Transitive Inference Ability in Young Children

by

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Abstract

A great deal of controversy surrounds the age of development of logical reasoning as assessed by the ability to make transitive inferences. The purpose of these experiments was to assess transitive inference in young children using a method that was not subject to the alternative interpretations which plague earlier research. In Experiment I, 9 children, with a mean age of 59 months, were tested using a new paradigm, and it was found that the subjects could correctly answer transitive inference questions at a significant rate ($p<.04$). Experiment II was an attempt to assess a concept underlying transitivity. Specifically, Experiment II assessed the understanding that, in an array $A>B>C>D>E$, the difference between B and D is greater than the difference between C and D where the relationship between B and D must be inferred. 18 children were tested and were separated into two age groups for the purpose of data analysis. The mean age of the younger group was 55.11 months, and the mean age of the older group was 62.33 months. Results of analyses revealed that older subjects had a significantly greater understanding of the concept being assessed.

Acknowledgements

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To understand the nature and development of reason and logical thought is a central goal of modern psychology. In the field of developmental psychology, much attention has been focused on how the ability to reason changes from childhood to adulthood. The first systematic and, even today, the most influential description of how cognition changes as a child matures was proposed by the Swiss psychologist Jean Piaget (Ginsburg & Opper, 1969). His theory separates cognitive development into four stages. Each stage represents a qualitative change in the thought processes of the child from that of the previous stage. The first stage is the sensorimotor stage, which includes the age range of birth to approximately two years. The major characteristic of this stage is the lack of symbolic thought. The ability to use mental symbols signifies movement into the stage of preoperations, which includes the age range of approximately 2 years to 7 years. Although the preoperational child is capable of manipulating mental symbols, the rules governing these manipulations are not logical.

Movement into the stage of concrete operations, age 7 years to 12 years, is signified by the ability to solve problems requiring the use of basic, everyday logical principles. However, the concrete operational child can solve problems using logic only as long as they involve concrete, tangible objects. The final stage of cognitive development,

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This thesis follows a modified version of the style of the Publication Manual of the American Psychological Association, Third Edition, (1983).

formal operations, is characterized by the ability to use logical principles in connection with thought about both concrete and abstract entities.

A pivotal assumption of Piaget's theory is that children in higher stages of cognitive development are able to solve problems that are beyond the capabilities of children in lower stages. For example, to differentiate a concrete operational child from a preoperational child, one would utilize a task which required the child to use some form of basic logic. One such problem that was used by Piaget is the transitive inference problem. Transitive inference is the ability to infer that A is related to C if one knows that A is related to B and that B is related to C. Transitive inference is believed to be one of the first forms of logical thought to develop. Piaget tested for the ability to make a transitive inference by using a verbal task. For example, Piaget would tell a child the following: Tom is taller than Bob and Bob is taller than Jim. He would then ask the child, "Who is taller (or shorter), Tom or Jim?" Piaget found that children could not reliably solve this problem until the age of about 7 years, and the ability to solve this and related problems marked the entry into Piaget's stage of concrete operations.

Piaget reasoned that the preoperational child could not solve transitive inference problems because of fundamental characteristics of his mental processes. Principally, the preoperational child is said to think in a categorical fashion rather than in a relative fashion. When given the information that Tom is taller than Bob, the preoperational child would mentally assign an absolute label of "big" to Tom and a label of "small" to Bob. Likewise, when given the information that Bob is taller than Jim, the preoperational child assigns an absolute label of "big" to Bob and a label of "small" to Jim. Because of categorical thought, the preoperational child is unable to understand that Bob, the reference point for both other persons in the problem, can simultaneously be small, relative to Tom, and big, relative to Jim. Without this realization, the child cannot coordinate the pieces of information in order to make the transitive inference. Transitive inference is just one task that diagnoses the general problem of categorical thought in young children, which would seriously hinder a child's understanding about mathematics and other important concepts.

The ability to make transitive inferences was viewed by Piaget as one of the major abilities discriminating concrete operational from preoperational children. His position on this issue was largely accepted in the field of child psychology until the early 1970s. However, in their study of transitive inference in 4-year-old children, Bryant and Trabasso (1971) argued that the younger child does not lack the ability to make a transitive inference, per se, but lacks the memory capacity necessary to retain the information given in the problem until it is needed in order to answer the inference question. This claim had a substantial impact in developmental psychology because it challenged a fundamental assumption of Piaget's theory.

The basic paradigm of the Bryant and Trabasso (1971) study involved an array of 5 different colored rods of gradually increasing length (Figure 1a). The children in this study were in one of three age groups with a mean age of 4 years, 5 months; 5 years, 6 months; and 6 years, 7 months, respectively. The children were tested on an individual basis.

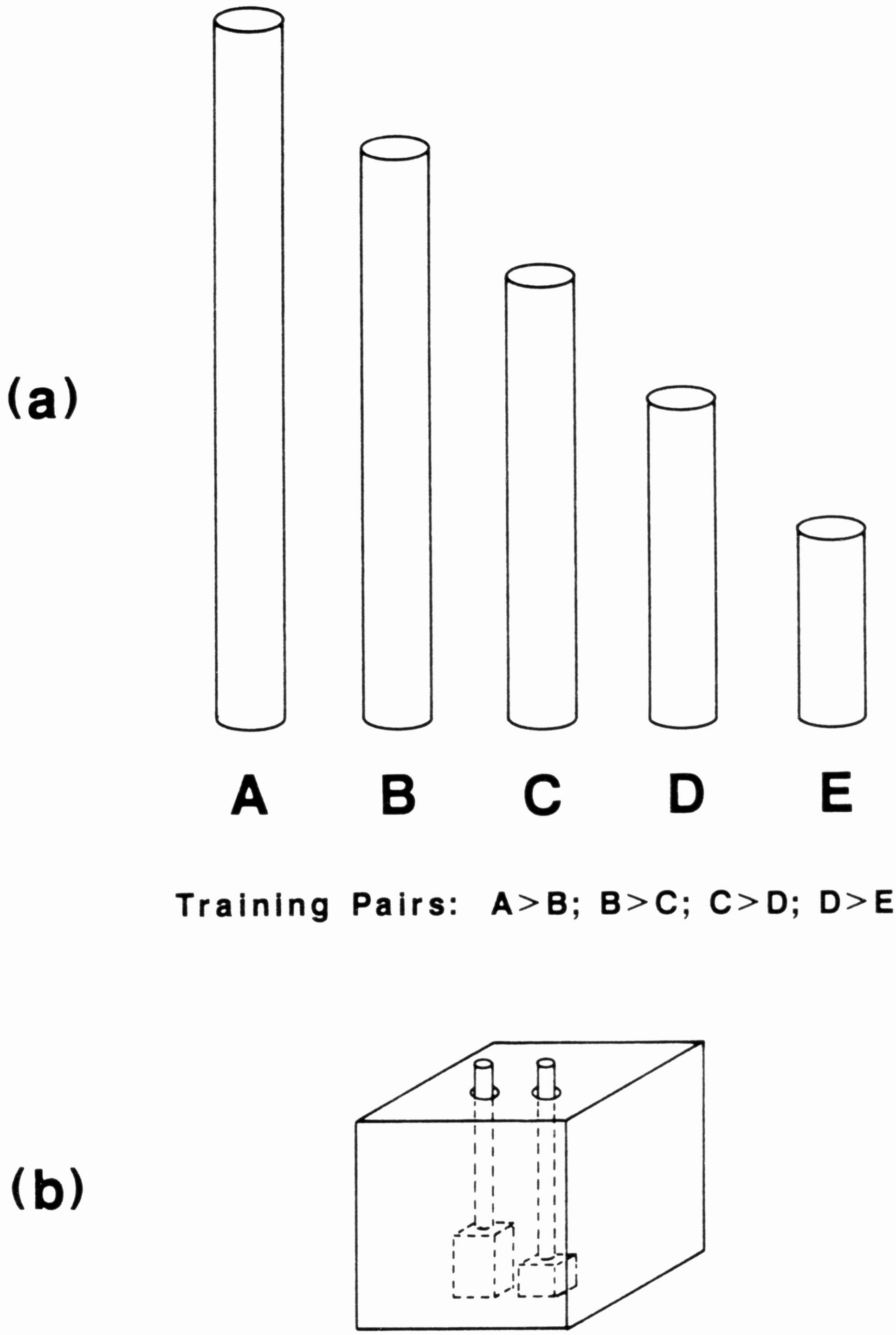

Figure 1. The Bryant-Trabasso paradigm (1971)

During memory training, the first phase of the study, the children were shown the following pairs of rods one at a time in either forward or reverse order: A-B, B-C, C-D, and D-E. Note that only adjacent pairs were trained. No information was given about non-adjacent pairs A-C, A-D, A-E, B-D, B-E, and C-E. Each pair of rods was displayed using a box which revealed the ends of the rods but which hid the actual lengths of the rods from the child's view (Figure 1b). For each pair of rods, the experimenter told the child which of the pair was longer (or shorter). After this initial exposure to each adjacent pair, the child was questioned about the pairs in the order given above and asked to select the longer (or shorter) rod of each pair. If the child answered incorrectly, he was corrected by the experimenter. After the child had learned to respond correctly to each of the pairs 8 out of 10 times, the pairs were presented in a random order. The child was required to respond correctly six successive times to each pair before training was completed. Any child who failed to achieve this criterion was eliminated from the study.

In the test phase of this study, the child was shown pairs of rods and asked to select the longer (or shorter) of each pair. In addition to the training pairs, the child was tested on non-adjacent pairs A-C, A-D, A-E, B-D, B-E, and C-E. It was hypothesized by the authors that one would be required to use transitive inference in order to make these additional discriminations. The pair B-D was considered the critical test of transitive inference because neither rod B nor rod D were consistently referred to as "bigger than" or "smaller than" during training. The results of the Bryant and Trabasso (1971) study revealed that children at all three age levels correctly answered the critical transitive inference question, B-D, at a rate significantly above chance. This seems to indicate that, contrary to Piagetian theory, even 4-year-olds can reliably make transitive inferences. Moreover, no significant age differences were found.

A theory of the procedure used by children and adults to solve transitive inference problems was proposed in the form of a linear-ordering model by Riley and Trabasso (1974). According to this model, one employs transitive inference to construct a mental array of the objects in the transitive inference problem and then mentally scans the array in order to answer the transitive inference question. For example, in the Bryant and Trabasso (1971) study, one would conclude that the child integrates the training pairs A>B, B>C, C>D, and D>E into a mental image of the linear array A>B>C>D>E. Trabasso and his colleagues also proposed that the construction of this array in the Bryant-Trabasso experimental setting occurred during the training phase of the study.

Support for the linear-ordering model is provided by Trabasso, Riley, and Wilson (1975), whose results revealed that reactions times during testing decreased as the distance between the terms in the array increased. This effect, known as the distance effect, is explained by the fact that terms that are more widely separated are more easily discriminated when one scans a mental array of the terms.

The results of Bryant and Trabasso (1971) have not gone unchallenged. The main criticism has been that, as a result of the extensive training procedures used by Trabasso and his colleagues, young children are able to successfully solve transitive inference problems using methods which are not based on the principle of transitivity. Several authors have proposed alternatives to the linear-ordering model whereby children employ the categorical thinking characteristic of the preoperational child to answer the transitive inference questions. One such model, the labeling model, was proposed by DeBoysson-Bardies and O'Regan (1973). According to this model, the young child does not form a linear array of the items in the problem. Rather, he attaches absolute labels of size to the items in the problem. The young child would make "transitive inferences" in situations similar to the Bryant-Trabasso experimental setting in the following manner (see Figure 2):

1) He attaches absolute labels of size to any rods possible. Therefore, A is labeled as "long" and E is labeled as "short" because, during training, A is always referred to as "longer than" and E is always referred to as "shorter than" other rods.
2) A rod that is associated with a rod that has an absolute label will acquire that label through repeated pairings with that rod. Therefore, B is labeled as "long" because it is paired with A during training, and D is labeled as "short" because it is paired with E during training.
3) To answer questions during testing concerning non-adjacent rods, the child simply responds in accordance with the labels attached to the rods in question. For example, to answer the question "Which is longer, B or D?", the child would answer B because it is labeled "long", not because of the use of transitive logic.

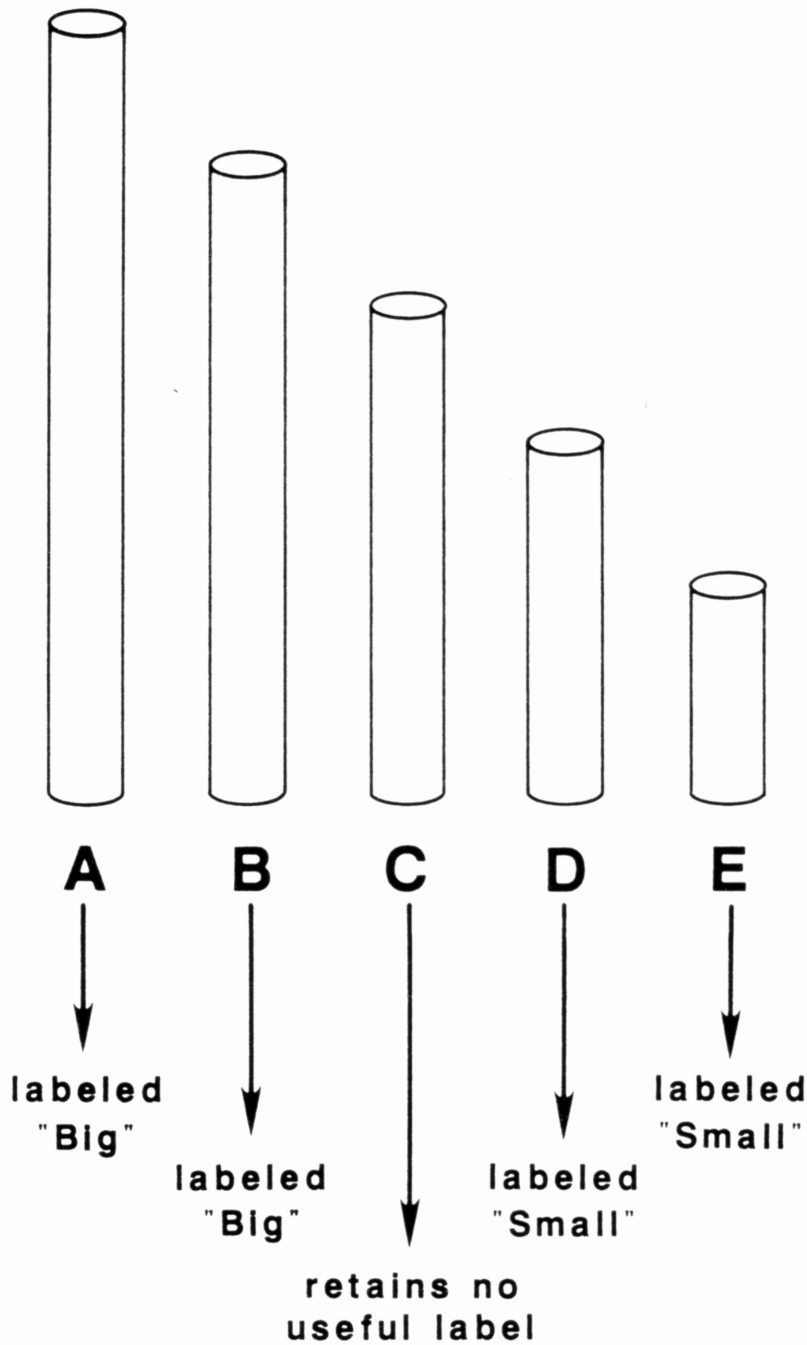

Figure 2. The labeling model of DeBoysson-Bardies and O'Regan (1973)

The labeling model was supported by a study conducted by DeBoysson-Bardies and O'Regan (1973). In this study, children were trained using Bryant and Trabasso's procedure on the premises A>B and C>D and then tested on all possible pairs of the rods. It was hypothesized that if the labeling model was correct, the children would respond that A>D and C>B, even though they had no basis for making this judgement. The results supported this hypothesis. The authors reasoned that the children responded in such a way because A and C were labeled "big" while B and D were labeled "small" during training. However, another explanation for the children's judgements in this situation is possible. It may be the case that experimenter "demand characteristics" were operating. That is, although the children had no basis for judging the relationship between A and D and between C and B, they may have done so because they were asked to make such a judgement by an adult and made the assumption that the question could be answered or it would not have been asked. Evidence countering the labeling model has been presented by Harris and Bassett (1975).

Another alternative to the linear-ordering model of Trabasso and his colleagues is the sequential-contiguity model proposed by Breslow (1981). Like Trabasso's model, Breslow assumes that the child forms a linear ordering of some sort during training. Unlike Trabasso, however, Breslow proposed that the child does not utilize the relational terms of "longer than" and "shorter than" to form this ordering. Because of categorical thought, the young child is confused by the fact that some rods are referred to as "longer than" in some premises while, at the same time, are referred to as "shorter than" in other premises. For example, he is confused that rod B is referred to as both shorter than A and longer than C. He does, however, eventually learn that B somehow "goes with" A and "goes with" C. Breslow proposed that the child retains these associations in the form of unordered pairs such as (A,B) or (B,A) and (B,C) or (C,B). (See Figure 3.)

(A,B) (B,C) (C,D) (D,E)
(B,A) (C,B) (D,C) (E,D)
←long portion   short→ portion

Sequential-contiguity model

A>B>C>D>E

Linear-ordering model

Figure 3. The sequential-contiguity model of Breslow (1981) vs. the linear-ordering model of Riley and Trabasso (1974).

In the sequential-contiguity model, the end rods A and E are important because they are only referred to in one manner during training (i.e., A is always "longer than" and E is always "shorter than"). Therefore, A and the rods that "go with" A form the "long" portion of the linear ordering and E and rods that "go with" E form the "short" portion of the linear order. (See Figure 3.) To answer a transitive inference question such as "Which is longer, B or D?" the child would access the portion of the linear order corresponding to the comparative used in the question, or, in this case, the portion associated with "long". Because A is long, the child would then recall which rods "go with" A. Because B "goes with" A, the child would answer the above question correctly, but not because he made a transitive inference based on the fact that B>C and C>D.

Both the labeling model of DeBoysson-Bardies and O'Regan and the sequential-contiguity model of Breslow are questioned by evidence provided by Halford and Kelly (1984). In this study, children were trained on the standard premises A>B, B>C, C>D, and D>E along with the two additional premises A>D and B>E according to the Bryant and Trabasso paradigm. It was hypothesized that if the labeling and/or sequential-contiguity models were operating, the addition of the two non-adjacent premises would produce chance responding on the critical B-D comparison. According to the labeling model, rod D is now paired with A ("long") as well as with E ("short"), and rod B is subjected to similar pairings. Because both B and D are paired an equal number of times with a rod labeled "long" as they are paired with a rod labeled "short", neither rod B nor D will retain a useful size label according to the labeling model. Likewise, according to the sequential-contiguity model, if the child accessed rod A because it is long in an attempt to determine which was longer, B or D, he would find that both B and D "go with" A. Therefore, he would be unable to discriminate between B and D. However, if the linear-ordering model of Trabasso and Riley was operating, this disruption of the B-D comparison would not occur. The pattern of results of this study was essentially the same as that obtained by Bryant and Trabasso (1971), thus supporting the linear-ordering model.

However, Halford and Kelly (1984) had several other criticisms of the methods employed by Trabasso and his colleagues. These authors argue that if transitive inference is employed during training to construct a mental array, as claimed by Trabasso and his colleagues, then the elimination of subjects who fail to reach criterion and the presentation of premises in serial order would bias the results. This position is based on the assumption that using transitive inference to form a linear array during training represents a significant memory aid. Therefore, subjects who fail to reach criterion may actually represent children who are unable to use transitive inference to integrate the premises into an array, the elimination of whom would bias the sample. Also, the presentation of premises in serial order would artificially inflate the number of children who reach criterion by facilitating the construction of a mental array.

In a second study reported by these authors, children were trained on premises in one of two conditions: overlapping (A>B, B>C, C>D) or nonoverlapping (A>B, C>D, E>F). To eliminate sources or potential bias, children who failed to reach criterion were not eliminated, and premises were presented in a random order. It was hypothesized that if the children were not able to use transitive inference to integrate the premises in the overlapping condition, the overlapping premises would require more trials for the children to learn because of the confusion created by having rods B and C presented in two premises.

Subjects were in one of four age groups: 3 years, 7 months to 4 years, 6 months (mean = 3 years, 10 months), 4 years, 7 months to 5 years, 6 months (mean = 5 years), 5 years, 7 months to 6 years, 6 months (mean = 6 years, 1 month), and 6 years, 7 months to 7 years, 6 months (mean = 7 years, 1 month). Results revealed that the overlapping condition was significantly more difficult than the nonoverlapping condition for the youngest group but not for any of the other age groups. The authors interpreted these results to mean that the children of the youngest age group were incapable of integrating the premises and that the results of Bryant and Trabasso (1971) were indeed biased. However, it should be noted that the mean age of Bryant and Trabasso' youngest group was 4 years, 5 months, somewhat older than Halford and Kelly's youngest group with a mean age of 3 years, 10 months.

The controversy over the age of emergence of transitive inference is far from resolved. Proponents of the Piagetian position still contend that young children do not possess this ability but succeed in the Bryant-Trabasso paradigm by using categorical thinking to solve the transitive inference problems by nontransitive means. The Bryant-Trabasso paradigm has yielded some impressive evidence of young children making transitive inferences. However, the criticism of the extensive training procedure cannot be ignored. It is important to develop a new paradigm whereby the memory capacity of the young child is not overloaded, but the child is not required to participate in exhaustive training of premise information. It is the purpose of the first study presented to develop such a paradigm.

The purpose of the second study is to assess transitive inference with an entirely different type of question, one that is not subject to the alternative interpretations of the labeling and the sequential-contiguity models. Specifically, does the young child understand that, in an array of objects where A>B>C>D>E, the size difference between C and D, for example, is not as great as the size difference between B and D? In other words, does the child understand that, although B and C are both "big" in relation to D, the degree of "bigness" is not the same? If it can be determined that a child does understand this concept, it would be difficult to successfully argue that the child is employing categorical thinking.

Experiment I

Method

Subjects

Subjects included 9 preschool children enrolled at a local daycare center and included 5 girls and 4 boys. The subjects ranged in age from 52 months to 68 months with a mean age of 59 months.

Materials and Procedure

Each child was tested on four arrays. The arrays used were the five-object arrays of circles, squares, rectangles, and rods described in the Appendix. The objects in each array will be referred to by letter, with A denoting the largest object in the array and E denoting the smallest object in the array. Other materials used included the hand puppet described in the Appendix.

Each child was tested on an individual basis with experimenter and child facing one another seated cross-legged on a carpeted floor. Initially, the experimenter introduced herself to the child and asked the child about his recent activities. The experimenter then randomly selected three objects from the first array (the particular array varied randomly from child to child) and arranged them according to size in front of the child. The experimenter asked the child to tell the color of each object and to point to the largest and to the smallest. The child was then asked to cover his eyes while the experimenter removed one of the objects, either the largest or the smallest, and placed it in a bag. The experimenter asked the child whether the now-hidden object was big or little and what color it was. The child was then introduced to the puppet, who conversed with the child for a few minutes. The purpose of these activities was to familiarize the child with the experimenter and with answering questions about hidden objects.

The session then moved into the testing phase. Each array was presented, singularly, in linear order. The designated "hidden" object, shown in Figure 4, remained in the bag in which the array was stored. The puppet explained to the child that he had another (square) that was hidden in the bag that was bigger than E and smaller than C. This premise always compared the hidden object to the objects adjacent to it in the array. The order of comparatives in the premises (i.e., "the hidden square is bigger than E and smaller than D" versus "the hidden square is smaller than D and bigger than E") was counterbalanced across arrays for each subject. The experimenter touched the object in question as the puppet stated the premises. The puppet then asked the child to repeat this information one time. The child was then asked if the (square) hidden in the bag was bigger or littler than B. This transitive inference question always compared the object in the bag with D, for the circle and rectangle arrays, or with B, for the square and rod arrays. The experimenter responded "good" to the child's answer regardless of its correctness. After answering the question, the child was asked to repeat the premise information once again as a check of premise retention.

The order of comparatives in the inference question, whether the correct answer was the first or second comparative given, was also counterbalanced across arrays for each subject. Also, the order of the presentation of arrays was counterbalanced across subjects.

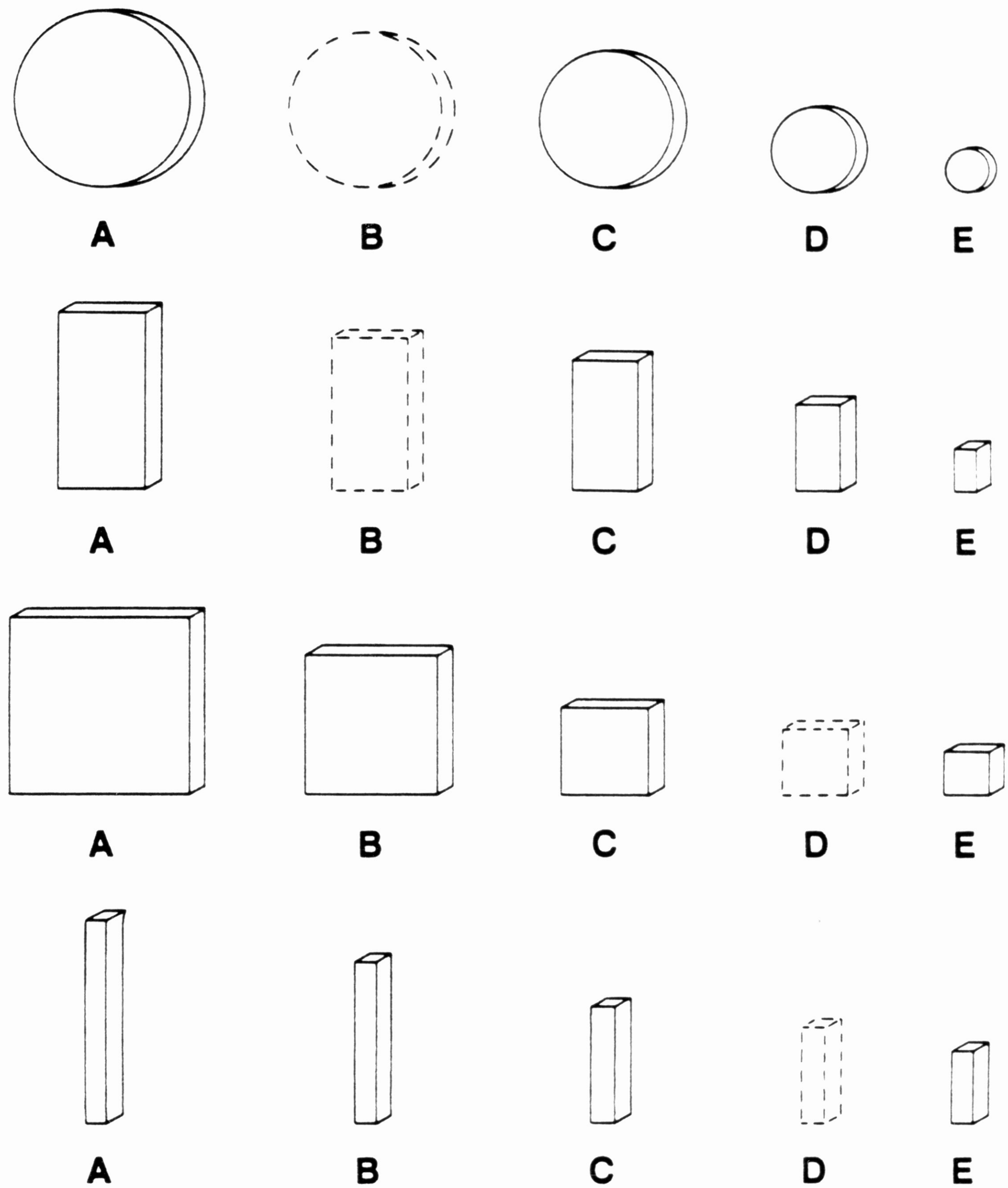

Figure 4. The five-object arrays. The designated "hidden" object is shown in dashed lines.

At the end of the testing session, the child was praised for his performance and was allowed to select from a number or colorful decals in appreciation for his participation. Each session lasted 10-15 minutes.

Results and Discussion

The rate of correct responses (i.e., correct use of transitive logic) was analyzed using a binomial distribution test. Of the nine subjects tested, five answered all 4 transitive inference questions correctly ($p<.0002$). Six of the subjects answered at least 3 of the 4 transitive inference questions correctly ($p<.04$). All nine of the subjects answered at least 2 of the 4 transitive inference questions correctly ($p<.04$).

The results of this analysis support the conclusion that children of this age group are capable of making transitive inferences. However, one can still hypothesize a means whereby a child could employ categorical thinking to solve transitive inference problems in this experimental setting. For example, consider the case where B is the hidden object in an array where A>B>C>D>E. When asked whether B is larger or smaller than D, a child may respond "larger" because B is associated with A and C in the premise information, which are both "large" compared to D. Such a conclusion does not require the use of transitive inference to interpret the information that B>C and C>D.

It was the purpose of the second study to investigate this question further. Specifically, it was assumed that if one had a true understanding of transitivity, one would understand that, although B and C are both larger than D, the difference between B and D is greater than the difference between C and D. Experiment II was an effort to determine whether children of this age group understand this concept underlying transitivity.

Experiment II

Method

Subjects

Subjects included 18 preschool children, 8 boys and 10 girls. They ranged in age from 53 months to 65 months with a mean age of 58.72 months. 13 of the children were enrolled in one day school while the remaining 5 children were enrolled in a different day school. The average age of the children attending the first school was 59.23 months, while the average age of the children attending the second school was 57.40 months. The average age of the boys was 57.75 months, and the average age of the girls was 59.50 months.

Overview of Procedure

The purpose of Experiment II was to assess the child's understanding that, in an array A>B>C>D>E, the size difference between two non-adjacent objects is greater than the size difference between two adjacent objects. To assess this concept, a tool had to be developed that would quantify the child's perception of the relative size difference of two objects. A "ruler", composed of 5 sections of progressively darker purple, was designed for this purpose. The ruler and all other materials used in Experiment II are described in detail in the Appendix. Experiment II was divided into four sessions, two orientations sessions and two testing sessions, each lasting 10-15 minutes. Each session was conducted on an individual basis with the experimenter and child seated facing one another on a carpeted floor with the ruler extended from left to right between them.

The purpose of the first orientation session was to familiarize the child with the experimenter and with answering questions using the ruler. The purpose of the second orientation session was to further ensure the child's understanding of the ruler and to assess his perception of size differences using three-object arrays in which all objects were visible.

The purpose of the testing sessions (sessions 3 and 4) was to assess the child's perception of relative size differences in the context of a transitive inference problem. Each child was tested on four arrays of 5 objects each. Each testing session consisted of only two arrays to maintain a session length of no more than 15 minutes. Also, each testing session was conducted under a different condition, which will be described fully in the Procedures section.

To clarify terminology, throughout Experiment II the size difference between any two objects in an array will be referred to, in general, in "step-size" units. In an array A>B>C>D>E, where the size change is consistent across the array, the estimate of the size difference between two adjacent items in the array is denoted as a "1-step" estimate, and the estimate of the size difference between two non-adjacent items in the array separated by only one item is a "2-step" estimate. (See Figure 5.) For example, the size difference between A and C is a 2-step, and the size difference between A and D is a 3-step.

<u>Orientation Session I - Materials and Procedure</u>

As stated in the overview, the purpose of the first orientation

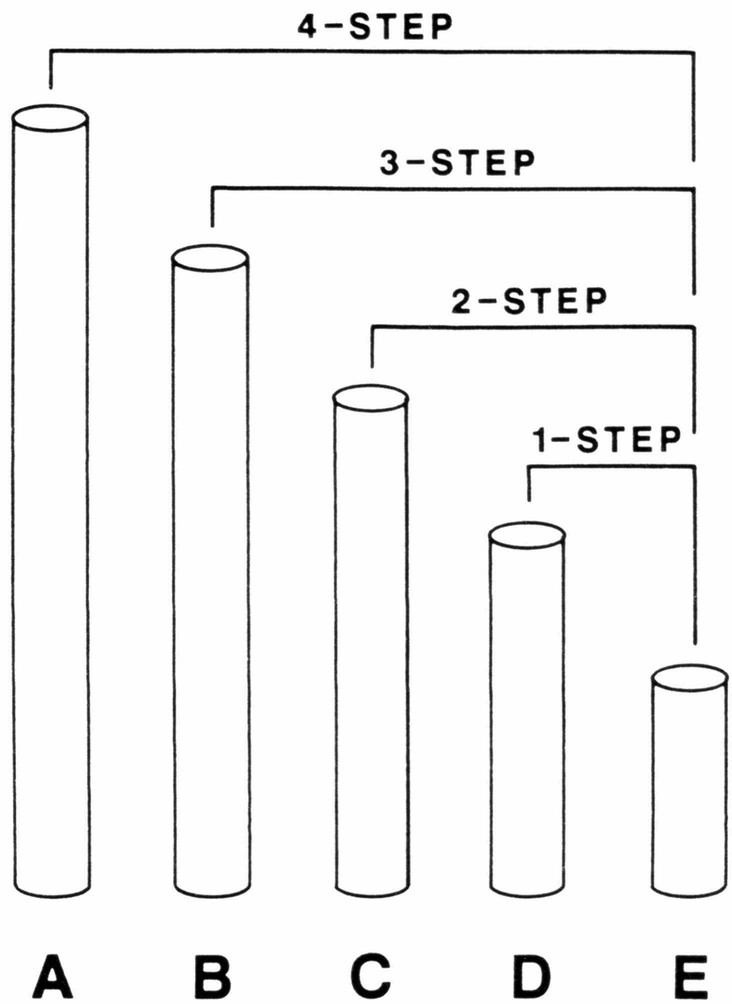

Figure 5. Step-size estimates

session was to familiarize the child with the experimenter and with answering questions using the ruler. The session began with the experimenter introducing herself and asking the child a few questions about himself. The child was then introduced to the puppet.

The child was told that he was going to be asked some "how much" questions and would be able to respond by placing a token on one of the sections of the ruler. The meaning of the areas of the ruler were described to the child from left to right: Area 1 (lightest) - "not very much"; Area 2 (next-to-lightest) - "a little bit"; Area 3 (middle) - "just some"; Area 4 (next-to-darkest) - "a lot"; and Area 5 (darkest) - "a whole bunch".

Following the description of the ruler, the child was asked a series of questions to help orient him to responding with the ruler. First, the child was asked three questions concerning how much he liked various items. After each response, the experimenter showed the child where to place the token on the ruler. The experimenter then asked the child to name an item he liked a whole bunch, an item he liked not very much, and an item he liked just some. After each response, the experimenter asked the child where he should place the token to illustrate the response. The child was corrected if he placed the token in the wrong area. Finally, the child was asked six more questions concerning how much he liked various items. The child was asked to not answer verbally but to place a token on the ruler to see if the experimenter could correctly interpret his response.

After this orientation to the meaning of each section of the ruler, the child was asked a series of questions to familiarize him with using the ruler to answer questions concerning the size difference between two objects. The child was told that the experimenter was going to ask him some more "how much" questions except these would be "how much <u>bigger</u>" questions. At this time, the three pictures of animals were displayed in a random triangular arrangement, and the child was asked to name the animals pictured.[1] The experimenter referred to the animals by the names given them by the child. (The deer was occassionally labeled as a "reindeer," and the squirrels were occassionally labeled as "chip-munks.") The picture of the deer was then flipped over, and the child was asked, "Which is bigger, the elephant or the squirrel? How much bigger?" The child placed one token on the ruler in response and was encouraged to leave it there so that he might remember his response. The picture of the deer was then flipped face up, and the picture of the elephant was flipped face down. The child was then asked, "Which is bigger, the deer or the squirrel? How much bigger?" The child placed the second token on the ruler in response. If the child placed the second token to indicate that the difference between the deer and the squirrel was not as great as the difference between the elephant and the squirrel, the experimenter stated, "So the deer is bigger than the squirrel, but not as much as the elephant. Is that right?" If the child did not place the second token in such a manner, the experimenter questioned the child about his placement of the token (i.e., "Is the deer as much bigger than the squirrel as the elephant is? Why not? If this token shows how much bigger the elephant is than the squirrel, where could you put the token that shows how much bigger the deer is than the squirrel?").

The procedure just described was repeated in this exact manner in each of the four sessions of the experiment and, for the sake of expediency, will be referred to as the animal-comparison procedure. The purpose of this procedure was to orient the child to comparing the size differences between pairs of objects using the ruler. It was repeated each session to ensure that the child was correctly interpreting the ruler.

After the animal-comparison procedure, the child was told that he would be asked some more "how much bigger" questions with shapes. The purpose of these questions was to familiarize the child with comparing the size differences between pairs of shapes in an array. The arrays used in Orientation Session I included the three-object arrays of circles, squares, triangles, and rectangles described in the Appendix. As each array was presented, it was displayed with all three shapes in linear order.[2] For each of the four arrays, the child was asked two comparisons: a 1-step comparison (either A-B or B-C) and a 2-step comparison (A-C). An example question is: "Which is bigger, the red square or the blue square? How much bigger?" The experimenter touched the shape in question as it was named. The child was corrected if he answered the "Which is bigger?" question incorrectly.

The following variables were counterbalanced across arrays: whether the two-step comparison was asked first or second, the order of the shapes in the question (i.e., "Which is bigger, A or C?" as opposed to "Which is bigger, C or A?"), whether the one-step comparison was A-B or B-C, and whether the largest shape in the array was to the experimenter's left or right. The order of presentation of the arrays was counterbalanced across subjects.

At the close of the first orientation session, each child was praised for his performance and permitted to select from a number of colorful decals. The first orientation session averaged 15 minutes in length.

<u>Orientation Session II - Materials and Procedure</u>

The second orientation session began with the experimenter reintroducing herself and the puppet and asking the child about his recent activities. The child was then asked if he remembered how to use the ruler and what the areas of the ruler represented. The experimenter reiterated the meaning of each area of the ruler. The child was then asked to respond to a few "how much do you like" questions by placing a token on the ruler. Following this, the animal-comparison procedure was repeated.

The purpose of the second orientation session was to assess the child's perception of the size difference between objects in a three-object array. Each child was asked two comparisons on four arrays as in the first orientation session. The arrays used in the second orientation session included the three-objects arrays of hexagons, rhombuses, ladders, and oblongs described in the Appendix.

The manner in which the questions were asked and the counterbalancing controls used were identical to those of the first orientation session.

When the second orientation session ended, the child was again praised for his performance and allowed to select from a number of colorful decals. The second orientation session averaged 10 minutes in length.

Testing Sessions (3 and 4) - Materials and Procedure

Each testing session began with the experimenter reintroducing herself and the puppet and asking the child about his recent activities. Following this, the experimenter reiterated the meaning of the areas of the ruler and repeated the animal-comparison procedure.

As stated in the overview of the procedure, the purpose of the testing sessions was to assess the child's perception of the size difference between two objects in the context of a transitive inference problem. Each child was tested on four arrays over two sessions, two arrays per session, to minimize the length of the sessions. The arrays used included the five-object arrays of circles, squares, rectangles, and rods described in the Appendix. For each array, the child was asked three types of questions: the transitive inference question, the transitive comparison questions, and the miscellaneous comparison questions.

Transitive Inference Question

The designated "hidden" object for the array remained in the bag in which the array was stored, and the remaining four objects of the array were displayed in linear order. (See Figure 6.) The child was told that there was another square in the bag that was bigger than E and smaller than C. This premise always compared the hidden object to the objects adjacent to it on both sides in the array. The experimenter touched the objects in question as the premise was stated. The child was asked to repeat the premise. After the child had done so once correctly, the child was asked, "Which is bigger, the square in the bag or D?" The premise information and the transitive inference question was the same for the rod array. When B was the hidden object, as in the

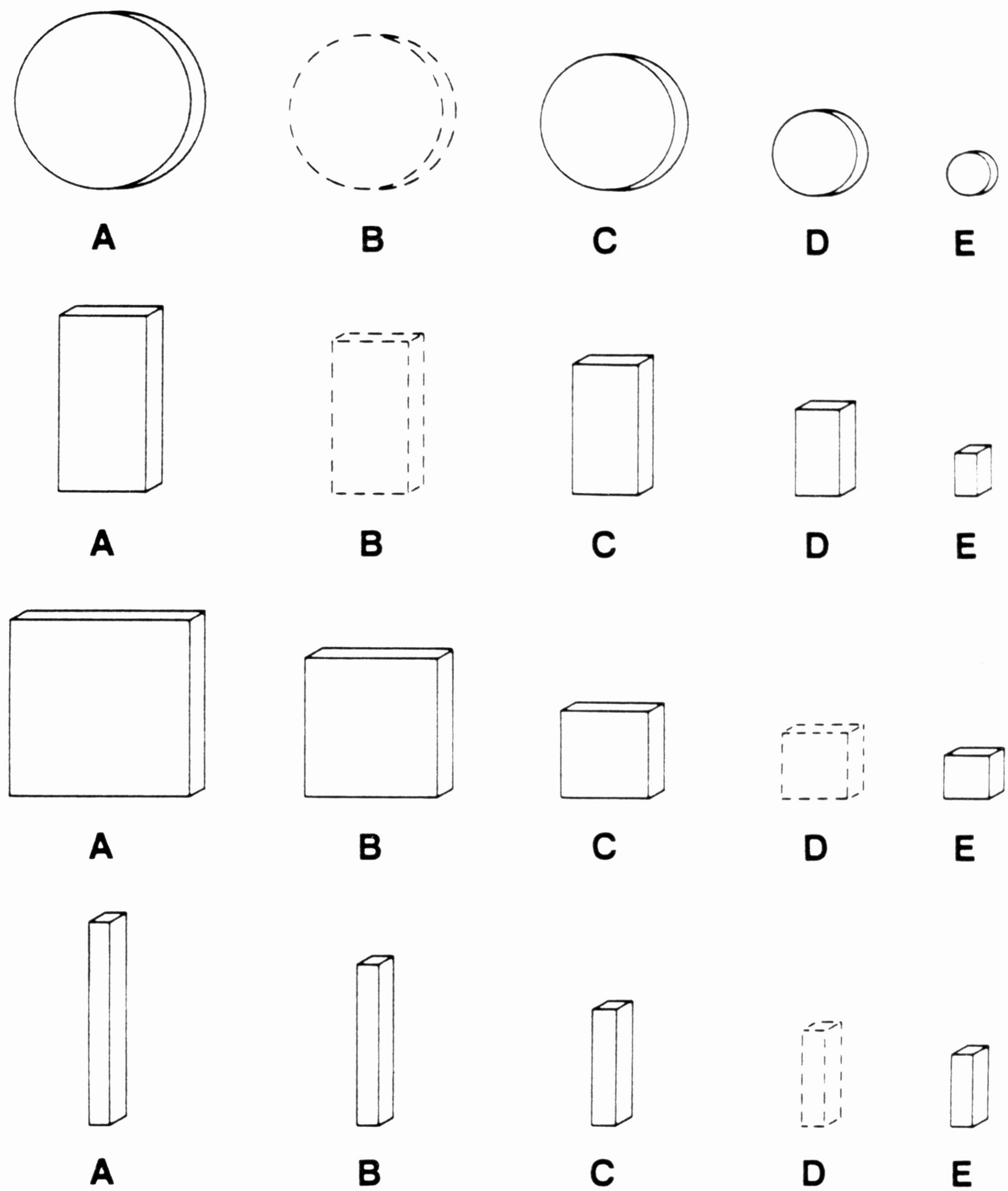

Figure 6. The five-object arrays. The designated "hidden" object is shown in dashed lines.

circle and rectangle arrays, the premise information was "I have another circle which is bigger than C and smaller than A," and transitive inference question was, "Which is bigger, the circle in the bag or D?"

Transitive Comparison Questions

The transitive comparison questions always followed the transitive inference question.[3] After the child responded as to which object was bigger, the one in the bag or the one that was visible, the experimenter asked, "How much bigger?" If the child responded verbally, the experimenter asked him to show the experimenter on the ruler. The experimenter then asked the child to make a 1-step comparison between the visible object of the transitive inference question and C. For the square and rod arrays, the questions asked were, "Which is bigger, B or C? How much bigger?" For the circle and rectangle arrays, the questions were, "Which is bigger C or D? How much bigger?" The child was then asked to repeat the premise information again as a check of premise retention.

Miscellaneous Comparison Questions

In addition to the above questions, the child was asked two miscellaneous comparisons, a 1-step comparison and a 2-step comparison. For each comparison, the child was asked which object was bigger and to indicate how much bigger on the ruler. For the circle and rectangle arrays, the child was asked to compare A and D, and to compare A and C. For the square and rod arrays, the child was asked to compare C and E and to compare B and E.

Hidden/Visible Conditions

As stated earlier, each child was tested during two sessions with two arrays in each session. For each child, one session was conducted in the Visible condition, and one session was conducted in the Hidden condition. For the Visible condition, the arrays were presented in exactly the manner just described. In the Hidden condition, two of the objects displayed for the child were covered using the covers described in the Appendix. (See Figure 7.) As the object under the cover was placed before the child in the linear array, its size in relation to the objects that could be seen was described. For the circle and rectangle arrays, A and C were placed under covers, and for the square and rod arrays, E and C were placed under covers. As can be seen by the size description of the covers in the Appendix, the covers maintained the linear order of the array (i.e., the cover for A was bigger than the cover for C which was bigger than the uncovered D, and the cover for E was smaller than the cover for C which was smaller than the uncovered B).

The following variables were counterbalanced across arrays: the order of the comparisons in the premise, the order of the objects in the transitive inference question (whether the correct answer was the first or second object stated), and whether the miscellaneous questions were asked before the transitive inference question or after the transitive comparison questions. The order of the presentation of arrays and whether the Visible condition preceded or followed the Hidden condition were counterbalanced across subjects.

At the end of each testing session, the child was praised for his performance and allowed to select from a number of colorful decals. Each testing session averaged 10 minutes in length.

Results

For the purpose of analysis, the subjects were divided into two age

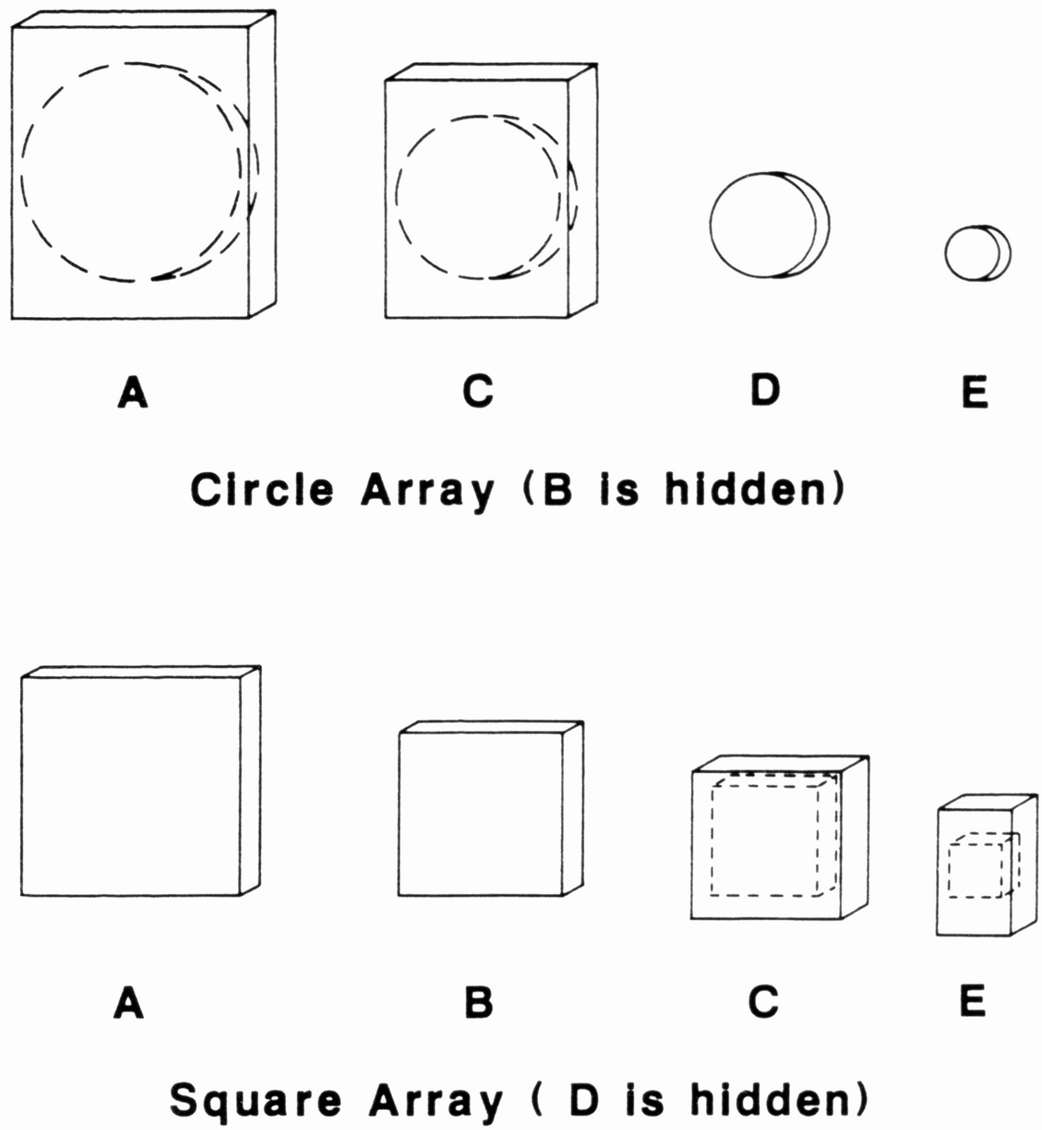

Figure 7. The use of covers in the Hidden Condition

groups: young (58 months and younger) and old (59 months and older). The mean age of the younger group was 55.11 months, while the mean age of the older group was 62.33 months. A binomial distribution test was used to analyze the rate of correct responses to the transitive inference question. All 9 younger subjects answered at least 2 out of the 4 transitive inference questions correctly ($p<.04$). Of the 9 older subjects, 8 answered at least 2 out of the 4 transitive inference questions correctly, a rate which failed to reach significance ($p=.17$). For the total group of subjects, however, the number of subjects answering at least 2 out of the 4 transitive inference questions correctly was significant ($p<.02$). Therefore, it appears that, as in Experiment I, the children were capable of correctly answering the transitive inference question.

To analyze the variation in the step-size estimates made by the subjects, a three-way analysis of variance with mixed measures was employed. The within-subject measures included Condition (hidden vs. visible) and Step-size Estimate (1-step estimate vs. transitive-step estimate vs. 2-step estimate). As stated in the Procedures section, the transitive-step estimate is essentially a $1\frac{1}{2}$-step estimate. The between-subjects measure was Age Group. The cell means for this analysis are shown in Table 1.

Results of this analysis revealed a significant main effect for Step-size Estimate ($p<.001$) and a significant interaction between Step-size Estimate and Age Group ($p<.01$). No other effects achieved significance.

Post-hoc t-tests were used to further clarify the contributions of

Table 1

Mean Step-Size Estimates in Visible and Hidden Conditions

	Step-Size		
Group	1-step	Transitive-step	2-step
Younger			
Hidden	3.61	3.22	3.61
Visible	3.56	3.17	4.39
Older			
Hidden	3.67	4.39	4.44
Visible	3.44	4.11	4.44

Note. Maximum estimate = 5.00.

the individual cell means to the significant effects found by the analysis of variance. The tests compared the step-size estimates made by younger subjects to the comparable estimates made by older subjects (i.e., 1-step of older children vs. 1-step of younger children, transitive-step of older children vs. transitive-step of younger children, and 2-step of older children vs. 2-step of younger children). It was found that the only significant difference existed between the mean transitive-step estimate made by the younger children and that made by the older children in both the Hidden Condition ($t=2.39$, $df=16$, $p<.05$) and in the Visible Condition ($t=1.94$, $df=16$, $p<.05$).

These results suggest that the younger children did not correctly integrate the hidden object into the array. As can be seen from the cell means, the younger children estimated the transitive-step to be smaller than the 1-step rather than larger. The older children, on the other hand, estimated the transitive-step to be larger than the 1-step and smaller than the 2-step. Therefore, it appears that the older children were correctly integrating the hidden object into the array.

It is necessary to determine whether the younger children's inability to judge the transitive-step to be larger than the 1-step stemmed from a failure to correctly integrate the hidden object into the array or simply from an inability to discriminate between different step-size estimates (i.e., an inability to discriminate between a 1-step and a 2-step). To answer this question, the data from Orientation Session II was analyzed using a two-way analysis of variance with mixed measures. Recall that Orientation Session II consisted of 4 three-object arrays where A>B>C and all three objects were visible. For each array, the child was asked to make a 1-step estimate (either A-B or B-C) and a 2-step estimate (A-C) for each array. The within-subject measure for this analysis was Step-size Estimate (1-step estimate vs. 2-step estimate), and the between-subjects measure was Age Group. The cell means for this analysis are shown in Table 2.

The results of the analysis revealed a significant main effect for Age Group ($p<.03$), a significant main effect for Step-size Estimate ($p<.0001$), and a significant interaction between Age Group and Step-size Estimate ($p<.02$). As can be seen from the cell means, the younger children were able to discriminate between the 1-step and the 2-step. Therefore, results indicate that the younger children were able to discriminate between step-size estimates when all objects involved were visible.

A second three-way analysis of variance with mixed measures was used involving the test session data to determine whether the difference between the younger children and older children would remain if the correctness of the response to the transitive inference question was controlled. As in the first three-way analysis of variance, the within-subject measures were Condition and Step-size Estimate, and the between-subjects measure was Age Group. Only arrays for which the response to the transitive inference question was correct were included in the analysis. The cell means for this analysis are shown in Table 3.

The results of the analysis revealed a significant main effect for Step-size Estimate ($p<.003$) and a significant interaction between Step-size Estimate and Age Group ($p<.02$). As can be seen from the cell means, the younger children estimated the transitive-step to be smaller

Table 2

Mean Step-Size Estimates Made by Children in Orientation Session II

Group	Step-Size 1-step	Step-Size 2-step
Younger	3.03	4.19
Older	4.19	4.61

Note. Maximum estimate = 5.00.

Table 3

Mean Step-Size Estimates in Visible and Hidden Conditions

for Arrays with Correct Response to Transitive Infererence Question

		Step-Size		
Group	n[a]	1-step	Transitive-step	2-step
Younger	9			
Hidden		3.61	3.22	3.61
Visible		3.56	3.17	4.39
Older	7			
Hidden		3.67	4.39	4.44
Visible		3.44	4.11	4.44

Note. Maximum estimate = 5.00.

[a]Numbers of children who had at least one array per condition in which the response to the transitive inference question was correct.

rather than larger than the 1-step, while the older children estimated the transitive-step to be larger than the 1-step and smaller than the 2-step. Therefore, it appears that the correctness of the response to the transitive inference question did not significantly contribute to the differences between the younger and the older children found by the first analysis of variance.

It was necessary to conduct a third three-way analysis of variance that controlled for the influence of memory. If one recalls from the Procedure section, the child was asked to repeat the premise information following the transitive inference and transitive comparison questions for each array. Therefore, this analysis only included arrays for which the child remembered the premise information. As in the previous three-way analyses of variance, the within-subject measures were Condition and Step-size Estimate, and the between-subjects measure was Age Group. The cell means for this analysis are shown in Table 4.

Once again, a significant main effect for Step-size Estimate was found ($p<.002$). However, although the younger children continued to estimate the transitve-step to be smaller than the 1-step while the older children estimated it to be larger, the interaction between Age Group and Step-size Estimate failed to reach significance ($p=.1527$). Therefore, it appears that memory could be a factor contributing to the differences between the step-size estimates made by the younger children and those made by the older children.

Another factor that is important to examine is whether, for each array, the transitive-step was judged as larger than the 1-step rather

Table 4

Mean Step-Size Estimates in Visible and Hidden Conditions for Arrays with Correct Premise Retention

		Step-Size		
Group	n[a]	1-step	Transitive-step	2-step
Younger	8			
Hidden		3.50	2.94	3.63
Visible		3.50	3.25	4.38
Older	9			
Hidden		3.67	3.83	4.56
Visible		3.50	4.17	4.44

Note. Maximum estimate = 5.00.

[a]Numbers of children who had at least one array per condition in which the response to the transitive inference question was correct.

than comparing average transitive-step estimates with average 1-step estimates. If the transitive-step was judged as larger than the 1-step, a "correctness" value of 2 was given to the array. If the transitive-step was judged as being equal to the 1-step, a correctness value of 1 was given to the array. If the transitive-step was judged as being smaller than the 1-step, a correctness value of 0 was given to the array. A two-way analysis of variance with mixed measures was used where the within-subject measure was Correctness of Estimate (Hidden Condition vs. Visible Condition), and the between-subjects measure was Age Group. The cell means for this analysis are shown in Table 5. The cell means had a possible range of 0.0 to 4.0 (two arrays per subject per cell).

The analysis revealed a significant main effect for Age Group ($p<.01$). Therefore, by inspecting the cell means, it appears that the older children were significantly more capable of judging the transitive-step as being larger than the 1-step than were the younger children on an array-by-array basis.

A series of analyses of variance were conducted to examine the influence of the counterbalanced variables on the correctness of response to the transitive inference question and on the step-size estimates. In the course of these analyses, a three-way interaction was revealed between step-size estimate, whether the hidden object was B or D, and whether the first array encountered during testing had the hidden object as B or D ($p<.001$). It was determined that the interaction was atheoretical. More information concerning this analysis may be obtained from the author.

Table 5

Mean Correctness Value in Hidden and Visible Conditions

	Condition	
Group	Hidden	Visible
Younger	1.67	2.11
Older	3.11	2.89

Note. Maximum correctness value = 4.00.

Discussion

In summary, the results of Experiment II revealed a significant main effect for step-size estimate and a significant interaction between age and step-size estimate. This interaction, however, was not significant when memory was controlled. Another analysis revealed that the older children were significantly more able than the younger children to correctly interpret the relationship between the transitive-step estimate and the 1-step estimate on an array-by-array basis.

It is apparent from these results that children under the approximate age of 5 years are not able to answer certain types of questions that older children are able to answer. Specifically, the younger children consistently estimated the transitive-step to be smaller, rather than larger, than the 1-step. Such an error was not made by the older children. It appears that the younger children are not able to use the premise information in combination with transitive inference to determine the relationship between the transitive-step and the 1-step.

In terms of Riley and Trabasso's linear-ordering model, the younger children are not correctly integrating the hidden object into the array. In other words, when B was the hidden object, the step-size estimates of the younger children suggest that they are forming a mental image of the array A>C>B>D>E rather than A>B>C>D>E. Note that both arrays would yield the correct answer to the question, "Which is bigger, B or D?"

It may be possible to interpret the performance of the younger children using a limited version of Breslow's sequential-contiguity model. According to this model, when the child is told that the hidden object (B) is bigger than C and smaller than A, he would retain the information that B "goes with" A and "goes with" C. If the hidden object B "goes with" the larger end of the array, it can be seen how the child could correctly answer the transitive inference question. However, the sequential-contiguity model does not offer an explanation for the younger children's integrating B between C and D rather than between A and C.

The usefulness of DeBoysson-Bardies and O'Regan's labeling model in the interpretation of the younger children's performance is also limited. The labeling model would require that the hidden object be repeatedly paired with an object with an absolute label of size in order to acquire that label itself. In Experiment II, the hidden object was only paired with an object with an absolute label (A or E) twice, once when the experimenter stated the premises and once when the child repeated the premises before answering the transitive inference question. Also, the labeling model cannot offer an explanation for the younger children's failure to correctly interpret the relationship between the transitive-step and the 1-step.

The results of the three-way analysis of variance which controlled for premise retention does support the position of Trabasso and his colleagues that stresses the importance of memory in solving transitive inference problems. In this analysis, although the pattern of results remained the same with the younger children continuing to estimate the transitive-step to be smaller than the 1-step, the interaction between age and step-size estimate failed to reach significance. Such a result warrants caution in generalizing from this study to a statement that a significant change in cognitive abilities occurs at approximately the age of 5. More children will have to be tested before the pattern of results can be understood. However, the difference between the older and younger children is supported by the finding that the older children were significantly more likely to estimate the transitive-step to be larger than the 1-step on an array-by-array basis.

Whether or not there exists a significant difference between the older children and the younger children, it is clear that the older children understand that, in an array A>B>C>D>E, the difference between B and D is greater than the difference between C and D, where the relationship between B and D must be inferred. This concept is one which is basic to an understanding of transitivity. The assessment of this concept, as in Experiment II, does not place an undo strain on the memory capacity of the young child nor is it subject to alternative interpretations as is Bryant and Trabasso's premise-training procedure.

Because of the small sample size of this study, it is important that additional children be tested. Based on the pattern of results of this study, however, it appears that an understanding of transitivity emerges at a younger age than proposed by Piaget, or at the approximate age of 5 years, but at an older age than that suggested by Bryant and Trabasso's original research (1971).

Notes

1. Five of the subjects did not experience the animal-comparison procedure during their first orientation session. All subjects experienced the animal-comparison procedure during the second orientation procedure.
2. During the first orientation session, three of the subjects did not view the three-object array all at once but only viewed the two objects being compared.
3. Note that the transitive comparison questions consisted of a 1-step estimate (either B-C or C-D) and the "transitive-step" estimate (the B-D comparison). As can be seen from the sizes of the objects described in the Appendix, the size of the four visible objects displayed in the array decreased in a consistent fashion so as not to leave a "hole" where the hidden object would be inserted into the array. Therefore, because the relative size difference between the hidden object and the objects adjacent to it in the array is half of the size difference between any other adjacent pairs in the array, the B-D comparison represents a "$1\frac{1}{2}$-step" estimate.

Appendix

Arrays

1. 5-Object Arrays

Four arrays of geometric shapes were cut from $\frac{3}{4}$" plywood. The shapes were painted either red, blue, green, yellow, or white so that the objects in an array were each of a different color. The colors were counterbalanced across arrays. The shapes and dimensions of each are listed in the table below.

	Object				
Array	A	B	C	D	E
Circle	12"	$10\frac{1}{2}$"	9"	6"	3"
Rectangle	12"x6"	$10\frac{1}{2}$"x$5\frac{1}{4}$"	9"x$4\frac{1}{2}$"	6"x3"	3"x$1\frac{1}{2}$"
Square	12"x12"	9"x9"	6"x6"	$4\frac{1}{2}$"x$4\frac{1}{2}$"	3"x3"
Rod	14"x$1\frac{1}{2}$"	11"x$1\frac{1}{2}$"	8"x$1\frac{1}{2}$"	$6\frac{1}{2}$"x$1\frac{1}{2}$"	5"x$1\frac{1}{2}$"

2. 3-Object Arrays

Eight arrays of geometric shapes were cut from colored posterboard of either red, blue, or green so that the objects in an array were each of a different color. The colors were counterbalanced across arrays. The shapes and dimensions of each are listed in the table below.

	Object		
Array	A	B	C
Circle	12"	9"	6"
Square	12"x12"	9"x9"	6"x6"
Triangle	12"(base)x$10\frac{1}{4}$"(height)	9"x$7\frac{3}{4}$"	6"x$5\frac{1}{8}$"
Rectangle	12"x6"	9"x$4\frac{1}{2}$"	6"x3"

Array	Object A	Object B	Object C
Hexagon	6"(diameter)x3"(side)	4"x4"	2"x1"
Rhombus[1]	6"(base)x3"(height)	$3\frac{1}{2}$"x$2\frac{1}{4}$"	2"x$1\frac{1}{2}$"
Ladder	9"x3"	7"x3"	5"x3"
Oblong[2]	9"x3"	$6\frac{5}{8}$"x3"	5"x3"

[1] 2 parallel sides with remaining sides at opposing 60° angles of base
[2] 2 parallel sides 3" apart with rounded ends

Other Materials

1. Ruler and Tokens

Five 6"x2" pieces of white posterboard were attached end-to-end with $\frac{1}{4}$"-wide black tape. Each section of the ruler was painted the same shade but different intensities of purple. The lightest section of the ruler was at one end with each of adjacent section painted progressively darker. The tokens were 2 plastic chips which were 1" in diameter and $\frac{1}{8}$" thick.

2. Animal Pictures

Three 2"x2" pictures of animals were obtained from a children's game. One picture was of a deer, one was of two squirrels, and the last was of two elephants, one adult and one baby.

3. Posterboard Covers

Four covers were constructed from white posterboard. The dimensions of the covers were 16"x13"x$1\frac{1}{2}$", 13"x10"x$1\frac{1}{2}$", 8"x8"x$1\frac{1}{2}$", and 7"x4"x$1\frac{1}{2}$".

4. Hand Puppet

A simple hand puppet was made from a brown sock with black button eyes.

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