejected following a disconfirmation. The third assumption is that when the subject rejects an hypothesis and resamples (i.e., during Strategies) he always selects a locally-consistent hypothesis.

Finally, the set of systems is specified a priori. The following set was considered:

Stimulus Preference (abb. S-P): The subject selects an hypothesis and persists with it for the three feedback trials.

Hypothesis Checking (abb. H-Ch): The eight hypotheses are ordered by the subject into the pairs of hypotheses from each of the four dimensions, as though the subject imagines a list of the four pairs of hypotheses. He goes through this list, testing each hypothesis in turn, one dimension at a time. Thus, he tries an hypothesis, then, if it is disconfirmed, he tries its complement (the opposite hypothesis on the same dimension). If that is disconfirmed he tries an hypothesis from another dimension, then its complement, etc.

Dimension Checking (abb. D): As with H-CH the hypotheses are ordered by the four dimensions. In this case, the subject recognizes that after the first trial disconfirmation of an hypothesis also logically disconfirms the entire dimension. (This is logically correct since the just-disconfirmed hypothesis was, when it had been sampled, locally consistent. Its complement, therefore, of necessity had at that time been locally inconsistent). After each disconfirmation, therefore, the hypothesis comes from a different dimension.

Focusing (abb. Fo): With each feedback the subject eliminates all disconfirmed hypotheses, whether explicitly manifested or not. Thus, each hypothesis manifested is consistent with all the preceding feedback-trial information. The hypothesis after the third feedback trial is, of necessity, the solution.

The analysis: In principle, the experimenter's decision about the system employed by a particular subject on a particular problem is simple. He inspects the first three hypotheses and, on the basis of the particular hypothesis sequence, decides which system is being manifested. However, a more detailed treatment of the general analytical technique is required because there are certain small complications. There is an occasional overlap in the manifestation of two systems. For example, a subject who is following the D system may, when resampling after the third feedback trial, select the correct dimension and, perforce, the solution hypothesis. The resulting hypothesis sequence might be identical to that of a subject following the Fo system. Such confounding requires special techniques for arriving at valid estimates of the frequency with which the various systems occur. These techniques vary somewhat with each type of confounding and with the feedback sequence.

Because of these complications the categorizing of protocols will be described separately for each sequence of feedback trials. Problems with confounding will be discussed as they arise. Before proceeding, however, a few definitions will be helpful: (1) the feedback, "right" or "wrong" will be symbolized by + or −, respectively. A subscript (e.g., $+_2$) will indicate the trial on which the feedback occurred. (2) The subscripts i, j, k, and l will refer to the four dimensions. Thus, the symbol $\underline{H}_j$ will refer to the first hypothesis seen from the j^{th} dimension. If the j^{th} dimension is color and "black" is the first hypothesis observed from this dimension, the $\underline{H}_j$ = black. The complementary, or opposite, hypothesis will be indicated by the prefix "op." Thus, if $\underline{H}_j$ = black, then op$\underline{H}_j$ = white.

the feedback sequence $+_1$ $-_2$ $-_3$) may be estimated from the following considerations: The corrected D value contains two components, those sequences which cannot be confused with the Fo sequence (labelled D') and those sequences which resemble the Fo sequence (labelled D*). The frequency of D is the sum of the two frequencies, i.e.,

$$f(D) = f(D') + f(D^*),$$

where f(D') is obtained directly from the data. Similarly, the sequences in the category labelled Fo' contain two different sets of sequences: those which are actually the result of the Fo system (labelled Fo) and those which are from the D system (D*). These two frequencies combine giving

$$f(Fo') \text{ and } f(Fo) + f(D^*),$$

where f(Fo') is obtained directly from the data.

These two equations contain three unknowns. A third equation is obtained from these considerations: With orthogonal stimulus sequences a subject who is holding the D system and who will receive $+_1$ and $-_2$ may start the problem with one of only two hypotheses (there are four Hs which lead to a correct response on trial 1; two of these lead to an error on trial 2). Starting with one of these two hypotheses, D*, the sequence resembling the Fo sequence, will occur one-fourth of the time; starting with the other hypothesis that Fo-resembling sequence will occur one-half the time. Since the probability that this subject (holding the D system) will start the problem with each of these two hypotheses is one-half, the probability of D* occurring is given by $1/2(1/4) + 1/2(1/2) = 3/8$. Similarly, D' will occur 5/8 of the time. Therefore, the required third equation is

$$f(D^*) = (3/5)f(D').$$

Solving the three equations yields:

$$f(D) = f(D') + (3/5)f(D')$$

and $$f(Fo) = f(Fo') - (3/5)f(D').$$

Thus, the value $(3/5)f(D')$ must be added to and subtracted from, respectively, the initial, tentative frequency assignments for the D system and the Fo system

Sequence: $-_1 \; -_2 \; -_3$

S-P manifestation: $-\underline{H}_{1-i} \quad -\underline{H}_{2-i} \quad -\underline{H}_{3-i}$

H-Ch manifestation: This system has two sets of sequences depending upon whether one assumes that the subject holds an hypothesis before the problem starts or whether one assumes that the subject receives information from the first trial before applying his system. Each procedure yields its own unique sequence. Either sequence, therefore, was regarded as an instance of H-Ch.

These sequences are: $-\underline{H}_{1-i} \quad -\underline{H}_{2-j} \quad -_3\mathrm{op}\underline{H}_{-j}$ or $-\underline{H}_{1-i} \quad -_2\mathrm{op}\underline{H}_{-i} \quad -\underline{H}_{3-j}$

D' manifestation: $-\underline{H}_{1-i} \quad -\underline{H}_{2-j} \quad -_3(H_{-k}=\underline{H}^{+})$

The same confounding between D and Fo exists with this feedback sequence as with the preceding. Also, the same correction procedure is appropriate:

$$f(D) = f(D') + (3/5)f(D'), \text{ and}$$

$$f(Fo) = f(Fo') - (3/5)f(D'),$$

where $f(D')$ and $f(Fo')$ are frequencies obtained from the initial cataloguing:

Sequence: $+_1 \; +_2 \; -_3$

S-P manifestation: $+\underline{H}_{1-i} \quad +\underline{H}_{2-i} \quad -\underline{H}_{3-i}$

H-Ch manifestations: $+\underline{H}_{1-i}$ $+\underline{H}_{2-i}$ $-_3 op\underline{H}_i$

D' manifestation: $+\underline{H}_{1-i}$ $+\underline{H}_{2-i}$ $-_3(\underline{H}_j = \underline{H}^+)$

Here, again, a subject holding the D system would, if the correct dimension were second on his list, produce a sequence resembling focusing. Since the correct dimension cannot be first on this subject's list (the given feedback sequence has an error on trial 3, an impossible event if the subject had started out holding $\underline{H}^+$) it may be either second, third, or fourth. One-third of the time it will be second and a Fo sequence will result, i.e.,

P(D*/D) = 1/3, and P(D'/D) = 2/3.

Therefore, f(D*) = (1/2)f(D'), and

F(D) = f(D') + (1/2)f(D')

f(Fo) = f(Fo') - (1/2)f(D')

Sequence: $-_1 +_2 -_3$

S-P Manifestation: $-\underline{H}_{1-i}$ $+\underline{H}_{2-i}$ $-\underline{H}_{3-i}$

H-Ch' Manifestation: As with the sequence $-_1 -_2 -_3$, it is necessary to recognize that H-Ch can have one of two forms: the subject may hold an hypothesis before the first feedback trial or he may start through his list after receiving information from the first feedback trial. In the latter case no difficulties arise. The manifestation is $-\underline{H}_{1-i}$ $+\underline{H}_{2-i}$ $-_3 op\underline{H}_i$. If, however, the subject uses the initial feedback trial to reject the first hypothesis from the first dimension on his list, then the disconfirmation at trial 3 causes a shift to a new dimension, yielding the sequence $-\underline{H}_{1-i}$ $+\underline{H}_{2-i}$ $-\underline{H}_{3-j}$. It should be obvious that this sequence is identical to that produced by

D and, if $\underline{H}_j = \underline{H}^+$, by Fo. The confounding with D will be treated here; the confounding with Fo will be treated subsequently.

If $\underline{H}_j = H^+$ then the sequence could be the result of H-Ch or of D. A simple way to deconfound is to view the next hypothesis the subject employs. If his system is H-Ch, then he will show $-\underline{H}_{1-i}\ \ +\underline{H}_{2-i}\ \ -\underline{H}_{3-j}\ \ -_4 op\underline{H}_j$. This clearly is not a product of D. If, on the other hand, the subject is holding the D system, then he will show $-\underline{H}_{1-i}\ \ +\underline{H}_{2-i}\ \ -\underline{H}_{3-j}\ \ -\underline{H}_{4-k}$.

In summary, (H-Ch') manifestation:

$(H\text{-}Ch)_1$: $-\underline{H}_{1-i}\ \ +\underline{H}_{2-i}\ \ -_3 op\underline{H}_i$, or

$(H\text{-}Ch')_2$: $-\underline{H}_{1-i}\ \ +\underline{H}_{2-i}\ \ -_3(\underline{H}_j = \underline{H}^+)\ \ -\underline{H}_{4-k}$

Fo' manifestation: $-\underline{H}_{1-i}\ \ +\underline{H}_{2-i}\ \ -_3(\underline{H}_j = \underline{H}^+)$

Correction required: Whereas with previous feedback sequences only the D and Fo systems yielded the same hypothesis sequence, here three systems $(H\text{-}Ch)_2$ as well as D and Fo, can yield the same hypothesis sequence. The derivation of the correction here, however, parallels the derivation in the previous cases.

Thus, the corrected frequency for $(H\text{-}Ch)_2$ contains two components, those sequences, here labelled $(H\text{-}Ch')_2$, not confuseable with the other two system patterns, and the sequence which resembles that from the Fo system, labelled $(H\text{-}Ch^*)_2$. The frequency of $(H\text{-}Ch)_2$ is the sum of the two frequencies, i.e.,

$$f(H\text{-}Ch)_2 = f(H\text{-}Ch')_2 + f(H\text{-}Ch^*)_2.$$

Similarly, $f(D) = f(D') + f(D^*)$

Also, $f(Fo) + f(Fo') - f(H\text{-}Ch^*)_2 - f(D^*)$.

Values for the primed variables are obtained directly from the data. In order to determine the corrected values of the systems, i.e., $f(H\text{-}Ch)_2$, $f(D)$ and $f(Fo)$, it is necessary first to determine the values of $f(H\text{-}Ch^*)_2$ and $f(D^*)$. These may be obtained from the following considerations:

For $(H\text{-}Ch)_2$: A subject's hypothesis sequence will resemble the Fo system only if the correct dimension is second on his list. Since it cannot be first on the list (H_i cannot be H^+ because of the error given at the third feedback trial), it will be second one-third of the time. Therefore, $P\left[(H\text{-}Ch^*)_2 \middle| (H\text{-}Ch)_2\right] = 1/3$, and $P\left[(H\text{-}Ch')_2 \middle| (H\text{-}Ch)_2\right] = 2/3$. From this we obtain, $f(H\text{-}Ch^*)_2 = (1/2)f(H\text{-}Ch')_2$.

For D: The consideration which applies to $(H\text{-}Ch)_2$ applies here. One-third of the time a subject who holds the D system and who receives the feedback sequence $-_1 +_2 -_3$ will have the correct dimension second on his list. Therefore,

$P(D^* | D) = 1/3$, $P(D' | D) = 2/3$, and

$f(D^*) = (1/2)f(D')$.

The appropriate corrected equations are

$$f(H\text{-}Ch)_2 = f(H\text{-}Ch')_2 + (1/2)f(H\text{-}Ch')_2$$

$$f(D) = f(D') + (1/2)f(D'), \text{ and}$$

$$f(Fo) = f(Fo') - \left[(1/2)f(H\text{-}Ch^1)_2 + (1/2)f(D')\right].$$

Appendix D

Sample Data Sheet With Each Hypothesis-Sampling System Illustrated.

one stimulus array

one stimulus card

Group ______ Age ______ Name ______ S No. ______

Solution	Problem	Forms	Colors	Feedback	Order Strategy												
X	1	X,T	red=white green=black	+,-,-	Focusing	F1 s b T ld	l w X lu	H1	F2 l b T lu	s w X ld	H2	F3 l b X ld	s w T lu	H3	F4 s b X lu	l w T ld	H4
							+	large	−		white		−	X	+		X
						F5 l w X lu	s b T ld	H5	F6 l b T lu	s w X ld	H6	F7 l w T ld	s b X lu	H7	F8 s w T lu	l b X ld	
						+		X		+	X		+	X		+	
large	2	S,J	green= white orange=black	+,-,-	Dimension Checking	F1 l w S lu	s b J ld	H1	F2 s w S ld	l b J lu	H2	F3 l b S ld	s w J lu	H3	F4 s b J ld	l w S lu	H4
						+		white	−		L U.		−	S		+	S
						F5 s b S lu	l w J ld	H5	F5 s w J lu	l b S ld	H6	F7 l w S lu	s b J ld	H7	F8 s w S ld	l b J lu	
						−		large		+	large	+		large		+	
L	3	N,L	blue=white brown=black	+,+,-	Hypothesis checking	F1 s w N ld	l b L lu	H1	F2 s b N lu	l w L ld	H2	F3 s b L ld	l w N lu	H3	F4 l b N ld	s w L lu	H4
							+	large		+	large		−	small		+	small
						F5 l b L lu	s w N ld	H5	F6 s b N lu	l w L ld	H6	F7 s b L ld	l w N lu	H7	F8 l b N ld	s w L lu	
							=	L U	−		L D.	+		L D	−		
X	4	S,X	blue=white green=black	+,+,-	Stimulus Preference "black"	F1 l w S ld	s b X lu	H1	F2 l b X ld	s w S lu	H2	F3 l b S lu	s w X ld	H3	F4 l w X lu	s b S ld	H4
							+	black	+		black	−		black		−	black
						F5 s b X lu	l w S ld	H5	F6 s w S lu	l b X ld	H6	F7 s w X ld	l b S lu	H7	F8 s b S ld	l w X lu	
						+		black		+	black		−	black	−		
small	5	T,V	red=white blue=black	+,-,-	Position Perseveration "left"	F1 s w T ld	l b V lu	H1	F2 l b T ld	s w V lu	H2	F3 l w V ld	s b T lu	H3	F4 s b V ld	l w T lu	H4
						+		LLLL	−		LLL	−		LLLL	−		LLLL
						F5 s w V lu	l b T ld	H5	F6 s w T ld	l b V lu	H'	F7 s b T lu	l w V ld	H7	F8 l w T lu	s b V ld	
						−		LLLL	−		LLLL	−		LLLL	−		
V	6	P,V	purple=white pink=black	-,+,-	Position Alternation "left-right"	F1 l w P ld	s b V lu	H1	F2 s w P lu	l b V ld	H2	F3 l b P lu	s w V ld	H3	F4 s b V lu	l w P ld	H4
						−		RLRL		+	LRLR	−		RLRL		−	LRLR
						F5 l w V lu	s b P ld	H5	F6 l b P lu	s w V ld	H6	F7 l b V ld	s w P lu	H7	F8 s b P ld	l w V lu	
						+		RLRL		+	LRLR	+		RLRL		+	
line down	7	R,J	purple=white orange=black	-,-,+	Unsystematic	F1 l w R ld	s b J lu	H1	F2 s w R lu	l b J ld	H2	F3 s b R ld	l w J lu	H3	F4 s b J lu	l w R ld	H4
							−	white	−		J		−	black	−		large
						F5 s w R lu	l b J ld	H5	F6 s w J ld	l b R lu	H6	F7 s b R ld	l w J lu	H7	F8 l b J ld	s w R lu	
							+	large		−	L D	+		L.D.	+		

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F1 = Feedback one
S = small l = large
b = black w = white
T = T X = X
LD = Line down / LU = Line up

H1 = Hypothesis one — inferred from 4 cards constituting a blank-trial probe

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