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ABSTRACT

This study examines problems related to (1) the development of children's understanding of temporal cycles, and (2) the relationship between cyclic concepts and cognitive development. Piagetian tests of classification and seriation and a variety of specially designed cyclic tasks were administered to 62 children, ranging in age from 4 to 10 years. Results show major progress in the representation of cyclic order and recurrence during the age period examined. The age patterns support the theoretical distinction between the cyclic features of order and recurrence. Children are able to produce a correct order of the elements of a cycle about two years earlier than they are able to distinguish permutations which preserve cyclic order from those which violate it. The ability to produce a correct order is related to seriation performance, but not classification performance, when the variance attributable to age is partialled out. Continuity responses appear to be unrelated to performance on either of the Piagetian tasks tested when age is controlled. (Author/BF)

The Development of Children's Understanding of Temporal Cycles[1]

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Abstract

Developmental psychological approaches to the study of time have fallen mainly into three categories, studies of time perception; studies of logical, reconstructive abilities; and studies of the understanding of conventional time systems. The present work examines problems spanning the latter two categories, the development of children's understanding of temporal cycles and the relationship between cyclic concepts and cognitive development. Sixty-two children, ranging in age from four to ten years old, were administered Piagetian tests of classification and seriation and a variety of specially designed cyclic tasks. Results show major progress in the representation of cyclic order and recurrence during the age period examined. For a variety of particular cycles order responses were shown before continuity responses. The ability to produce a correct order is related to seriation performance but not classification performance when the variance attributable to age is partialled out. Continuity responses appear to be unrelated to performance on either of the Piagetian tasks tested when age is controlled.

The Development of Children's Understanding of Temporal Cycles[1]

Developmental psychological approaches to time have dealt with several distinct aspects of temporality. Piaget's (1971) work on children's understanding of succession and duration has focused on logical, reconstructive aspects. His tasks assess children's ability to make deductions about the relative succession or duration of two events or to reconstruct the order in which events in a process must have occurred. A second more diverse body of research is addressed to describing the development of children's understanding of conventional systems of time. These studies attempt to determine ages at which children master specific time systems, for example, calendars, seasons, and times of day (e.g., Ames, 1946; Oakden & Sturt, 1922; Springer, 1952). Research in the area of conventional time has been mainly descriptive and shows little attempt to model constituent abilities. But conventional time systems probably have a number of features which require logical abilities to master. Therefore, an analysis of constituent conceptual features and the required abilities may illuminate the developmental pattern.

The problem of cyclic concepts provides a point of convergence between the logical and conventional analyses, but this problem has not been approached directly in either. Temporal cycles have properties which are only partially represented in Piaget's (1971) description of linear time schemes and which have not yet been clarified by children's answers to questions about days of the week, times of day, and seasons of the year. One of the properties which cyclic time shares with linear time is temporal order. In either scheme a set of events is put into order according to the relationships of 'earlier' and 'later.' However, cyclic time has the additional property of recurrence - events re-occur periodically. Certain series of 'earlier' or 'later' relationships, those which equal the period of the cycle, have the same starting and end point, at least if one focuses on the names and other communalities among those points. The feature of recurrence entails that there be no fixed earliest event in a set of cyclical events because any member will recur if one continues in the 'earlier' or 'later' direction.

There is some question whether or not Piaget's grouping model (see Flavell, 1963; Piaget, 1942, 1949, 1950, 1957) would predict that the joint understanding or ordinal and recurrent aspects of cyclic time would be a concrete operational achievement. Within intervals of a cycle shorter than one period, the elements can be uniquely ordered according to an assymetrical relation, priority in time. This kind of ordinal structure is consonant with Piaget's Grouping V. However, no one of the groupings as formulated describes the structure of recurrence. Such a formulation would have to include the property that certain sequences of assymetrical relations are equivalent to an identity transformation.

The intent of the present study is to describe the pattern of development of cyclic time concepts and to explore the relationship between the achievement of these concepts and established concrete operational abilities. This investigation incorporates two aspects of the methodology used in the logical time studies: 1) the tasks require the child to manipulate and make judgments about concrete materials, and 2) competence is inferred from a pattern of responses and not the face validity of answers to particular questions. In contrast to the logical time studies, the events to be conceptualized are not demonstrated. Rather the child is provided with cards which depict or name parts of a cycle and asked to arrange or judge them in accordance with his knowledge of their organization.

The particular cycles to be studied differ in several ways. First, some are linked to natural cycles (e.g., diurnal or annual cycles) whereas others depend on arbitrary conventions (e.g., days of the week). Second, they vary in the duration of their periods: some as short as a few minutes while others span a year. Third, some of the cycles are entirely novel (one task uses materials which depict the repetitive activity of a laborer) while others are familiar to children (e.g., the events which normally occur at different times of the day). Finally, the cycles differ in "temporality": all but one depend on cyclic temporal phenomena; the remaining task assesses the child's ability to construct a spatial cycle (one period in the oscillation of a wave). Each of these dimensions of difference reflects a basis for comparing ages.

In addition to the cyclic tasks each child in the present study is administered standard tests of classification and seriation ability. These two abilities were selected because they are supposed to depend upon competence modeled by fundamentally distinct and well-exemplified groupings (I and V; Piaget, 1957; Flavell, 1963). They are of interest for two reasons. First, since Piaget found that the child's understanding of logical time is acquired together with a variety of concrete operational tasks, it is of interest to see whether the same is true for cyclic time. Second, although the recurrent aspects of temporal cycles cannot strictly be accounted for by the eight groupings, it is possible that classification or relational abilities may contribute to the understanding of temporal cycles; in that case, seriation or classification tasks may well correlate with performance on the cyclic tasks.

Method

Subjects

Sixty-two children, mainly from a suburban and semirural school district near Rochester, New York participated in the study. All of the children in the youngest group and some in the next youngest group were enrolled in one of two private nursery school/day care centers. The remaining children were pupils in an elementary school in the same town. Participating children returned a parental consent form to their schools.

Four age groups were constituted as follows:

I. Fifteen 4-year-olds, ranging in age from 4; 0 to 5; 0 with a mean age of 4; 7.

II. Seventeen 5- and 6-year-olds, ranging in age from 5; 1 to 6; 6 with a mean age of 5; 11.

III. Fifteen 8-year-olds, ranging in age from 7; 6 to 8; 4 with a mean age of 7; 11.

IV. Fifteen 10-year-olds, ranging in age from 9; 6 to 10; 7 with a mean age of 10; 0.

Procedure

All children were individually tested by a single experimenter, the author. Testing typically took place during two sessions of 20 to 40 minutes each, usually separated by several days. Several of the youngest children were unable to finish most tasks and were therefore tested in a single session. Occasionally, older children were seen in more than two sessions when testing was interrupted by a school activity.

The entire procedure consisted of three parts administered in the following order: first, a pair of Piagetian tasks, next, a set of cycle tasks presented in one of 15 random orders, and finally a pair of tasks dealing with complex cyclic order. For the sake of brevity the complex cyclic tasks and several subtests will not be reported.

Tasks

Piagetian Tasks. The Classification Task consisted of three subtasks adapted from Inhelder and Piaget (1964). In the Free Classification Sub-task the child was presented with 27 small geometric pieces cut from 4 mm. thick composition board and brightly painted. The collection included at least one piece with each combination of color (red, yellow, or blue) and shape (triangle, square, circle or semicircle). Children were given several paraphrases of instructions to put pieces together which go together and after an arrangement was produced were asked if other ways were possible. In the second sub-task they were instructed to put the same forms into four boxes according to the way the pieces belonged together. Performance on these sub-tasks was jointly scored according to four levels described by Inhelder & Piaget (1964). One point was awarded if the child produced a graphic collection, two for small collections of pieces sharing attributes, and three for consistent sorting according to only one dimension. Four points were awarded if a) the child sequentially sorted by each dimension, b) stated that this could be done, or c) produced an arrangement showing a hierarchic relation between dimensions. The third sub-task consisted of four class inclusion questions pertaining to a subset of the original forms consisting of three red squares, two yellow squares and four yellow triangles. The following four questions were administered, and each was scored as correct or incorrect:

Are all the triangles yellow?

Are all the red ones square?

Are all the square ones red?

Are all the yellow ones triangles?

One point was awarded for each correct answer. This number was added to the score for the first two subtasks and this sum, ranging from zero to eight, constituted the Classification Score.

Seriation Task. The Seriation Task was based on a procedure described by Elkind (1964). Fourteen thin wooden sticks of lengths ascending from 6 to 18 mm. were divided into two interspersed sets of nine and five members. The children had an opportunity to order the sticks. A score of from one to six was awarded depnding upon whether or not children could order the nine sticks or smaller sets and whether or not they could insert the set of five extras.

Daily Activities Task. This task consisted of a series of subtasks all using the same stimulus set. Figure 1 shows the set of four cards depicting waking up in the morning, working at school, eating dinner, and sleeping at night. At the beginning of the first subtask the child was introduced to "some pictures of different times." The child was asked to identify each picture. When the child's identification diverged from

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Insert Figure 1 about here

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the intended one the experimenter suggested a name ("morning", "school", "dinner", or "night"). Next the child was told to "put them the way you think they go." The experimenter recorded correctness (any starting point was acceptable but the true order need be preserved). When a child seemed to have arranged the cards at random they were shuffled, and he was asked to arrange them again. This was repeated until it was clear whether or not the child could recreate a particular order. If subsequent sorts differed from the order of the first, most or all of the succeeding sub-tasks were skipped.

The next sub-task to be reported required the child to judge the correctness of three alterations of his order. The first two were cyclic permutations (i.e., preserving the original cyclic order): the left most or right most card was moved to the other end. The third, non-cyclic permutation consisted of reversing the middle two cards. This sub-task was scored as correct only if all three judgments were correct.

Seasons Natural and Seasons Activities Tasks. Figure 1 shows the stimulus cards used in the Seasons Natural and Seasons Activities Tasks. Both tasks consisted of the same set of sub-tasks as the Daily Activities Task.

Workman Task. Figure 2 shows the stimulus set used for the Workman Task. Cards were presented in disarray and the child was instructed to put them the way they go. Following the spontaneous arrangement, the Permutation Sub-task described above was administered. The arrangement and permutation judgments were each scored either correct or incorrect as in the previous tasks.

Perceptual Task. Four segments of a period of an oscillating wave were isolated to produce the spatial cycle stimuli shown in Figure 2. The child was shown the model card (middle of Figure 2) and asked to

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Insert Figure 2 about here

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observe how the line "goes up into the white and down into the gray; up into the white and down into the gray." The model card was left in view and the child was given the four cards, randomly ordered, to arrange. The experimenter pointed out that the gray part of these cards belonged on the bottom, as in the model cards. Children were then asked to judge the correctness of each permutation. Arrangements and permutation judgments were scored as in previous tasks.

Holiday Task. This task used a set of cards depicting the holidays: Easter, Fourth of July, Halloween and Christmas/Hannukkah (see Figure 1). After the Spontaneous Sort Sub-task, children were administered the permutations subtask. Again, each of the twc substasks were scored correct or incorrect.

Days of the Week Task. This task and the following one were administered only to children who could read. A mixed set of cards naming the days of the week was presented and children were asked to "put them the way they go." Next, the child was asked where he would put extra end members (Sunday and Saturday or Monday depending on the child's arrangement). The experimenter noted whether the child matched each to the identical day or placed it on the opposite end.

Months Task. This task was identical to the previous one except that cards naming the months were used and the extra end members were January and December.

Results

Age Trends

Each of the pictorial cyclic tasks produced dichotomous distributions of success or failure on the Order and Permutations Sub-tasks. Tabulation by age group showed that all measures except the Workman Permutations index increased with age (Pearson X^2 test produced $p < .05$). The Workman Permutations X^2 approached significance ($p < .07$).

Comparison between individual tasks on the Order and Permutations indices was accomplished by estimating from the cross-tabulations the age at which 50% of subjects succeeded on each task and computing variance estimates based on the binomial distributions of age groups above and below the 50% age crossover. The estimates of the age at which 50% of subjects succeeded suggested that children were able to accurately order the elements of the Daily Activities set at a somewhat earlier age (about five years) than was the case for the other cyclic sets (about six- to six-and-one-half-years), and that ordering ability for the temporal tasks preceded the ability to discriminate correct from incorrect permutations (about eight- to eight-and-one-half-years). The Perceptual Permutations Task, which could be judged correctly by the recognition of good form, surpassed 50% correct by six years, about two years earlier than the other Perceptual tasks. However, confidence intervals showed that none of these differences was significant.

Further analyses of age patterns in the pictorial cyclic tasks were performed using composite Order and Permutations indices which pooled performance across tasks. Order I was computed for each subject as the mean of the Order scores of the Daily Activities, Seasons Natural, Seasons Activities, Holiday and Workman Tasks. Order I was counted as missing when more than one of its components was missing. Permutations I was computed in a similar manner using the Permutations scores of the same tasks. The Perceptual scores were excluded from these indices because, at least in the case of the Permutations index, the pattern of intercorrelations indicated separate spatial and temporal factors. Table 1 shows

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Insert Table 1 about here

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the mean Order I and Permutations I scores as a function of age group. An unweighted means analysis of variance was performed on these indices including only the subjects in Groups II, III and IV whose scores were present for both. This analysis supported the conclusions that scores increased overall with age ($F_{(2,38)} = 28.85$, $p < .01$), that Order I scores were greater overall than Permutation I scores ($F_{(1,38)} = 39.40$, $p < .01$), and that Permutations I increased somewhat more rapidly than Order I between five and ten years ($F_{(2,38)} = 3.36$, $p < .05$).

Two nonpictorial sets tested the ability to order and represent recurrence only in children who could read. All of the eight- and ten-year-olds and the two five- and six-year-olds who could read ordered the Days of the Week set correctly. The Months set was correctly arranged by 87% of the eight-year-olds and 79% of the ten-year-olds. The index of recurrence for these sets was based on children's placement of duplicate end elements on either identical cards or the other (correct) end of the series. For the Days of the Week set a little over half of the eight-year-olds' responses matched identical cards, while all of the ten-year-olds put both cards on the appropriate end. For the Months set 67% of the eight-year-olds' responses matched identical cards, while 72% of the ten-year-olds put the card on the correct end. In each case responses favoring continuity became predominant at about the same age as children accurately judge the Permutations in the pictorial tasks.

Relations Between Abilities

The relationship between performance on the cyclic tasks and performance on the Piagetian tasks was investigated by correlational analysis. Order I is highly correlated with age in months (Pearson $\underline{r} = .76$, $\underline{p} < .01$) and Seriation score ($\underline{r} = .72$, $\underline{p} < .01$), and weakly correlated with Classification score ($\underline{r} = .27$, $\underline{p} < .05$). Since Order I is correlated with age it is reasonable to assume that at least part of the variance included in the correlations between Order I and the Piagetian measures can be attributed to general cognitive advances during this age period and not abilities specific to seriation or classification performance. Presumably, partial correlations which control for general age improvement more accurately reflect the latter specific relationships. When age in months is controlled Order I is still correlated with Seriation (partial $\underline{r} = .37$, $p < .01$), but its correlation with Classification becomes negligible (partial $\underline{r} = -.14$, n.s.).

The partial correlation between Order I and Seriation is even greater when two additional correlates of Seriation (Classification and a cyclic spatial index based on the order and permutation indices of the Perceptual Task) are partialled out as well (partial $\underline{r}$ = .49, $\underline{p} < .01$).

Permutations I is highly correlated with age ($\underline{r}$ = .72, $\underline{p} < .01$), moderately correlated with Seriation ($\underline{r}$ = .53, $\underline{p} < .01$) and weakly correlated with Classification ($\underline{r}$ = .27, n.s.) overall, but when age is partialled out Permutations I appears unrelated to either Seriation (partial $\underline{r}$ = .10, n.s.) or Classification (partial $\underline{r}$ = .03, n.s.).

Discussion

The results showed major increases in children's ability to represent a variety of temporal cycles during the age period examined. The advances in cyclic concepts occur at about the same ages as previous researchers have shown substantial changes in logical time concepts, in the understanding of many conventional time systems and in numerous Piagetian concrete operational tasks. The age patterns support the theoretical distinction between the cyclic features of order and recurrence. Children are able to produce a correct order of the elements of a cycle about two years earlier than they are able to distinguish permutations which preserve cyclic order from those which violate it.

The observed relationship between temporal ordering ability and performance on the length seriation task raises the possibility that this first level of understanding temporal cycles is rooted in cognitive structures related specifically to those serving Seriation performance. This would be consistent with Piaget's claim (1971, p. 286) that the construction of the order of temporal succession depends upon groupings similar to those underlying the ability to create a series from sticks of varying sizes[1]. The present study provided no comparable information concerning the understanding of recurrence as assessed by the Permutations tasks, since this index was not specifically related to either of the Piagetian measures. It is possible that this second level of understanding temporal cycles is related to Piagetian abilities not tested in the present study, but the clarification of the nature of this level remains a problem for further investigation.

Questions concerning the sequence of mastery of particular cycles were not resolved. However, it appeared that the most familiar cycle, that of daily events, was the first to be ordered and that this could be accomplished by preschool-age children. The other temporal cycles, including the Workman cycle, showed comparable ages of mastery, suggesting that the abilities assessed by the Order and Permutations tasks could be applied to cycles with which the child was completely unfamiliar.

Finally, it is clear that methodology of the sort used in the present study can provide an important supplement to the question and answer methods predominantly used in the literature on conventional time concepts. First, the use of concrete materials may allow a more adequate assessment of the time concepts of those preschool children who are unable to construct verbal representations of the relationship between events. Second, conducting particular tasks with several temporal systems, (or using novel temporal systems) permits the inference of constituent abilities which contribute to the child's understanding of time at different age levels.

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Footnote

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Footnotes

[1]Piaget notes that the construction of temporal series in his tasks was a later achievment than spatial series and argues that this was because children confused spatial with temporal order. In the present study, where no such confusion was possible, children constructed many temporal series at about the same age at which they mastered the Seriation Task. One notable exception was the ordering of events in the daily cycle, which children apparently mastered even at an earlier age than that at which they could order sticks.

Table 1

Order I and Permutations I Scores By Age Group

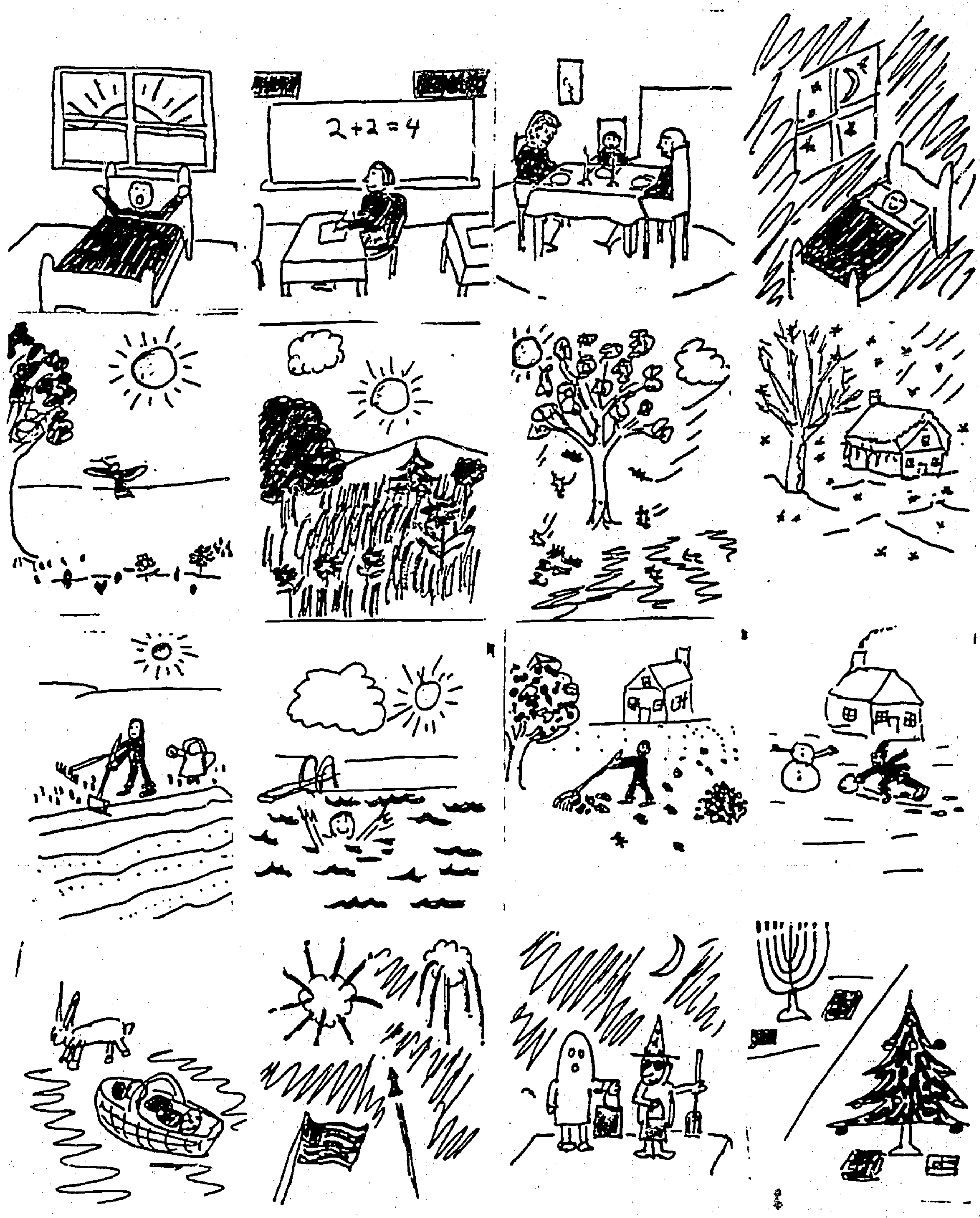
Age Group	Index: Order I Mean	S.D.	N	Permutations I Mean	S.D.	N
I	.2813	.0791	14	.0000	.0000	3[a]
II	.4265	.2785	17	.1115	.1583	13
III	.8000	.2390	15	.4179	.3861	14
IV	.9600	.1549	15	.8393	.2141	14

[a]Only three subjects in Group I completed four or five of the temporal Permutations tasks included in Permutations I.

Figure Captions

Figure 1. Stimulus cards used in (from top to bottom) the Daily Activities Task, Seasons Natural Task, Seasons Activities Task and Holiday Task. (Originals are in color.)

Figure 2 Stimulus cards used in the Workman Task (top) and Perceptual Task (middle and bottom).


2+2=4