A DEVELOPMENTAL COMPARISON OF TWO TYPES OF INFERENTIAL REASONING PROBLEMS

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by

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A Thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

Department of Psychology
Memorial University of Newfoundland
March 1977

St. John's Newfoundland

ACKNOWLEDGMENTS

This research was supported by a Scholarship awarded by the National Research Council of Canada, which was held by the author from March 1975 to September 1976.

I would like to express my deepest appreciation for the help and guidance provided by my Thesis supervisor, Dr. S.D. Moeser, whose advice and understanding was invaluable in the completion of this work. I remain grateful to Dr. R. Anderson and Dr. J. Strawbridge for their critical comments and helpful suggestions.

And, of course, I will always be indebted to my family and friends for their kind encouragement and patience.

ABSTRACT

An experimental paradigm was devised to extend and clarify the current literature on transitive inferential reasoning in children. Two analogous forms of reasoning problems--defined as locative sequences and serial orderings--were compared across the age levels of Kindergarten, Grade 2 and Grade 6. A two-alternative forced-choice test assessed performance on inference questions and on memory for the premises from which the inferences were drawn. There were no differences among the three age groups in inferential performance on the locative sequence problems but a marked age trend in performance on the serial ordering problems. However, a significant developmental interaction was not present in the memory question data nor in a separate memory control condition. The different developmental pattern of findings for the two problem types was explained in terms of the difficulty encountered by young children in representing a serially ordered information sequence in memory.

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I. INTRODUCTION

Traditionally, it is assumed that the ability to reason logically is an intellectual skill which develops gradually with age. However, Moeser (1976) recently reported findings that appear to contradict this assumption. She presented subjects in Kindergarten, Grade 2, Grade 6 and Grade 9 with sequences of one-proposition sentences such as <u>The ants ate the jelly</u>, <u>The jelly was on the table</u>, <u>The table was in the kitchen</u>. They were then tested on their ability to derive logical inferences from these statements, i.e., on whether they could infer that <u>The ants were in the kitchen</u>. Performance on this task was only 65% correct but was identical for the four age levels. Similarly, Paris and his colleagues (Paris & Carter, 1973; Paris & Mahoney, 1974) have failed to find any developmental trends in children's tendency to spontaneously generate inferences from sequences of semantically related one-proposition sentences.

Moeser (1976, Exp. II) also gave subjects from Kindergarten, Grade 2, Grade 6, Grade 9 and college, problem sets containing four statements, two of which could be used to infer another statement. An example of a problem sequence is: <u>The doll is in the small crib</u>, <u>The toy truck is on the sidewalk</u>, <u>The small crib is under the tree</u>, <u>The clown is riding on the donkey</u>. In this set, the first and third sentences can be used to derive the inference, The doll is under the tree. The subject's task is to choose between the correct inference and an incorrect alternative (e.g., The doll is on the sidewalk). Although the results revealed a slight age trend, there was an improvement in performance only at the Grade 9 and college levels; there were no differences among the Kindergarten, Grade 2 and Grade 6 protocols where developmental changes were expected.

Recently, Moeser (1976, Note 1) attempted to see whether this lack of a developmental trend might be attributed to the fact that the subjects had not learned the material sufficiently or simply had forgotten the individual premises by the time of test. She trained Kindergarten, Grade 2 and Grade 6 children on the individual premises until each could be recalled without error. Inference performance greatly improved for all subjects, but there were still no differences among the various age groups.

The type of reasoning task used in these studies can be expressed according to the axiomatic format: A $\underline{x}$ B, B $\underline{x}$ C, $\supset$ A $\underline{x}$ C, where the alphabetic characters represent the elements to be related (e.g., people, object names), $\underline{x}$ refers to some form of relational connective and the symbol "$\supset$" refers to an inferential implication derived from the previous two premises. The elements A and C, though never presented together in one statement, are both related to the element B. The subject must use this common

B element to coordinate the two disparate informational sequences and to generate the third proposition.

In the problems described above, the relationships among elements are expressed by locative prepositions. However, a more common type of inference problem defines the relationships in terms of comparative adjectives. An example would be, Edith is taller than Suzanne, Suzanne is taller than Lili, followed by the question, Who is the tallest: Edith, Suzanne or Lili? In order to derive the logically necessary conclusion that Edith is the tallest of the three, the subject is required to go beyond the individual comparisons given and combine the information from these two separately presented statements. The critical 'pivot' term here is "Suzanne" as it holds the status of common coordinator (the B element) within the two relationships. Thus, as in the locative sequence tasks, this type of inference connects two items by virtue of their relationship to a third. However, unlike locative sequences, comparative problems require that the elements in the statements be ranked along a continuous dimension with respect to the particular property expressed by the relational terms (e.g., height). That is, the relationships can be represented in terms of linear arrays in which the elements occupy serially ordered positions along a scale. Because of this particular property, these comparative reasoning tasks will be referred to as serial ordering problems.

Both locative sequence and serial ordering problems can be expressed in the same general axiomatic form described above. Though they differ in the nature of the relational concepts that interconnect the relevant premises, the two types of problems have analogous structural formats. For this reason, it might be expected that the same reasoning processes should underlie both types of problems. However, in contrast to the findings with locative sequences, the developmental literature provides much empirical evidence of ontogenetic changes in the ability to solve serial ordering problems.

Developmental trends between the ages of 5 and 11 years have been found on a variety of transitive inference problems using comparative relationships (Inhelder & Piaget, 1958, 1964; Piaget & Inhelder, 1967). In one type of study, subjects are presented with relationships expressed between actual physical objects. For example, the child is shown a tower of a certain height and is instructed to build a second tower of equal height but from blocks of different sizes to prevent a one-to-one reconstruction. The child must also take into consideration that this second table is a different height than the first and is situated behind a screen to prevent any direct visual comparison. To solve the problem, the child must use one of a variety of possible measuring instruments available to him to measure the first tower and to compare this measurement with the height of the tower he is building. In this way, the measuring instrument functions as a logical middle term through which the child can compare the two towers. This ability is assumed to indicate an understanding of inferential relations, which young pre-operational children (i.e., prior to 7-8 years of age) presumably do not possess (Piaget, 1953a; Piaget, Inhelder & Szeminska, 1960; Pulaski, 1971).

Another form of serial ordering problem that has been commonly studied involves the concrete transitivity of length. The basic paradigm involves showing the subject a pair of sticks A and B (of which A is longer), and then sticks B and C (of which B is longer) and later asking, "Which stick is the longest: A or C?" The studies are usually designed so that the particular stimulus materials and their manner of presentation prevent any solutions by direct perceptual means. Using this type of task, Smedslund (1963) presented children with sticks of different lengths, comparing each of the sticks until the subjects had learned all of the relationships. On a subsequent test for ability to deduce inferences based on these length relationships, he discovered an improvement from 4 to 10 years of age. None of the children at the 4-6 year old level, as compared to 85% of the oldest age group, were successful in attaining solutions.

Bryant and Tabasso (1971) studied the performance of children on a five term series problem using sticks that were color coded to represent differences in length. They found an improvement in performance on the critical inference pairs from 4 to 6 years of age. Developmental differences also appeared in the inferential performance of children on similar transitivity of length tasks (Trabasso, 1975; Trabasso, Riley & Wilson, 1975).

Murray and Youniss (1968) reported a significant age trend in Kindergarten, Grade 1 and Grade 2 children on a task in which the length relationships were expressed in the format A=B, B>C, but not when they were presented as A>B, B>C or as A>B, B=C. These findings were explained in terms of certain non-transitive strategies by which even young children can solve the problems if they are presented in either of the two latter forms. Youniss and Murray (1970) demonstrated advances through the ages of 6 to 8 years, though even at the oldest ages, only 31% of the subjects could perform perfectly on all three forms of the problem. Roodin and Gruen (1970) found that inferences involving length concepts increased from 5 to 7 years of age for both criteria of correct judgment and correct verbal justification. Coon and Odum (1968) included older age groups in their sample and reported a tendency for the number of transitive inference errors to decrease as age increased from 8 to 15 years.

Developmental trends have also been found in concrete tasks that involve other kinds of relationships. In a transitivity of weight task, the experimenter compares the weights of a series of colored blocks (e.g., A with B, B with C and C with D) and then pretends to weigh A and D, asking the child to predict their relative weights. Hyde (1970) found an ~~age trend~~ in the attainment of such inferential concepts for 6 to 8 year olds from a number of different cultural backgrounds. Cowan (1963) also demonstrated that performance on problems involving weight relations increased over an 8 to 13 year age span.

Serial ordering problems have also been presented such that inferential judgments had to be made solely on the basis of verbally presented hypothetical premises. Cowan (1963) found developmental trends when his transitivity of weight problems were expressed verbally. Glick and Wapner (1968) found a monotonic increase in performance on both concrete and verbal tasks as a function of age from 8 to 18 years on both measures of correct inferences and adequate justifications. Donaldson (1963) and Donaldson and Wales (1970) reported studies in which children were told 'stories' involving various serial relationships (e.g., height, age) and were later asked inference questions. Younger children experienced difficulty in attaining correct logical conclusions and in justifying their responses. The verbal mode of presentation has also been used by Piagetian researchers (Piaget, 1950, 1966, 1967; Piaget, Inhelder & Szeminska, 1960) who have reported developmental differences between the ages of 5 and 12 years of age in such tasks.

Although it appears that there are age differences when either form of presentation is used, there is some evidence to suggest that transitivity is achieved earlier with concrete means of presenting the material. This finding comes from serial ordering studies in which concrete materials have been used (Braine, 1959, 1964; Bryant & Trabasso, 1971), those involving a verbal presentation of the relational information (Donaldson, 1963; Piaget, 1966, 1967) and those which provided a direct comparison of the two modes (Cowan, 1963; Fisher, 1952; Glick & Wapner, 1968).

All of these data appear to support the view that inferential reasoning ability emerges relatively late in the course of cognitive development. Yet, they are contradicted by the findings obtained with locative sequences which have failed to uncover such a clear developmental pattern. This is of particular interest, since locative sequence problems have typically been presented in the form of verbally stated hypothetical premises from which one would expect developmental trends due to the young child's limited verbal skills. If the young child is indeed unable to make inferential judgments on logical problems of the serial ordering type and yet performs as well as adults on a similar form of reasoning problem that involves locative-spatial information, then a question arises as to his true logical competence. This issue is particularly relevant since transitive inference tasks involving comparative relationships have been typically used as indices of intellectual growth (e.g., Flavell, 1963; Osherson, 1974; Piaget, 1950, 1953b, 1967; Piaget, Inhelder & Szeminska, 1960; Sigel & Hooper, 1968).

Before assuming that these two types of problems differ significantly on a developmental factor, we must consider that such disparities in the developmental literature dealing with children's inferential behavior may simply reflect critical methodological differences in the paradigms used to test for them. One of these differences is in the kind of stimulus materials used for the two types of problems. The verbal materials typically employed in serial ordering problems have involved reference to people's names. These names may be particularly difficult to represent in memory or to retain over time especially for younger individuals whose verbal systems are relatively immature. The proper nouns such as "Edith", "Suzanne" or "Lili" have no readily identifiable or easily distinguishable imaginal referents to manipulate or transform in the course of problem solution. The use of such materials probably serves to discourage the use of imaginal mnemonics. Thus, subjects attempting to encode the relational information expressed as serial ordering problems may have had to adopt a more verbal type of processing strategy that is not readily available to younger children. On the other hand, most locative sequence studies have utilized high imagery concrete nouns such as "doll", "tree", "table" which may be easier to represent in memory, thus facilitating their performance. Some evidence for this suggestion comes from studies conducted by Riley (1976) who found a dramatic improvement in the inferential responding of young children when they were provided with pictures of faces to associate with the names. These kinds of differences in stimulus materials for the two types of problems may have played a significant role in producing a different developmental pattern of results.

Some of the designs used to study serial ordering problems may actually have been insensitive to the presence of transitive reasoning ability. Braine (1959) argues that such tasks as tower building involve a knowledge of measurement concepts that tends to confound true transitivity ability and thus is an inappropriate technique for studying inferential reasoning. He also contends (Braine, 1964), that the capabilities of young children similarly tend to be underestimated when verbal methods of testing are used. He conducted an experiment using a non-verbal training and assessment procedure and found that children as young as 4-5 years of age were able to arrive at correct inferential conclusions. The simple training and testing procedure employed by Trabasso and his colleagues (e.g., Bryant & Trabasso, 1971; Riley & Trabasso, 1974) also suggest that the developmental differences described in the literature might not be so marked when tasks are constructed which tap the actual logical abilities of the young child.

This problem of insensitivity of the test to measure genuine inference ability also applies to some of the locative sequence tasks studied. However, in this case, the error would lead one to interpret the presence of inferential ability in younger children when in fact it is absent. For example, the false recognition paradigm has been employed by some researchers (e.g., Paris & Carter, 1973; Paris & Mahoney, 1974) as an index of inferential behaviour. In this paradigm, the subject is presented with a set of semantically related sentences and later given a test containing these original statements plus inferential statements that were not presented before but could be derived from the original ones. Identifying the inferential statements as having been presented before was assumed to be indicative of inferential reasoning. However, this type of test is relatively insensitive to developmental changes simply because of a positive recognition bias on the part of the younger children--they tend to make more 'yes' responses than older children regardless of test content. By using a paradigm that is inappropriate for a developmental analysis, it is not surprising that Paris and his colleagues failed to find age trends in solutions to locative sequence problems. Indeed, they must conclude that the younger children tend to perform better on the inference test due to their pre-disposition to make more recognition errors on all of the test items.

Other studies have failed to eliminate the utilization of solution strategies that provide correct inferential conclusions through non-transitive means. Smedslund (1965, 1969) has pointed out a number of such strategies that, if not controlled for, would create a misleading impression of the child's actual abilities. One of the possible strategies recognized by many researchers (e.g., Bryant & Trabasso, 1971; Murray & Youniss, 1968; Smedslund, 1963; Youniss & Murray, 1970) is the ability to get inferences correct by simply 'parrotting back' a verbal label learned during the initial comparisons. For example, in the sequence A>B, B>C, the term "A" has always been designated as bigger, "B" sometimes as bigger but "C" never bigger than anything else. Thus, when asked "Which is bigger: A or C?", the child chooses the correct solution "A", but only because it was the only item that had been consistently labelled as "bigger" during the acquisition trials. The availability of this strategy in the test situation leads to the interpretation that genuine inferences had occurred when, in fact, they had not.

The developmental literature also contains many experiments that are inextricably confounded by a number of extraneous factors. For example, some researchers have attempted to control for the factor of guessing in concrete transitivity of length tasks by incorporating Mueller-Lyer illusions into their test measures. Thus, if the correct inferential choice was the longer of the two sticks, the materials were constructed so as to make this stick appear shorter than the incorrect alternative. It was assumed that the tendency to overcome the countervailing perceptual illusion to choose the correct stick indicated a relatively stable concept of transitivity. Using these techniques, some researchers claim to have found developmental trends (McManis, 1968; Roodin & Gruen, 1970; Smedslund, 1963). This procedure, however, obviously confounds inferential performance with the fact that younger children may tend to be more susceptible to perceptual illusions. There is some evidence to suggest that children tend to interpret relational terms such as "big" and "more" in terms of their phenomenal instead of actual size (Braine, 1964), and would therefore incorrectly choose the alternative suggested by the illusion. Other researchers have used the willingness to conform to social pressure as an index of the stability of transitivity concepts (e.g., Coon & Odum, 1968). They found that as age increased there was a decrease in the tendency of children to agree with the non-inferential conclusions of others. Again, inferential behavior is necessarily confounded by changes in one's tendency to conform to peer standards as a function of age.

The Present Study

The literature review suggests that children encounter much difficulty in reasoning about comparative relationships expressed in the form of inference problems but are relatively facile in dealing with locative-spatial information. However, it appears that there are many factors that tend to create an experimental situation which is more amenable to finding significant age trends in serial ordering problems and none when locative sequence problems are studied. More experimental investigation into the area is required in order to clarify the pattern of findings associated with the two types of reasoning problems.

Hitherto, there have been no studies which involved a direct comparison of performance on both problems by the same subject. This approach would not only help to resolve the developmental issue, but would also provide a means to evaluate two hypotheses that have been offered to explain the age trends in serial ordering problems. One interpretation is, of course, the traditionally held notion of an underlying deficit in logical thinking in the young child. Another view is that the developmental findings simply reflect a difficulty in handling serially ordered information sequences. That is, the young child is less efficient in establishing a representation of a series of items in memory. This position, like the former, would predict an age factor in solving serial ordering problems but, unlike the former argument, would not predict such age discrepancies in the locative sequence data. The within-subject design adopted in this study enables us to separate and examine these two hypotheses experimentally.

Since the developmental literature on inferential reasoning appears to be plagued with methodological problems, the experimental paradigm attempted to eliminate many of the factors contributing to misinterpretation of previous findings. For example, the same methodology, problem formats and modes of presentation were used for both types of problems. To mitigate the argument that different trends in the data are due to the nature of the stimulus materials, common and easily imageable nouns were used in all of the problem sets. To reduce any linguistic difficulties with the relational terms, only the "unmarked" form of the comparative adjectives was used (e.g., "taller than" as opposed to "shorter than"). These have been shown to be more easily comprehended by children (Donaldson & Wales, 1970) and adults alike (Clark, 1969a, 1969b). In addition, only comparatives which refer directly to concrete and physical dimensions were employed. Riley (reported in Trabasso, 1975) has suggested that children tend to find these forms easier than adjectives which do not have direct physical referents.

Inferential responses were measured using a forced choice recognition test which, according to Anderson and Bower (1973, p. 351), is a sensitive test for the contents of the memory store. The children were also tested on their memory for the individual premises which make up the critical inferences to ensure that they were able to remember the material at the time of test and to provide additional information as to how the propositions might be stored and combined in the memory system.

This type of test measure also eliminated the possibility of subjects assigning differential size labels to each of the elements. Repeating back verbal labels would be of no value in a paradigm which uses a forced-choice task as its test measure. In each of the inference questions, the subject had a choice between two alternatives, both of which contained an "A" term which exceeded the other two terms on some dimension (e.g., "Is A>B or is A>X?"). This rendered it more likely that correct responses actually reflected genuine inference ability.

Some researchers claim to have demonstrated evidence of transitive reasoning ability at approximately 4-6 years of age (Braine, 1959, 1964; Brainerd, 1973; Bryant, 1973; Bryant & Trabasso, 1971; Harris & Bassett, 1975). However, research efforts have also been directed toward a substantiation of the Piagetian estimate of 7-8 years of age (McManis, 1969; Murray & Youniss, 1968; Smedslund, 1963, 1965; Youniss & Furth, 1973; Youniss & Murray, 1970) and a heated controversy over both data and interpretation has arisen. These findings have given rise to the cognitive-developmental issue concerning the accurate specification of the age at which reasoning ability first occurs. Since the controversial literature centers around the age of 5-6 years (Kindergarten) and 7-8 years (Grade 2), these age groups were studied in their performance on both types of reasoning problems. Since there is a significant transition that appears to occur in the child's manner of reasoning about relational operations in the period between 7 and 11 years of age (according to Piaget), subjects of 11-12 years of age (Grade 6) were also included to allow the further demonstration of developmental trends, if any exist.

It is predicted that there will be a significant interaction between age and problem type, i.e., that there will be a developmental trend in the data for serial ordering problems but none in the data for locative sequence problems. This finding would support the pattern of results documented in the literature on inferential reasoning in children and thus discount explanation in terms of methodology differences. This finding would also suggest a specific problem on the part of the younger children with serially ordered information sequences as opposed to an actual logical inability to deal with relational information per se.

II. METHOD

Subjects

Thirty-six elementary school children were randomly sampled from each of grades Kindergarten, 2 and 6 with equal numbers of males and females from each grade. The school that these children were attending was under the jurisdiction of the Roman Catholic School Board and is situated in Manuels, Conception Bay, Newfoundland.

Materials

Three locative sequence problems and three serial ordering problems were constructed, the former consisting of the relations "in-under", "in-in", "on-in" and the latter expressing the comparative relations "fatter than", "bigger than", "taller than". Each problem was presented as a pair of interrelated premises with a third unrelated sentence. The first sentence linked element A with element B (Premise 1) and the second sentence linked the same element B of the first premise with a third element C (Premise 2). The last sentence introduced a relationship between two new items (X and Y) which were not logically related in any way to the preceding two premises. This distractor sentence was designed such that its elements were able to fit readily into the overall theme expressed by the related sentences, thus providing a source of plausible alternatives in the forced choice tests which followed. An example of this format taken from the locative sequence problems is as follows: "The tiny gray mouse (A) was in the basket (B). The basket (B) was under the large bed (C). The spider (X) was under the armchair (Y)"; an example from the serial ordering problems is: "The old sailor (A) was fatter than the soldier (B). The soldier (B) was fatter than the fireman (C). The policeman (X) was fatter than the farmer (Y)." Each of the problems was always presented in the order of Premise 1, Premise 2 and distractor. For both problem types, the elements consisted of common animal and object names that are familiar to children.

Three additional problem sets were constructed wherein the A, B, C, X and Y elements were interchanged to control for the possibility of response biases based upon prior learned verbal associations or intuitive expectancies concerning what sorts of inter-item relationships are most likely to occur in real life situations. These control versions were of the following formats: Version 2 exchanged elements C and Y in Version 1, thus controlling for response biases concerning C and Y. An example of this format is: "The tiny gray mouse (A) was in the basket (B). The basket (B) was under the armchair (Y). The spider (X) was under the large bed (C)." Version 3 exchanged elements A and X in Version 1, e.g., "The spider (X) was in the basket (B).

The basket (B) was under the large bed (C). The tiny gray mouse (A) was under the armchair (Y)." Version 4 exchanged elements C and Y in Version 3, e.g., "The spider (X) was in the basket (B). The basket (B) was under the armchair (Y). The tiny gray mouse (A) was under the large bed (C)." All of the stimulus materials are presented in Appendix A.

Each problem was followed by three types of questions: (1) inference, (2) memory for the first premise, (3) memory for the second premise. The question testing for inferential ability required the subject to choose between the correct inferential conclusion and an incorrect alternative. For example, for Version 1 of the problems previously described, the inference question consisted of the following, "Was the tiny gray mouse (A) under the large bed (C) or was the tiny gray mouse (A) under the armchair (Y)?" For the other control versions, this question entailed the decisions: (2) AY-AC, (3) XC-XY, (4) XY-XC. Similarly, the question testing for memory for Premise 1 was constructed in the form AB-XB, e.g., "Was the tiny gray mouse (A) in the basket (B) or was the spider (X) in the basket (B)?" The other versions of this question were: (2) AB-XB, (3) XB-AB, (4) XB-AB. The question testing for memory for Premise 2 was of the form BC-BY, e.g., "Was the basket (B) under the large bed (C) or was the basket (B) under the armchair (Y)?" The other versions were of the format: (2) BY-BC, (3) BC-BY, (4) BY-BC. Thus, by constructing the four problem versions in this manner, the two alternatives in each of the three forced-choice questions which followed a problem were completely counterbalanced such that both were correct and incorrect an equal number of times across and within subjects. The inference question was always asked immediately following the completion of problem presentation (i.e., before the two memory questions were asked) to ensure that subjects were basing their inferential judgments solely upon information acquired from the initial problem presentation and were not being aided by the premises being repeated in the memory questions.

Procedure

The experiment was conducted in a small room which was provided by the principal of the school. The experimenter (a female graduate student) and the subject sat in desks facing each other. After conversing with the child for a minute or two, the experiment commenced with the following instructions:

> I am going to read you some stories and I would like you to listen really carefully because at the end of each story, I'm going to ask you some questions to see how much you can remember about it, okay? So, listen very carefully.

Experimental Group

There were 12 male and 12 female subjects in each of grades Kindergarten, Grade 2 and Grade 6 who were tested on their reasoning ability. They were assigned to conditions according to the order in which they arrived. The first subject received Version 1 of the problems; the second, Version 2, and so on. One half of the subjects of each sex and grade received the problem sets starting with a locative sequence problem and half started with a serial ordering problem, with the five subsequent problem types alternating. The order of testing the two premises was also alternated such that each premise was tested first (following the initial inference question) for half of the problems and tested second for the remaining half.

The experimenter read each of the three sentences in a problem twice. Each of these sentences was followed by an acquisition question to ensure that the child had heard it accurately and understood its meaning. After the child responded to the question, the sentence was repeated before proceeding to the next sentence. As an example of this procedural format, consider the following locative sequence problem:

Experimenter:	The comic book was on the red wagon. The comic book was on the red wagon. Where was the comic book?
Child:	On the red wagon.
Experimenter:	That's right. The comic book was on the red wagon.

The next two sentences were presented in the same manner. All of the locative sequence acquisition questions were of the form, e.g., "Where was the comic book?"; all of the serial ordering acquisition questions were of the form, e.g., "What was the apple tree taller than?" Whenever the subject responded incorrectly to an acquisition question, the experimenter read the sentence twice and asked the question again. The task required about 10-15 minutes to complete.

Control Group

A second group of 36 children (12 per grade level) were assigned to a condition which controlled for the possibility that differences in inferential and/or memory performance for the two types of problems could be attributed to pre-experimental biases in retention for the words making up the two types of problems. These subjects were therefore presented with a Yes-No noun recognition test that assessed their ability to remember the nouns which comprised the locative sequence and serial ordering problems received by the experimental subjects.

Two noun lists were constructed: one consisting of the 15 nouns (and their modifiers) which were used in the locative sequence problems, and the other consisting of those nouns (plus modifiers) used in the serial ordering problems. All of the subjects were tested on both noun lists. Half of them received the nouns used in the locative sequence problems first and half received the nouns used in the serial ordering problems first. The nouns in the two lists were randomly arranged with the provision that one word from each of the three problem sets was read before another word from that set was presented. Three different list orders were constructed for both problem types and each was given to four subjects in each grade. These lists are illustrated in Appendix B. Each subject was first given the following instructions:

> I am going to read you a list of words that I would like you to remember for me. After I read them to you, I will read you another list of words and I want you to tell me which words I said before, okay? So, listen very carefully to all of these words and try to remember them for me.

Then, the first list of 15 nouns was read at a rate of approximately one item every two seconds. Following this acquisition phase, the subject received a test list which consisted of the original 15 nouns plus 15 additional distractor items that were not heard before. The child was instructed to say "Yes" or "No" on the basis of whether or not he felt that he had heard the word in the test list presented before. After this first test was completed, the second list of nouns was read which was followed by the second test (refer to Appendix C for the noun tests).

The control subjects also ensured that children of these ages could adequately comprehend the meaning of the particular relationships that were entailed in the inferential judgments. After the two noun tests were administered, each subject was presented with a picture relations test which consisted of six pairs of 29 cm by 21 cm drawings which pictorially illustrated the spatial and comparative relationships expressed in each of the inference problems (refer to Appendix D). The experimenter said, "Now I'm going to show you some pictures and ask you some questions about them." She then held up each pair of pictures and asked questions of the form: e.g., for the locative relations, "Which apple is in the basket? Which cup is on the drum? Which pair of skates is under the table?" and for the serial relations, "Which snowman is fatter? Which pig is bigger? Which flower is taller?" The subject was instructed to point to the picture in each pair which illustrated the relational concept.

Subjects who received the locative noun test first also received the locative picture relations test first and vice versa. These two memory control tasks required about 10 minutes to complete.

III. RESULTS

Control Group

The number of correct "yes" responses (hits) and the number of incorrect "yes" responses (false alarms) on both noun tests were calculated for each subject. These data were first transformed into d' scores (after Hochhaus, 1972) before any further analysis was done. This procedure served to control for the possibility that one of the noun lists may have been intrinsically more difficult than the other due to greater confusion arising between the target items and the false alternatives. A two-way analysis of variance performed upon these transformed scores failed to reveal any statistically reliable differences between the memory performance on these two lists of nouns, $\underline{F}$ (1, 33) = .70, MS_e = .51. Neither was there a significant interaction between noun type and age, $\underline{F}$ (2, 33) = .66, MS_e = .51.

Figure 1 illustrates the hit rate as a function of problem type and age. The failure to obtain significant differences between groups on this factor mitigates the argument that the pattern of results found for the experimental group could be merely due to difficulties experienced in learning those particular nouns used in one of the two problem types. The analysis indicates that subjects of all

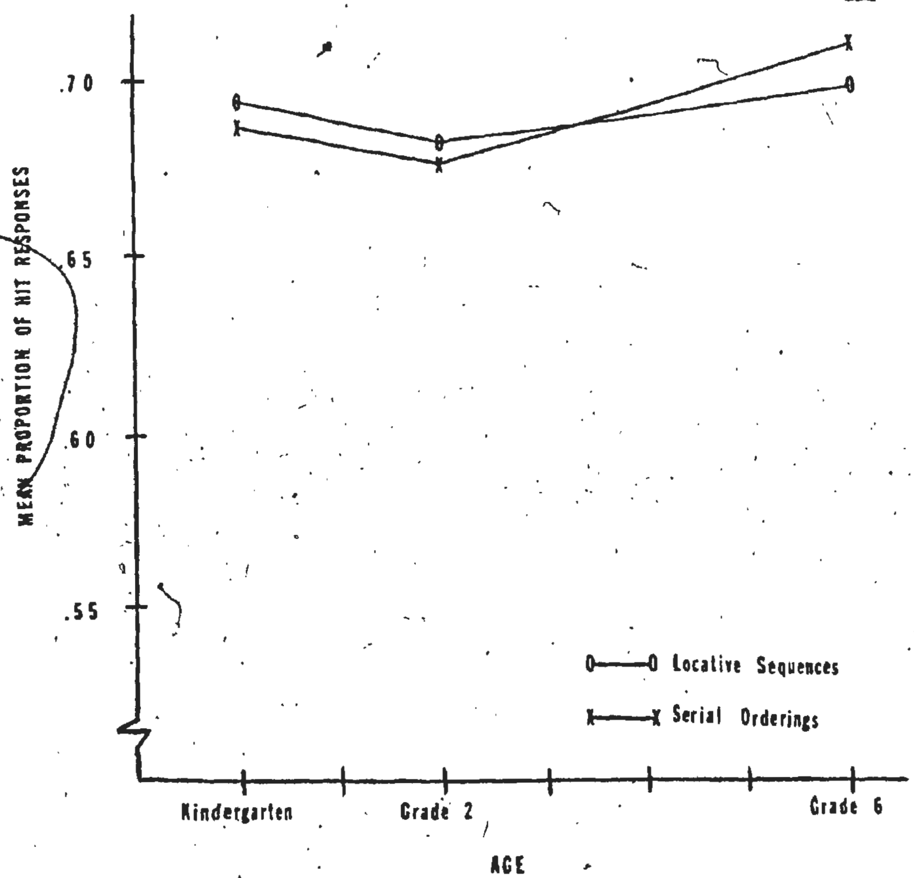

Figure 1. Mean proportion of hit responses made on the two noun tests as a function of age.

ages were as able to remember the nouns used in serial problems as they were able to remember the nouns used in locative sequence problems. The analysis of variance summary table is shown in Appendix E.

None of the subjects experienced any difficulty in providing correct responses to the picture relations test. Because every one of them scored 100% in their comprehension of each of the six relational expressions, it was not necessary to submit these responses to any statistical analysis. These findings indicate that the particular serial and locative relationships chosen for the experiment were readily understood by each of the age groups involved.

Experimental Group

The number of correct inferences obtained by each subject was submitted to a 3 x 2 analysis of variance with age (Kindergarten, Grade 2, Grade 6) as one factor and problem type (serial ordering problems versus locative sequence problems) as the other factor, with repeated measures performed on the latter. The inference scores revealed a significant main effect of problem type, $\underline{F}$ (1, 69) = 9.73, MS_e = .48, which indicates that the subjects over all ages tended to be more successful at drawing inferences of a spatial-locative nature than on those involving serial relationships. The interaction between age and problem type also proved to be statistically significant, $\underline{F}$ (2, 69) = 3.12,

$MS_e = .48$. As can be seen in Figure 2, performance on locative sequence problems remained comparable across all ages at a relatively high 80% level whereas success on serial ordering problems tended to increase monotonically with age from a low rate of 57% to a maximum of 80%, matching performance on the locative sequence problems. Thus, the significant difference between problem types appears to be due primarily to a much poorer performance on the serial ordering problems by the younger children. The analysis of variance summary table for these data appears in Appendix E.

This tendency for an age trend on the serial problems is evident in each of the three kinds of comparative relations employed. However, there is no indication of an age trend in any of the locative relationships tested. (See Appendix F for a table illustrating performance on the individual problem sets).

The memory scores on the two premises were submitted to a 3 (age) x 2 (problem type) x 2 (premise) analysis of variance. The summary table for this analysis is presented in Appendix E. The only significant finding was an effect of problem type, $F\ (1,\ 69) = 12.80$, $MS_e = .65$, which indicates that premises expressing locative relationships ($\bar{X}$ correct = 2.39) were more easily remembered than those containing serial relationships ($\bar{X}$ correct = 2.05). The figure in Appendix G illustrates these findings graphically. Though the interaction between age and problem type is not statistically

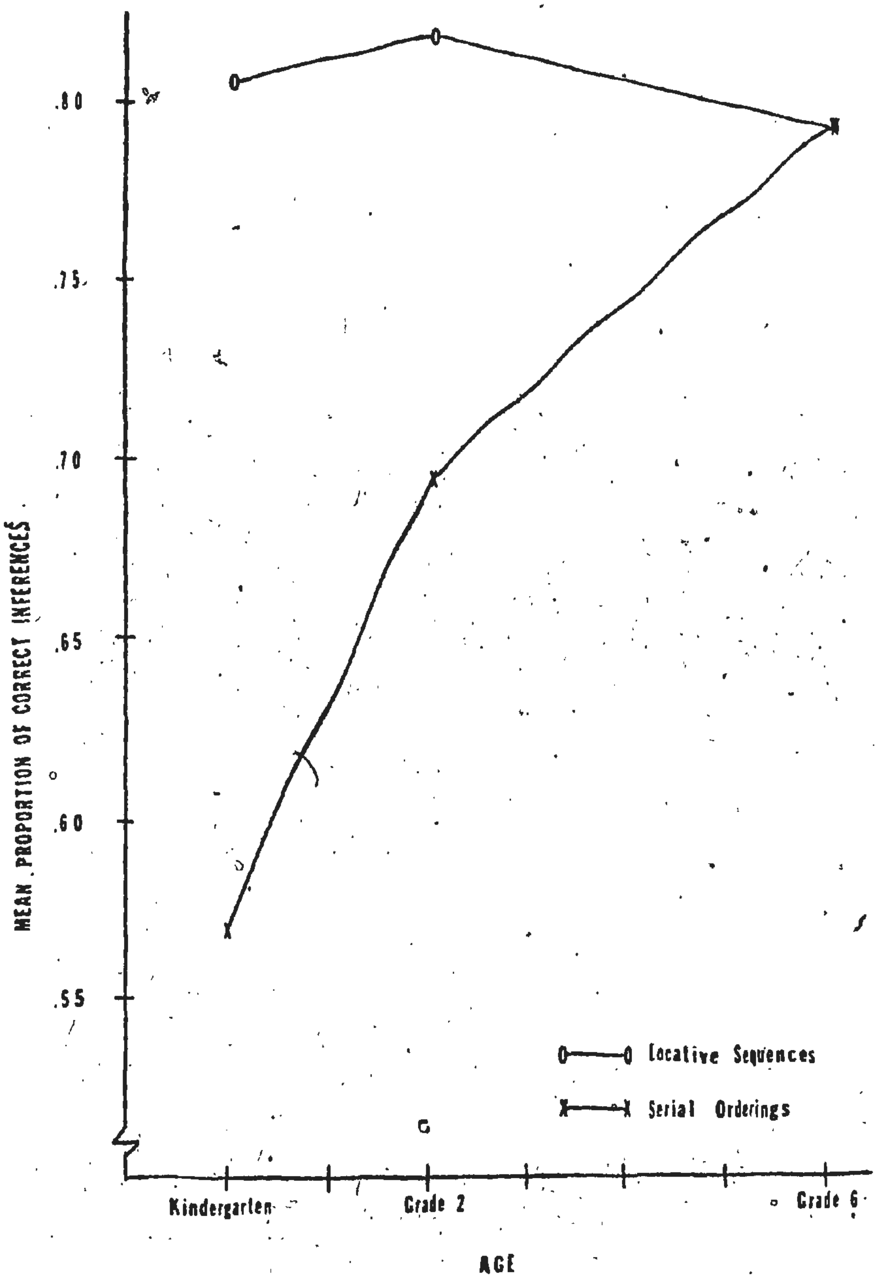

Figure 2. Mean proportion of correct inference scores on the two types of problems as a function of age.

significant, it does tend to approximate the inference scores in Figure 2.

To test for the interrelationship between inference ability and memory ability, six 2 x 2 Chi-Square tests were performed on the data appearing in Table 1. Each contingency table included the following cells: (1) the number of times an inference and both premises were correct; (2) the number of times an inference was correct and both premises were incorrect; (3) the number of times an inference was incorrect and both premises were correct; and (4) the number of times an inference and both premises were incorrect. The Chi-Square statistics emerging for the locative sequence problems for Kindergarten, Grade 2 and Grade 6 were 0.44, 3.69 and 0.58 respectively; and for the serial ordering problems were 0.04, 0.77 and 1.22 respectively. None of these measures were significant at the .05 level. This finding indicates that inferential ability and memory for the relationships comprising the inference were statistically independent of each other in each of the six groups, i.e., there was a consistently low degree of interrelationship between correct inferences and their corresponding memory scores.

There were alternative ways of examining the data which served to reduce some of the guessing variance. For example, a 3 x 2 Chi-Square analysis was performed upon the

Table 1

Distribution of Inference and Memory Scores on the Two Problem Types as a Function of Age

	Locative Sequences				Serial Orderings			
	IM[1]	$I\bar{M}$[2]	$\bar{I}M$[3]	$\bar{I}\bar{M}$[4]	IM	$I\bar{M}$	$\bar{I}M$	$\bar{I}\bar{M}$
Kindergarten	44	4	4	4	15	5	13	5
Grade 2	39	4	6	3	26	6	9	4
Grade 6	41	3	8	0	34	4	6	2
	78.5%	7%	12%	2.5%	58%	11.5%	22%	8.5%

Note 1: Inference correct and both premises correct.
Note 2: Inference correct and both premises incorrect.
Note 3: Inference incorrect and both premises correct.
Note 4: Inference incorrect and both premises incorrect.

data obtained from those particular subjects who answered all three of the inference questions correctly on either or both of the two problem types. Appendix H presents these data along with similar scores calculated for the two memory questions. The data suggest the absence of an age trend in inferential ability in locative sequence problems in comparison to an observable one in the serial ordering problems, but this received no statistical support from the Chi-Square analysis, $\chi^2(2) = 2.81$. Also, the number of problems in which a perfect score was obtained on all of the locative sequence and/or all of the serial ordering inference questions as a function of age was calculated (see Appendix J). There is an age trend evident in the scores obtained on the serial ordering inferences but not for locative sequence scores. A Chi-Square test on these data produced a value of $\chi^2(2) = 5.80$, $.05 < p < .10$.

The data for the number of subjects getting all of the serial ordering or all of the locative sequence problems correct were also examined in terms of conditional probabilities. These scores are presented in tabular form in Appendix I. The proportion of children answering all three serial ordering inferences correctly given that they also had gotten all three locative sequence inferences correct was very low in Kindergarten and Grade 2 children. However, these same age groups demonstrated much higher probabilities of answering all three locative sequence inferences correctly given that they had gotten all three serial ordering inferences correct. The probabilities for the Grade 6 group were about the same for both measures. These findings show that, for the younger aged children, (1) good performance on the locative sequence problems does not necessarily imply good performance on serial ordering problems but that (2) good performance on the serial ordering problems does suggest good performance on locative sequence problems. The type of inference to be derived did not appear to be such a significant factor for the Grade 6 subjects.

These alternative measures therefore serve to support the findings obtained in the main analyses and show that the significant interaction between age and problem type is a fairly robust finding emerging from the present study.

IV. DISCUSSION

The marked age trend in attaining solutions to serial ordering problems was not accompanied by a similar developmental pattern for locative sequences. This finding reflects the pattern of results reported in the developmental literature and mitigates the argument that the trends merely result from disparities in methodology or faulty experimental designs. It appears that young children have difficulty in drawing inferences of a serial nature but are able to provide the correct solutions to analogous problems requiring the integration of spatial-locative information.

One of the critical components of the inferential process is the simultaneous consideration of a common intermediate term from two different points of view, i.e., that B is both greater than C and less than A (Flavell, 1963; Piaget, Inhelder, & Szeminska, 1960). Pre-operational children are presumed to be unable to perform these mental operations to solve logical inference problems. Thus, it is believed that the primary drawback to logical thinking in children is an intellectually egocentric outlook in which the coordination of information is largely based on unreflective perception (Piaget & Inhelder, 1974). However, this type of intellectual egocentrism and inability to deal with reversible operations should also apply to locative sequence problems. For example, if given the sequence, The spider was in the basket, The basket was under the armchair, the child must recognize the fact that the basket both contains the spider and, at the same time, is located under the armchair in order to deduce that, The spider was under the armchair. The relatively high degree of success across all age levels for locative sequence problems suggests that this reasoning ability is no more difficult for younger children than for older. Thus, while the data do support the Piagetian contention of an age trend in transitive problems characterized by serial relationships, they do not permit the generalization of these findings to an analogous form of reasoning problem.

The view that children do poorly on inferential reasoning problems due to an underlying logical deficiency assumes that genuine transitive inferences occur only through the coordination of the individual premises via their common terms during retrieval (e.g., Youniss and Furth, 1973). That is, the inference problem is approached as an implicit syllogism in which the subject retrieves from memory the related propositions and uses his knowledge of transitivity concepts to test for the truth of inferential assertions never explicitly stated. Since children are presumed to be unable to logically integrate the relational material about the connecting term, a mental operation that is required in solving such syllogisms, this position predicts that similar developmental trends would occur in inferential responding on both types of problems. With age, the children become better at retrieving the initial comparisons and combining them together at the time of test. Inferences which are arrived at by other processes (i.e., forming imaginary representations of the relationships in memory) are considered "sub-logical" and irrelevant to discussions of true logical development.

However, this view is not supported in the present study. There is a complete absence of any developmental trend in the locative sequence problems. In addition, there is some experimental evidence to suggest that these reasoning problems are not solved by retrieving propositions and coordinating them during the test presentation. For example, Moeser (1976, Exp. II) tested one group of subjects on their ability to draw inferences when they were actually provided with the coordinating middle terms as transitional cues to aid them in making the correct logical connections. They were asked to choose between a correct inference such as, *The doll was in the crib under the tree*, and an incorrect alternative, *The doll was in the crib on the sidewalk*. A second group received the usual form of forced-choice test which did not supply the critical intermediate term "in the crib" at the time of test. Moeser found that the cues were ineffective in improving inferential performance and suggested that the reasoning employed in solving these problems did not proceed via the integration of premises during retrieval. Thus, with locative sequence problems, subjects appear to generate the inferences from the related information during acquisition training rather than by following logical rules of deduction during the testing procedure.

There is also some evidence to suggest that serial ordering problems are not solved in a strictly logico-deductive manner. For example, it has been postulated (Huttenlocher, 1964, 1967, 1968; Huttenlocher & Higgins, 1971) that serial ordering problems are solved by constructing imaginally ordered spatial arrays to represent the serial information. Such mental representations correspond to those actually involved in assigning spatial arrangements to real objects in the environment. A similar position (DeSoto, London & Handel, 1965; Handel, DeSoto & London, 1968; Smith & Foos, 1975) contends that reasoning proceeds by spatially assigning each of the elements to positions in a serially ordered mental array. Other researchers (Potts, 1972, 1974a, 1974b; Riley, 1976; Scholtz & Potts, 1974; Trabasso, 1975; Trabasso, Riley & Wilson, 1975) have shown that reaction time responses are faster and more accurate to inferential statements that were not presented than to adjacent pairs of comparisons that were presented, which suggests that an integrated linear order is the preferred mode of representation of serial ordering problems. Training data have also indicated the same finding (e.g., Riley & Trabasso, 1974; Trabasso, 1975).

The absence of a developmental trend for locative sequence problems suggests that children may not suffer from an actual logical deficit per se. Rather, the fundamental problem encountered in solving serial ordering problems may lie in the formulation of an adequate internal representation of the ordinal relations expressed in the premises. If the reasoning process does involve these kinds of operations, it may be that younger children experience more difficulty in forming an appropriate memory representation of a serially ordered information sequence. They may be more likely to attempt to remember each premise as a separate unit of information or to be inefficient in forming a complete memory representation before the test.

The establishment of an array is probably the most efficient strategy in organizing serially structured information in that it "chunks" the information together in storage. If the premises are integrated and stored as a linear ordering A, B and C rather than separately as ordered pairs of terms AB and BC, relational questions can be answered directly by scanning the linear array. There is evidence that when subjects are encouraged to form holistic arrays to represent serial information (i.e., by receiving ordered sequences of relations or being trained in serial organization), they perform much better on inferential questions (Moeser & Tarrant, in press). This finding points out the necessity of storing interrelated premises as integrated units in order to derive logical inferences. Locative sequence expressions may be easier to represent holistically in memory, thus providing a spatially integrated knowledge structure that is more amenable to accessing inferential relationships. On the other hand, serially ordered information sequences may pose serious problems for individuals with less sophisticated organizational abilities.

Indeed, there is already some data to support the fact that young children encounter difficulty in handling linear array information. Researchers have found that the acquisition of serial orientation is difficult for the young child (Flavell, 1971; Murray & Youniss, 1968; Piaget, 1966). For example, children tend to have trouble in constructing a series of 10 sticks from the shortest to the longest and later inserting more sticks of varying lengths in their correct serial positions (e.g., Flavell, 1963; Piaget, 1952, 1967). There is a significant difference between 4, 5 and 6 year olds in the ability to discriminate and seriate size differences or to link a group of asymmetrical transitive relationships into a system (Sigel & Hooper, 1968). Others have claimed that the understanding of seriation is a prerequisite operation for transitive inference (Braine, 1959; Inhelder & Piaget, 1964; Youniss & Dennison, 1971; Youniss & Murray, 1970).

The fact that younger children have difficulty in forming a mental representation of serial ordering problems is also suggested by the memory data. The solutions to both types of reasoning problems require the integration of the second premise with the first. However, there seems to be a difficulty in coordinating information in serial ordering problems, i.e., the children obtained poorer overall memory scores. This suggests that subjects of all ages were much better able to incorporate the second premise into the knowledge structure set up by the first, when the relational information was of spatial-locative nature. The type of memory representation constructed for the retention of locative information appears to be much more conducive to the integration of further relational information into the memory structure.

Although data obtained from the memory questions for each of the two premises did not contain a statistically significant interaction between age and problem type, inspection of the figure in Appendix G reveals that they do, however, follow the same trend. This tendency suggests that, to some degree, the ability to draw inferences is associated with overall memory performance on the individual propositions from which the inference is composed. Indeed, the memory data tend to reflect the inference performance to a greater degree as the amount of integration required by the task increases, i.e., the data show a closer approximation to a developmental interaction as the task demands to coordinate disparate segments of information increase. For example, the memory control subjects had to learn discrete, unrelated units of information presented as a list of disconnected words. There was no suggestion whatsoever of an interaction in the data with all age levels performing comparably in remembering the nouns. On the other hand, the experimental subjects were required to learn specific premise information. These premises were related together to some degree but nevertheless were presented as disparate information sequences. Thus, in tasks where more integration is required, the data show a tendency towards a developmental interaction. However, only when the task necessitates an overall holistic integration of ideas (i.e., the coordination of two premise statements to derive a third) does the age-problem type interaction become statistically significant.

Thus, the findings of this study suggest that children do not necessarily suffer from a deficiency in logical reasoning skills. Indeed, other "sub-logical" reasoning operations may characterize the inferential process for both children and adults alike. Instead, the inability of children to solve some forms of relational inferences may be indicative of an underlying difficulty in forming an appropriate memory representation of the particular relationships involved. The developmental trends in reasoning may simply reflect ontogenetic changes in the ability to represent relational information efficiently in memory. The within-subject design of this study was valuable in showing that the same individual who was unable to perform well on serially ordered information sequences was indeed able to draw inferences based on locative-spatial information. An interesting question is whether the young children are actually unable to represent the items in memory or merely unaware that the relationships could be expressed as a serially ordered array, i.e., that such a mnemonic device is available. The degree to which the inferential reasoning of young children can benefit from specific training in the organization of serial information would provide more revealing information as to the nature and development of the reasoning process.

FOOTNOTE

1. Criterion for statistical significance was taken to be $p < .05$ throughout the paper.

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APPENDIX A

The four versions of stimulus materials used in the experiment.

Versions 1 and 2

1. The tiny gray mouse was in the basket.
The basket was under the large bed (armchair).
The spider was under the armchair (large bed).

Was the tiny gray mouse under the large bed?* or
Was the tiny gray mouse under the armchair?**

Was the basket under the large bed?* or
Was the basket under the armchair?**

Was the spider in the basket? or
Was the tiny gray mouse in the basket?* **

2. The old sailor was fatter than the soldier.
The soldier was fatter than the fireman (farmer).
The policeman was fatter than the farmer (fireman).

Was the old sailor fatter than the fireman?* or
Was the old sailor fatter than the farmer?**

Was the old sailor fatter than the soldier? * ** or
Was the policeman fatter than the soldier?

Was the soldier fatter than the fireman?* or
Was the soldier fatter than the farmer?**

3. The little doll was in the big box.
The big box was in the baby's bedroom (kitchen).
The toy truck was in the kitchen (baby's bedroom).

Was the little doll in the kitchen?** or
Was the little doll in the baby's bedroom?*

Was the big box in the kitchen?** or
Was the big box in the baby's bedroom?*

Was the toy truck in the big box? or
Was the little doll in the big box?* **

Note: Words in parentheses are those which were interchanged in Version 2.

* Correct for version 1.
** Correct for version 2.
* ** Correct for both versions 1 and 2.

4. The puppy was bigger than the fluffy white rabbit.
The fluffy white rabbit was bigger than the yellow duck (striped cat).
The rooster was bigger than the striped cat (yellow duck).

Was the puppy bigger than the yellow duck?* or
Was the puppy bigger than the striped cat?**

Was the rooster bigger than the fluffy white rabbit? or
Was the puppy bigger than the fluffy white rabbit?* **

Was the fluffy white rabbit bigger than the striped cat?** or
Was the fluffy white rabbit bigger than the yellow duck?*

5. The comic book was on the red wagon.
The red wagon was in the living room (back garden).
The baseball was in the back garden (living room).

Was the comic book in the back garden?** or
Was the comic book in the living room?*

Was the red wagon in the living room?* or
Was the red wagon in the back garden?**

Was the comic book on the red wagon?* ** or
Was the baseball on the red wagon?

6. The apple tree was taller than the flagpole.
The flagpole was taller than the swing (tent).
The wooden ladder was taller than the tent (swing).

Was the apple tree taller than the tent?** or
Was the apple tree taller than the swing?*

Was the apple tree taller than the flagpole?* ** or
Was the wooden ladder taller than the flagpole?

Was the flagpole taller than the tent?** or
Was the flagpole taller than the swing?

Versions 3 and 4

1. The spider was in the basket.
   The basket was under the large bed (armchair).
   The tiny gray mouse was under the armchair (large bed).

   Was the spider under the large bed?* or
   Was the spider under the armchair?**

   Was the spider in the basket?* ** or
   Was the tiny gray mouse in the basket?

   Was the basket under the large bed?* or
   Was the basket under the armchair?**

2. The policeman was fatter than the soldier.
   The soldier was fatter than the fireman (farmer).
   The old sailor was fatter than the farmer (fireman).

   Was the policeman fatter than the fireman?* or
   Was the policeman fatter than the farmer?**

   Was the soldier fatter than the fireman?* or
   Was the soldier fatter than the farmer?**

   Was the old sailor fatter than the soldier? or
   Was the policeman fatter than the soldier?* **

3. The toy truck was in the big box.
   The big box was in the baby's bedroom (kitchen).
   The little doll was in the kitchen (baby's bedroom).

   Was the toy truck in the kitchen?** or
   Was the toy truck in the baby's bedroom?*

   Was the toy truck in the big box?* ** or
   Was the little doll in the big box?

   Was the big box in the kitchen?** or
   Was the big box in the baby's bedroom?*

Note: Words used in parentheses are those which were interchanged in Version 4.

*	Correct for version 3.
**	Correct for version 4.
* **	Correct for both versions 3 and 4.

4. The rooster was bigger than the fluffy white rabbit.
The fluffy white rabbit was bigger than the yellow duck (striped cat).
The puppy was bigger than the striped cat (yellow duck).

Was the rooster bigger than the yellow duck?* or
Was the rooster bigger than the striped cat?**

Was the fluffy white rabbit bigger than the striped cat?** or
Was the fluffy white rabbit bigger than the yellow duck?*

Was the rooster bigger than the fluffy white rabbit?* ** or
Was the puppy bigger than the fluffy white rabbit?

5. The baseball was on the red wagon.
The red wagon was in the living room (back garden).
The comic book was in the back garden (living room).

Was the baseball in the back garden?** or
Was the baseball in the living room?*

Was the comic book on the red wagon? or
Was the baseball on the red wagon?* **

Was the red wagon in the living room?* or
Was the red wagon in the back garden?**

6. The wooden ladder was taller than the flagpole.
The flagpole was taller than the swing (tent).
The apple tree was taller than the tent (swing).

Was the wooden ladder taller than the tent?** or
Was the wooden ladder taller than the swing?*

Was the flagpole taller than the tent?** or
Was the flagpole taller than the swing?*

Was the apple tree taller than the flagpole? or
Was the wooden ladder taller than the flagpole?* **

APPENDIX B

The three acquisition lists of the nouns employed in the two types of problems.

Locative Sequences

Order 1	Order 2	Order 3
comic book	little doll	spider
baby's bedroom	tiny gray mouse	toy truck
basket	living room	red wagon
back garden	big box	baby's bedroom
armchair	spider	tiny gray mouse
kitchen	comic book	back garden
red wagon	basket	armchair
big box	kitchen	little doll
spider	back garden	baseball
living room	large bed	basket
toy truck	red wagon	big box
large bed	toy truck	living room
little doll	armchair	large bed
baseball	baby's bedroom	kitchen
tiny gray mouse	baseball	comic book

Serial Orderings

Order 1	Order 2	Order 3
apple tree	yellow duck	old sailor
fluffy white rabbit	wooden ladder	rooster
soldier	old sailor	wooden ladder
tent	rooster	fireman
old sailor	apple tree	swing
rooster	policeman	puppy
flagpole	fluffy white rabbit	farmer
policeman	swing	flagpole
puppy	farmer	fluffy white rabbit
wooden ladder	puppy	soldier
yellow duck	flagpole	apple tree
fireman	soldier	striped cat
swing	striped cat	policeman
striped cat	tent	yellow duck
farmer	fireman	tent

APPENDIX C

The locative sequence and serial ordering noun tests.

Locative Sequence Test	Serial Ordering Test
small baby robin	policeman*
baby's bedroom*	fish
baseball*	lamp post
ant	doctor
electric train	striped cat*
front yard	apple tree*
little doll*	brown fox
tiny gray mouse*	baker
coloring book	tent*
high table	happy clown
back garden*	heavy rope
paper bag	fluffy white rabbit*
chesterfield	old sailor*
red wagon*	rooster*
big box*	swing*
basket*	mailman
bathroom	green turtle
living room*	flagpole*
bucket	pilot
toy truck*	yellow duck*
blue sled	flower
large bed*	soldier*
kitchen*	puppy*
comic book*	ferris wheel
children's playroom	farmer*
hockey puck	lazy spotted cow
spider*	cave
basement	fireman*
teddy bear	wooden ladder*
armchair*	monkey

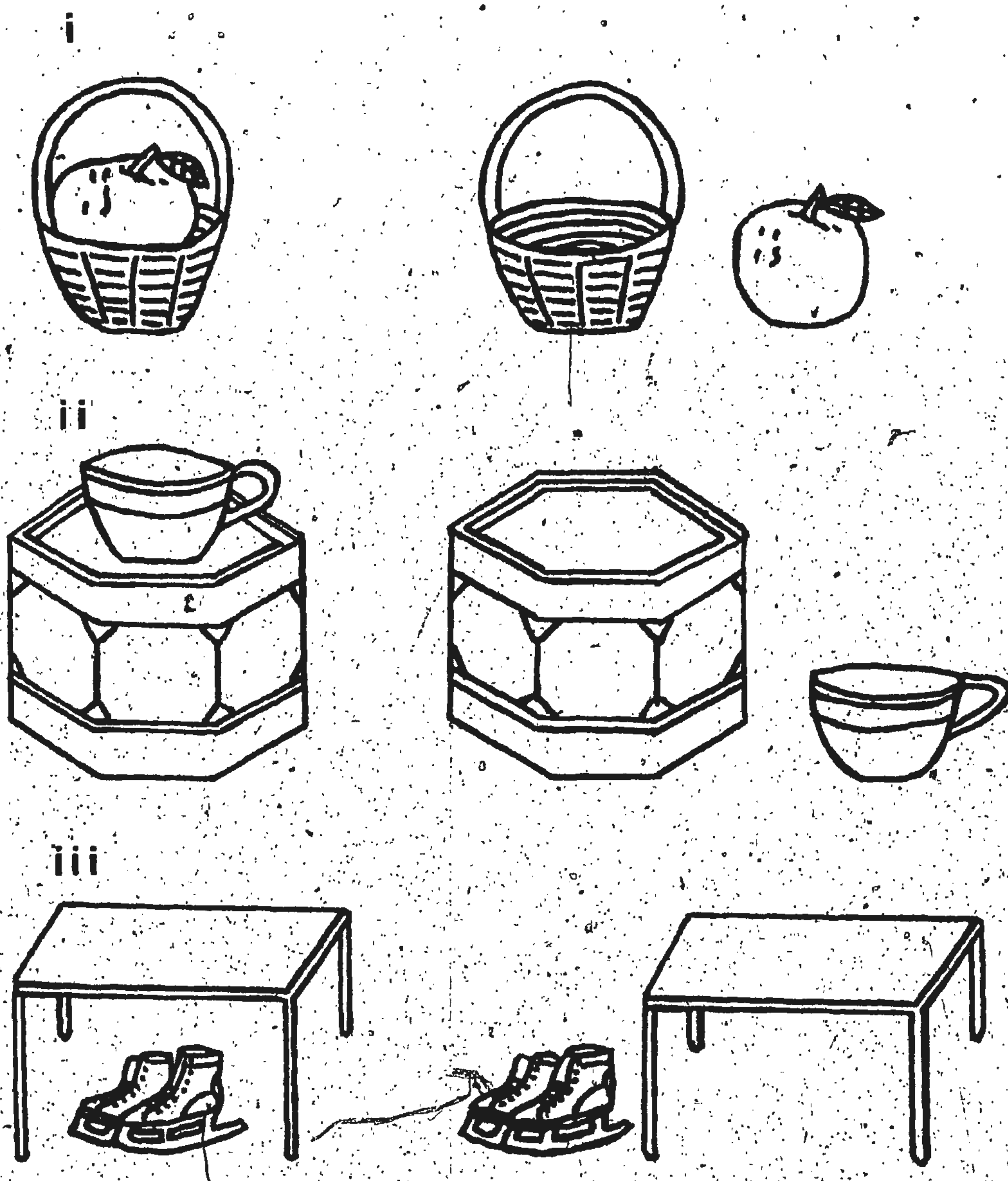
Note: * designates the target items.

APPENDIX D

The six pairs of pictures used in the picture relations test.

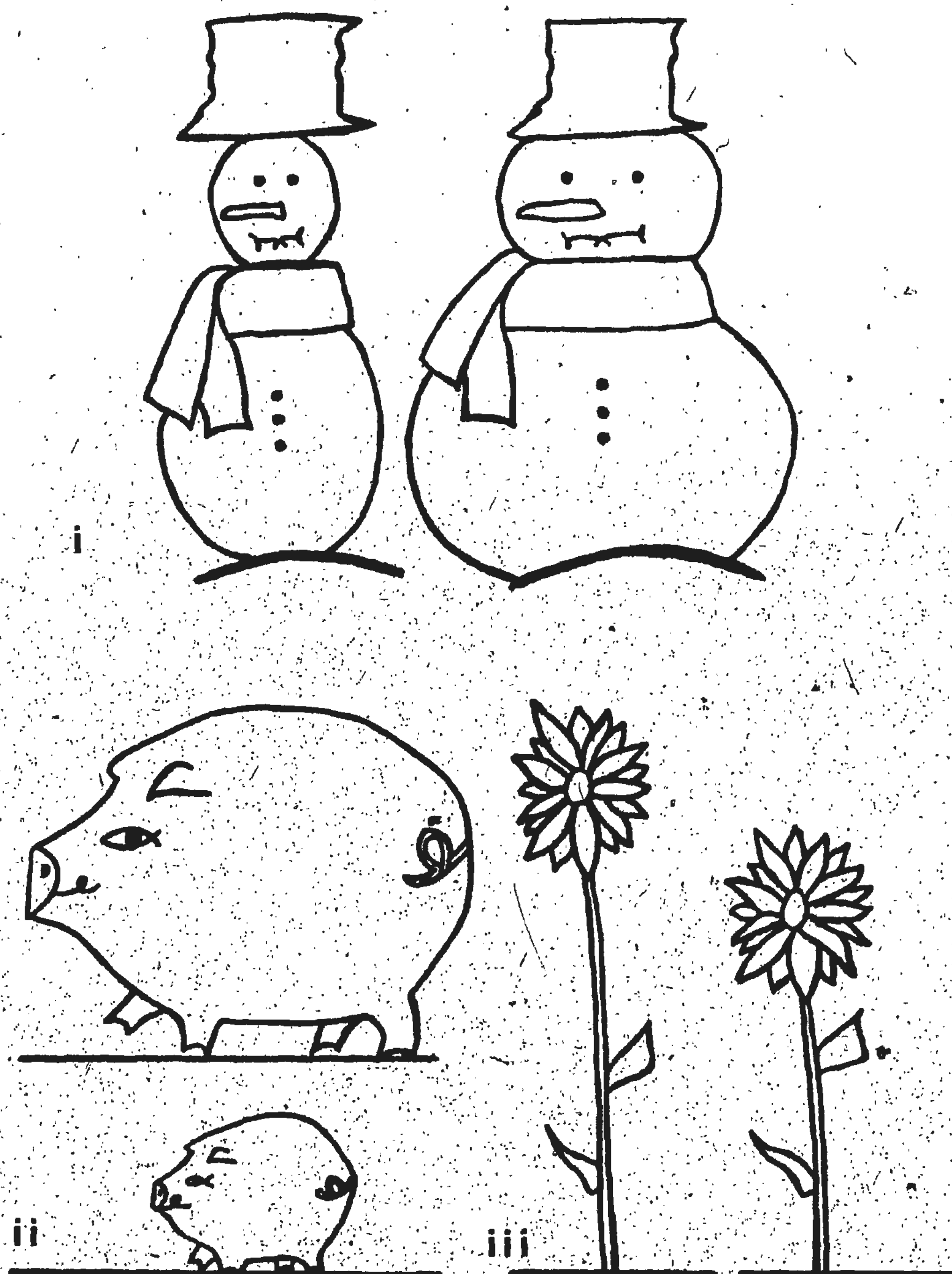
The three locative sequence relationships:

(i) in, (ii) on, (iii) under.



The three serial ordering relationships:

(i) fatter (ii) bigger , (iii) taller.



APPENDIX E

Table 1

Source	Degrees of Freedom	Mean Square	F-Ratio
A (Age)	2, 33	.11	.15
T (Problem Type)	1, 33	.36	.70
A x T	2, 33	.34	.66

Table 2

Source	Degrees of Freedom	Mean Square	F-Ratio
A (Age)	2, 69	1.22	1.80
T (Problem Type)	1, 69	4.69	9.73**
A x T	2, 69	1.51	3.12*

** $p < .01$

* $p < .05$

Table 3

Source	Degrees of Freedom	Mean Square	F-Ratio
A (Age)	2, 69	.97	1.11
T (Problem Type)	1, 69	8.34	12.80**
A x T	2, 69	.73	1.12
P (Premise)	1, 69	.42	.82
A x P	2, 69	.03	.05
T x P	1, 69	.78	1.18
A x T x P	2, 69	.09	.14

** $p < .01$

APPENDIX F

The number of subjects attaining correct inference and memory scores as a function of individual problem set.

	Locative Sequences				Serial Orderings		
	Kindergarten	Grade 2	Grade 6		Kindergarten	Grade 2	Grade 6
Inference				**Inference**			
"in-under"	20	20	20	"fatter"	13	16	17
"in-in"	20	18	20	"bigger"	13	18	17
"on-in"	18	21	17	"taller"	15	16	23
Premise 1				**Premise 1**			
"in-under"	21	21	18	"fatter"	15	18	17
"in-in"	21	18	19	"bigger"	13	15	17
"on-in"	16	16	21	"taller"	18	19	22
Premise 2				**Premise 2**			
"in-under"	21	19	20	"fatter"	18	17	19
"in-in"	20	16	21	"bigger"	14	14	11
"on-in"	17	20	19	"taller"	12	16	20

APPENDIX G

Figure 1. The mean proportion of correct memory scores (based on the average of both premises) made by each age level on the two types of problems.

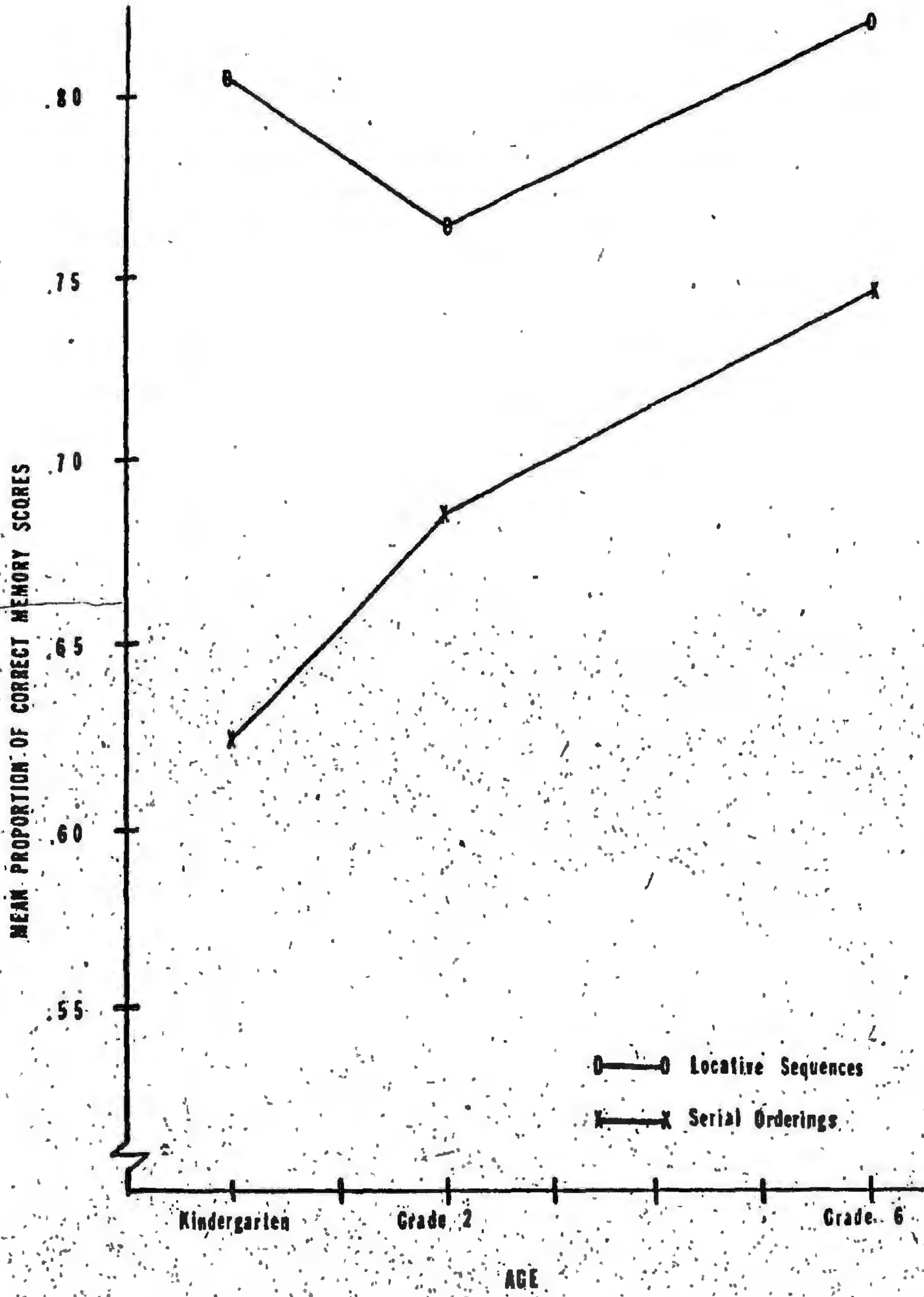

MEAN PROPORTION OF CORRECT MEMORY SCORES
.80
.75
.70
.65
.60
.55
O——O Locative Sequences
X——X Serial Orderings
Kindergarten
Grade 2
Grade 6
AGE

Figure 1

APPENDIX H

The number of subjects per grade who answered all three inference or memory questions correctly as a function of problem type.

	Kindergarten	Grade 2	Grade 6
Locative Sequences			
Inference	13	15	11
Premise 1	15	10	15
Premise 2	15	10	16
Serial Orderings			
Inference	5	8	12
Premise 1	5	12	13
Premise 2	4	11	8

APPENDIX I

The proportion of subjects of each age level attaining a perfect inference score on one type of problem given a perfect inference score on the other type of problem.

	Kindergarten	Grade 2	Grade 6
Serial Ordering/ Locative Sequence[1]	.231	.333	.727
Locative Sequence/ Serial Ordering[2]	.600	.625	.667

Note 1: All serial ordering inferences correct given that all locative sequence inferences were correct.

Note 2: All locative sequence inferences correct given that all serial ordering inferences were correct.

	Locative Sequences	Serial Orderings
Kindergarten	44	15
Grade 2	39	26
Grade 6	41	34

APPENDIX J

The number of problems in which both the inference and the two premises were answered correctly as a function of age.