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ABSTRACT

An analysis of children's narrative composition and art revealed concurrent development at both a general structural level and at a fine-grained detail level. A three-part study investigated whether this general cognitive pattern would be maintained across a different range of tasks: literary composition, scientific reasoning, and working memory. In the first part of the study, subjects, 80 children (aged 4, 6, 8, and 10 years, selected from a middle socioeconomic population) who had average to high-average scholastic ability, were asked to make up individual stories about a child their own age who has a problem to solve. In the second part, the same subjects were presented with a balance beam apparatus and asked to predict and to explain the resting position of beam when weights were placed in varying amounts. In the third part, the children were given the Mr. Cucumber Working Memory Measure. Results supported the previous notions that children's cognitive development proceeds through the same sequence of steps in a given domain and that children go through the same sequence during the same range. At the group level, performance on the three tasks was shown to be structurally equivalent and statistically indistinguishable, and, although the performance of individual subjects revealed more variation, the same general pattern held. (Three sets of figures are included.) (JK)

Horizontal structure: A neo-Piagetian analysis of structural parallels across domains

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Running head: Horizontal Structure

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The nature of cognitive developmental change has been the focus of considerable study since Piaget first articulated his theory of development (Piaget, 1950). During the intervening years, 2 major lines of thinking have evolved. Briefly, the proponents of the first argue that although advanced thinking is built upon the more elementary thought processes which proceed it, as Piaget suggested, cognitive performance advances independently in separate skill domains. That is, rate of developmental change may vary. This point of view is probably best exemplified by Flavell's postulation that "...the developments in question are temporally ordered rather than temporally concurrent" (Flavell, 1985, p.291).

The second line of thinking, which forms the theoretical basis of the present paper, is a re-conceptualization of the Piagetian notion that children's thinking is indeed stage like in that a characteristic type of thought exists at given age levels, across domains. The re-working of the horizontal structure concept was occasioned by the need to account for empirical evidence which countered Piaget's assertion that a coherent system or psychological structure ("structure d'ensemble") determined performance. Piaget (1970) reasoned that cognitive structures changed qualitatively with maturation and, as a result, cognitive development proceeds in universal stages. For example, 3 to 4 year-olds were said to be "intuitive" thinkers, whereas children of 7 or 8 years of age were thought to be capable of "the logic of function." Until children mastered this latter sort of thought they could not successfully perform certain classes of tasks, such as conservation.

A problem arose, however, when Piaget (Piaget & Szeminska, 1956)

determined that conservation tasks, themselves, were passed at different ages. For example, 5 or 6 year-olds typically were successful on conservation of number tasks,
whereas conservation of liquid tasks were not managed until 9 or 10 years. Such anomalies were referred to as the problem of "decalage" or unevenness and called into question the notion of universal stages (Brainerd, 1974, 1978; Fisher, 1980; Gelman, 1972; Gelman & Baillangeon, 1983). Recently, however, a small group of theorists have revived the notion of universal stages by reinterpreting it in terms of information processing theory (Case, 1978, 1985; Halford, 1980; Turiel, 1983).

One neo-Piagetian theorist is Case (1985), who, following Piaget, has proposed 4 qualitatively different cognitive stages, within each of which individuals progress through 4 substages. Unlike Piaget, however, he suggested that growth in processing capacity, as well maturational growth, determines cognitive development. Case suggested that at each subsequent substage, strategies become quantitatively more complex. An increase in working memory capacity (from 1 to 4 units) is hypothesized to make this progression possible, as it permits the child to focus on and integrate an additional chunk of information into his or her problem-solving procedure (see Figure 1).

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Insert Figure 1 about here

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The aforementioned horizontal decalage of conservation tasks can be explained within the neo-Piagetian framework by noting that, whereas children of 6 years (a) quantify each row of objects and (b) compare the results to determine which is greater, the conservation of liquid task requires that children (a) quantify the height of the liquid in each beaker, (b) quantify the width of each beaker, (c) compute height + width for each beaker, and (d) compare the 2 amounts. Two points are of interest here: First, both tasks require the same general cognitive operation (quantification of dimensions) and so are qualitatively the same. Second, the number of processing units required for the liquid task is greater than that needed for the number task, and so the tasks are quantitatively different. (The number task demands only 2 processing units, hypothesized to be available by 6 years, whereas the liquid task requires 4 processing units, thought to be available at 10 years). It would seem, then, that the reformulation of the concept of universal stages can account for the unevenness or decalage by postulating quantitative changes in the processing demand of qualitatively similar tasks.

A number of studies have been conducted to test Case's reformulation of general stage theory and, more specifically, the notion of horizontal structure. (Horizontal structure is thought to exist when children at age level 1 pass tasks X, Y, and Z at level 1, children at age level 2 pass the tasks at level 2, and so on). Whether making social judgements (e.g., determining degree of happiness by considering what birthday present was wished for versus what was received) or solving scientific reasoning tasks (e.g., balance scales, Siegler, 1976), Marini (1984) found that children's success depended on the number of chunks of information they could attend to and integrate and that this number was the same for both tasks across the 4 age groups studied (i.e., 1 at 4 years, 2 at 6 years, 3 at 8 years, and 4 at 10 years).

A horizontal structure has also been identified in creative thinking domains. An analysis of children's narrative composition (McKeough, 1984) and art (Dennis, 1984) revealed concurrent development at both a general structural level (i.e., the number of categories of information entertained by children at each age level was the same for both tasks) and at a fine-grained detail level (i.e., the number of chunks of information within each category of information was identical, across age groups). Finally, the pattern of intra-individual performance revealed that the majority of children scored at the same level on both tasks, and when deviation existed, it very rarely exceeded 1 performance level (Case, Marini, McKeough, Dennis, & Goldberg, 1986).

The results of the above studies called into question the dictum that "horizontal structure is the exception not the rule" (Fisher, 1980, p 80) and suggested that development in domains of diverse content may well be concurrent. The present study was conducted in order to determine if the general cognitive pattern identified previously would be maintained across a different range of tasks: literary composition, scientific reasoning, and working memory.

Story Composition Task

Method

Subjects. Eighty children (aged 4, 6, 8, and 10 years) who had average to high average scholastic ability (based on teacher evaluation and the Wechsler Intelligence Scale for Children-Revised, 1974, vocabulary subtest score) were selected from a middle socioeconomic population.

Procedure. Children were seen individually and were told: "I want you to tell me a story about someone, about your age, who has a problem they want to solve, you know, make all better. It can be a real problem but it doesn't have to be -- just a story about someone who has a problem they want to solve." The stories were recorded on an audio-cassette and later transcribed.

Scoring. Stories were assigned scores of 1, 2, 3, 4, or 5 based on the scoring criteria outlined in Figure 2. The reliability of the classification scheme was tested by having the stories scored by an independent rater. The ratings were in 81% agreement and the reliability coefficient (Cronbach alpha) was 0.95.

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Insert Figure 2 about here

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Results

The results of a structural analysis showed that 4-year-olds typically generated 4 interrelated events depicting a problem but failed to resolve it. Consequently, their stories seemed pointless. Nevertheless, the causally and temporally related event sequences suggested that 4-year-olds processing capacity could entertain at least 4 event units. At 6 years of age, children did represent a resolution. Thus, their stories were qualitatively different; they had a point or plot. Whereas the organizational scheme of the "pointless" 4-year-old stories was based on the interrelation of event to event, that of the 6-year-olds was based on the interrelation of event sequences to event sequence. This shift can be accounted for by postulating the consolidation of the 4-year-old event structure and the subsequent coordination of 2 such structures, by 6 years of age.

At 8 years, the attempt at resolution which met with success at 6 years was stymied, thereby creating a failed attempt category of events. This shift is described as quantitative rather than qualitative because although the addition of a failed attempt category did not result in a dramatic change (such as the introduction of plot), it nevertheless produced a dual focus in the stories (i.e., on a failed solution as well as on a successful one). Thus, the 8-year-old story structure consisted of 3 categories of event sequences: problem, failed attempt, and resolution.

Ten-year-olds elaborated on the above structure by generating a second problem associated with the failed attempt. Consequently, their resolutions had to account for 2 problems and so were more elaborate and better planned than were the fortuitous resolutions seen at the 8 year level.

Story scores (Figure 1 criteria) were subjected to a one way ANOVA which yielded a significant group effect $F(3,71) = 138.72$, $p < .001$. Non-orthogonal apriori tests of adjacent means (set at 0.01) demonstrated that group 1 < group 2 < group 3 < group 4. Furthermore, a trend analysis showed that the linear component was significant ($p < .001$) and accounted for 85% of the variance.

To test the prediction that the developmental progression was analogous to that postulated by Case, a predicted line was set up which set the levels of performance for each group at those specified by Case's theory. The actual mean scores for each age group were then plotted against these predicted values and the deviation of each subject's actual composition score from the predicted score was computed. An ANOVA performed on the deviation scores revealed that there was no significant difference among the four groups $F(3,71) = 0.57$. $p > .05$; nor was the grand mean effect significant $F(1,71) = 0.07$, $p > .05$). Finally, ω^2 was calculated and showed that the model accounted for 85% of the variance.

Balance Beam Task

Method

Procedure. The same group of children were given a scientific reasoning task, the balance beam task (Siegler, 1976; Marini, 1984). On this task subjects were presented with a balance beam apparatus and asked to predict and to explain the resting position of the beam when weights were placed in varying amounts at various distances from the fulcrum. Five problem types were given, each more difficult than its predecessor. Two trials weré offered at each level and administration ceased when both trails were failed at a given level. Scores were obtained by averaging performance across levels.

The first problem type could be solved by scanning relative amount, (i.e., a lot versus a little). The second problem type could be solved by counting the number of weight units on each side of the fulcrum and then, comparing the amounts to determine which side had more. In other words, children coordinated the scheme for numerosity with the previously used scheme for determining relative amount. On the third problem type children had to quantify weight units and then distance units, while on the fourth problem type, both the weight and distance variables had to be compensated for. A fifth level, included to eliminate a possible ceiling effect, required that subjects use abstract reasoning, that is, they form a directly comparable ratio between weight and distance on each side of the fulcrum (e.g., 1:4 :: 2:1).

Results

The results of a one way ANOVA performed on the balance beam scores yielded a significant group effect $F(3, 76) = 112.01$, $p < .001$. Non-orthogonal apriori test for adjacent means showed that the groups were in the following relationship: group 1 < group 2 < group 3 < group 4. Moreover, a trend analysis revealed that the linear component was significant (α set at .01) and accounted for 81% of the variance (non-linear = 1%). As before, a predicted line was set up and the deviation of actual scores from predicted scores were computed. ANOVA results showed that, when α was set at .01, the groups did not differ significantly $F(3, 76) = 3.18$, $p < .01$ and that the grand mean showed no significant vertical displacement $F(1, 76) = 2.7$, $p >$

.05. The ω^2 calculation indicated that the model accounted for 78% of the variance.

Working Memory Task

Method

Procedure. The same group of children were given the Mr. Cucumber Working Memory Measure. Children were presented with a cartoon figure on which stickers were affixed, and then presented with a figure without stickers and asked to point to the former position of the stickers. The test increased in difficulty across 5 levels, as the number of stickers to be remembered increased from 1 to 5. Again, the fifth level was included to eliminate a possible ceiling effect. Three trails were offered at each level and administration ceased when all 3 trials at a given level were failed. Scores were obtained by averaging performance across levels. (See Case, 1985, for a more complete description.)

Results

A one-way ANOVA performed on the working memory scores revealed a significant group effect $F(3,76) = 50.33$, $p < .001$. A trend analysis showed that the linear component accounted for 65% of the variance (non-linear = 1%). Apriori non-orthogonal tests of adjacent means revealed that group 2 < group 3 < group 4 (alpha set at .01). An ANOVA conducted on the deviation of the children's actual scores from those predicted by Case's theory showed that, when α was set at .01, the four groups performed similarly, $F(3,76) = .004$, $p > .05$ and the grand mean showed no vertical displacement $F(1,76) = 3.92$, $p > .01$. The ω^2 calculation revealed that the model accounted for 60% of the variance.

Structural Parallels Between Tasks

The story composition and balance beam tasks were presumed to be formally equivalent because on both, 4-year-olds utilized an integrated system of "first-order relations" to produce their responses (relations between events for stories and, for the balance beam task, relations between weights and the beam which determine relative amount). By 6 years, "second-order relations" were established, that is, relations between schemes for generating event sequences in stories and between schemes for determining relative amount and numerosity for the balance beam. Subsequent changes at 8 and 10 years, revealed the inclusion of an additional structurally equivalent scheme for both tasks. An inspection of Figure 3 shows that the processing demands of both structures increase from 1 to 4 across the 4 levels of the task.

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Insert Figure 3 about here

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Recall that the theory assumes that an increase in working memory capacity underlies substage performance change by enabling the child to entertain an additional chunk of information as capacity becomes available. Conversely, capacity is also thought to place a ceiling on performance by limiting the number of schemes that can be integrated. If this is the case, we would also expect to see parallels in performance on the Mr. Cucumber Working Memory Measure which requires that children apprehend a system of relations between the cartoon figure's body features and the position of stickers which increase in number from 1 to 5 across the 5 levels of the task. To test the hypothesis that the developmental progressions occur concurrently, children's performance on the 3 tasks was compared.

Results

First, to compare performance on the 3 tasks, the group means were graphed (see Figure 4). Next, to test the hypothesis that children's performance on the story and balance beam tasks were statistically indistinguishable, an ANOVA was conducted on the groups' deviation scores. The averaged scores did not vary by group $F(3, 71) = 2.18$, $p > .05$ nor did the grand mean show significant vertical displacement $F(1,71) = 0.38$, $p > .05$. Furthermore, there was no significant task $F(1, 71) = 2.79$, $p > .05$ and no significant task X group interaction effect $F(1, 71) = 1.52$, $p > .05$.

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Insert Figure 4 about here

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To test the hypothesis that children's performance on the working memory measure was statistically indistinguishably from performance on the story and balance beam tasks, 2 two-way ANOVAs were conducted. Results revealed no significant task effect $F(1,71) = 0.55$, $p > .05$ and no significant task X group interaction effect $F(3,71) = 1.87$, $p > .05$ for the story - working memory analysis. Similarly, no significant task ($F(1.76) = 1.43$, $p > .05$) nor task X group interaction effect ($F(3.76) = 2.46$, $p > .05$) was found for the balance beam working memory analysis.

An inspection of individual subjects' performance showed that 42% performed at the same level on the 3 tasks and that 82% scored at the same level on 2 of the tasks. Finally, 94% scored within 1 level on all 3 tasks.

Discussion

The question is essentially this: Does cognition develop independently in separate domains in a "A" then "B" then "C" fashion, or are the various capacities interrelated such that a characteristic way of representing and therefore solving problems exists at specific age levels?

As was noted in the introduction, there is general agreement among researchers that children's cognitive development proceeds through the same sequence of steps in a given domain. The results of the present study support this notion and, in fact, offer a model of when and why these sequences occur. More importantly for the current discussion, though, the findings also lend support for the notion that the sequences occur concurrently, that is, that children go through the same sequence during the same age range. At the group level, performance on the three tasks, literary composition, scientific reasoning, and working memory, was shown to be structurally equivalent and statistically indistinguishable, and, although the performance of individual subjects revealed more variation, the same general pattern held.

Two questions arise from these findings: (1) How can we account for synchrony in cognitive development on these 3 tasks? (2) How can we account for the increase in variation noted when individual performance was examined?

If we assume that maturation and experience are both operative, one possibility is offered by distinguishing between "structural" and "functional" working memory (Pascual-Leone, 1972). Changes in the structure of working memory space are thought to be brought about by maturation, while increased processing efficiency reduces the space required to execute an operation and so functionally increases working memory capacity. This latter type of change is influenced by experience within a given domain and so, might account for the asynchrony observed. Maturation, on the other hand, being largely biologically determined, might proceed at a more regular rate, and so account for the synchrony in development across content domains.

One final point remains to be addressed. How can the findings of the current study be explained in light of the work which suggested that "decalage is the rule, not the exception" (Fisher, 1980, p.80) One way to account for the present set of results might be to consider the method of subject selection. Teachers were asked to select average to high average achievers. If these directions caused them to select the good "overall" students rather than those who have good but less regular performance profiles, then the selection procedures could have slanted the outcome in favor of consistency across domains.

Probably a more important factor, though, is the grain of analysis used in the current study. Many of the previous studies which used a very general level of analysis, such as that utilized by Piaget, and so, overlooked the smaller quantitative steps, whereas the micro analysis used by the information processors proved to be so detailed that it failed to reveal the commonalities. The level of analysis used in the present work occupies the middle ground and so avoids both extremities by maintaining Piaget's notion of general stages by postulating a consolidation of elementary structures and a subsequent assembly of these into a system but recasting them in terms of quantitative capacity increase and resulting strategy change.

It is the capacity to represent problems in terms of second-order relations (i.e., dimensions or categories) that characterizes children's cognitive capabilities from 5 to 10 years and it is this capacity which is presumed to be responsible for the horizontal structure observed across the 3 tasks.

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Figure 1. Case's Stages and Substages

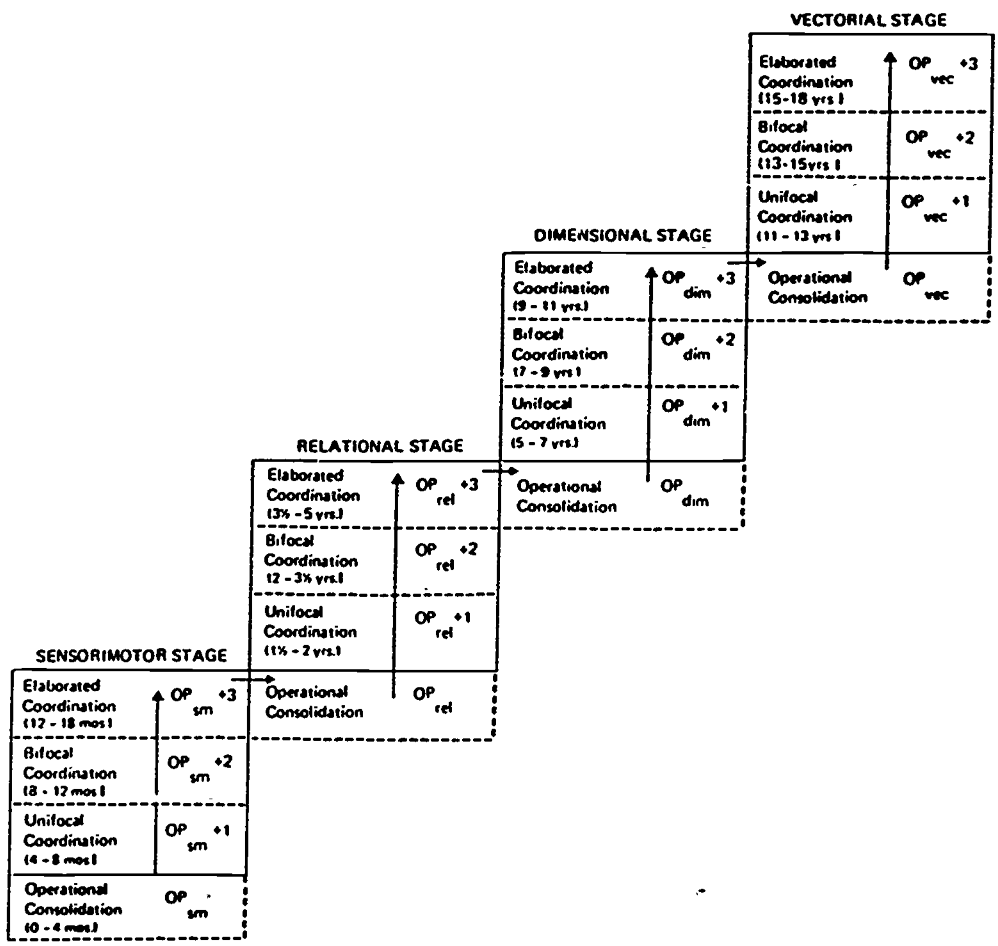

FIGURE 2

Scoring Criteria

Does the story have a problem?

NO = 0 YES

Is the problem resolved?

NO = 1 YES

Are there any failed attempts (or impediments) inserted before resolution?

NO = 2 YES

Is one impediment/attempt more significant than the others, with the ultimate resolution having a "well developed" or "carefully planned" feeling as a consequence?

NO =3 YES

Is the protagonist's inner world (i.e. psychological state) developed throughout the story, as well as or, in addition to his outer world?

NO = 4 YES = 5

Figure 3. Structure of Story and Balance Beam Task