20 Interactive Roles of Knowledge and Strategies in the Development of Organized Sorting and Recall

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This chapter addresses the issue of how existing knowledge in semantic memory affects children's use of cognitive strategies. Briefly, I propose that strategy usage is not a simple matter of whether a given cognitive strategy is or is not available to and usable by the child depending on his stage of maturation. Instead, the use of a given cognitive strategy, it appears, has a complex interaction with the amount and structure of the content knowledge to which the strategy is to be applied. Such a view brings up questions concerning the role of maturation per se in the acquisition of strategies. It suggests the possibility that maturation is correlated, but not causally related, to the rate at which more knowledge is acquired and also implies that the acquisition of this knowledge facilitates the acquisition and use of strategies. Empirical data that begin to demonstrate such an interaction is presented.

The fact that both knowledge and strategies (and their interaction) are discussed here implies that they are two separate components. Whether or not this is actually true is probably an academic question, and the debate concerning distinction between knowledge and strategies is unresolved at present (see Winograd, 1975, for a discussion). Nevertheless, in order to make some sense of the current developmental literature, it seems reasonable to assume, at least as a working hypothesis, that (domain) knowledge and strategies are separable and distinct.

I begin by describing a very robust developmental finding, the absence of organization in the young child's recall output. Typically, in the past, this has been attributed mainly to a strategic deficiency. It is hypothesized that the child fails to organize the inputs for proper storage, so that retrieval often fails to show any systematicity in the recall outputs.

ABSENCE OF ORGANIZATION

In a typical free recall task, a list of items is presented, and the subject is asked to recall them in any order. The sequence of recall may reveal the organization that the subject imposes on the stimulus items. Because the order of the output sequence does not match the order of the input sequence, some rearrangement of the input has been made by the subject so that the stimuli may be more compatible with an existing internal organization.

The presence of organization in the output is assessed by several measures, such as category clustering or subjective organization. For simplicity, this chapter focuses mainly on category clustering. The adult data show in general that, when items belonging to different categories (such as *Clothing, Furniture, Vehicles*) are randomly presented to an adult subject, the recall sequence will manifest clustering of items belonging to the same category (Mandler, 1967; Tulving, 1962). Young children, on the other hand, are not as likely to show strong category clustering (Bousfield, 1953; Cole, Frankel, & Sharp, 1971; Laurence, 1966; Nelson, 1969; Shapiro & Moely, 1971); and this tendency to cluster increases with age (Mandler & Stephens, 1967; Vaughan, 1968). Furthermore, this increase in clustering correlates with the general increases in the amount recalled, as well as with increasing age (Bousfield, Esterson, & Whitmarsh, 1958; Cole et al., 1971; Horowitz, 1969; Lange, 1978; Lange & Jackson, 1974; Liberty & Ornstein, 1973; Moely, Olson, Halwes, & Flavell, 1969; Neimark, Slotnick, & Ulrich, 1971; Rossi, 1964; Shultz, Charness, & Berman, 1973; Vaughan, 1968).

Although there is a general correlation between the amount of recall and the amount of clustering in both adults and children, it is not clear that the correlations denote the same kind of relationships for children and adults. First, the number of categories present in a stimulus list does not affect recall developmentally in children, but does so in adults (Mandler & Stephens, 1967). That is, for adults an increasing (up to 7) number of categories into which the stimulus set can be divided produces an increasing number of items recalled (Mandler, 1967), whereas this has not been a consistent finding in children (Mandler & Stephens, 1967; Worden, 1975). Second, first graders can recall unrelated items even when the subjective organization scores are low (Rosner, 1974). Finally, it has been possible to obtain clustering with even the youngest children, ages 2–3 (Rossi & Rossi, 1965). Hence, the relevance of the relation between amount of clustering and amount of recall is tenuous at best. Therefore, it is simply not clear that young children's low amount of recall is related to an inefficient organizational strategy, as might be the case in adults.

Nevertheless, there is a real absence of category clustering per se in young children's recall output, which can be further confirmed by their failure to form taxonomic categories in sorting tasks. Taxonomic categories generally refer to a category hierarchy, whereby basic objects such as chairs and tables can be grouped into the superordinate category, "Furniture" (Rosch, Mervis, Gray, Johnson, & Boyes–Braem, 1976). This level of organization is most commonly probed in the experimental paradigm, but the hierarchy can also include a lower level in which subordinate objects, such as rocking chair and captain's chair, can be grouped into the basic level category, *Chair*.

When asked to form groups of basic objects, young children typically do not do so taxonomically—they do not group together basic objects from the same superordinate category. Instead, children tend to group things for a variety of other reasons, such as on the basis of perceptual similarity (Melkman, Tversky, & Baratz, 1981; Tomikawa & Dodd, 1981), concrete situations (Goldman & Levine, 1963; Olver & Hornsby, 1966), association, and so on.

Children's sorting categories are also smaller and more fragmented; they often are constructed with different items, different sorting criteria, and presumably different conceptual properties than those of adults and older children (Goldman & Levine, 1963; Lange & Hultsch, 1970; Liberty & Ornstein, 1973; Saltz & Sigel, 1967; Saltz, Soller, & Sigel, 1972). Furthermore, even if children do form taxonomic categories, they are not often exhaustive; that is, they do not include all the items on the list in a given category (Annett, 1959; Flavell, 1970). Thus, children divide a set into more categories with a smaller number of items in each category (Lange & Jackson, 1974; Worden, 1974). Also, the younger children tend to take a longer time to reach a consistent sort than do the older children, suggesting that the bases of their organization are less stable.

Although it is not at all clear that there is a simple relation between categorization of the stimuli during sorting and clustering in recall, the two measures have been attributed to the same underlying deficiency—namely, that children lack abstract classification principles. In fact, there actually may be a very tenuous relation betweem the two measures, as is seen in Study Three.

AVAILABILITY OF KNOWLEDGE AND THE STRUCTURE OF CATEGORIES

In attempting to understand the absence of strong category clustering and the deficiency in taxonomic sorting in children, the natural questions to raise are whether categorical knowledge is available to children in the first place, and if the structures of children's categories are adequately developed to allow for the presence of categorical organization in the recall and sorting outputs.

The general consensus among investigators in this research area is that categorical knowledge is available to young children for the tested stimulus material. This conclusion is based on a variety of techniques used to assess categorical knowledge. In the majority of the cases, assessment of categorical knowledge is conducted by using supplementary tasks in conjunction with the primary task of sorting or free recall. Liberty and Ornstein (1973), in a postquestioning task, asked fourth graders to group "things that go together." Although these children did not initially cluster their recall outputs, they were able to "put things that go together." This is taken as evidence that they do have knowledge of the semantic relations among the items, but only the older children used this knowledge to organize their recall. Thus, the interpretation was one of production deficiency. Kobasigawa and Middleton (1972) also indicated that young children have explicit knowledge of taxonomic categories by asking subjects in the posttest interview to identify the six pictures (out of 24) that belonged to each of four categories. None of the children, including those in kindergarten, had any difficulty doing this even though their clustering and recall scores were significantly worse than the fifth graders. This is again taken as evidence for the availability of the knowledge that is not used for the purpose of recall or clustering.

In other cases, the research goal was to assess directly the structure and content of children's categorical knowledge. The evidence accumulated so far indicates that the structure of children's categories is fundamentally the same as adults, except that the children's categories may be more restricted, but both children and adults basically have the same categories and the same set of "core" or "typical" items. What may differ is the extent and size of the categories; the boundaries of young children's categories may be more restricted and less well defined than adults. Several studies support this conclusion. Using a recognition procedure, Saltz, Soller, and Sigel (1972) asked children to select exemplars of categories from a large set of pictures. Exemplars that were picked by 75% of the children were considered to be the "core" members, which are the "typical" members of a category. The basic finding was that the younger children's core members are a subset of older children's core members.

Using a sentence verification procedure to examine children's category structure, Rosch (cited in Mervis, 1980) asked subjects to indicate the truth of sentences such as "A dog is an animal." Both children and adults responded more quickly to such sentences if the instance was a typical exemplar of the category than if it was not. Furthermore, children made a greater number of errors in verifying atypical instances, suggesting that children have already learned the good, but not the poor, exemplars. Similarly, using a production task, Nelson (1974) asked children to generate instances of a superordinate category such as "Animals." Again, 5- and 8-year-olds generated predominantly the same set of core items, except that the younger children produced (1) fewer exemplars for each category, (2) inappropriate instances of a category, and (3) a more limited set of core items than adults (Rosner & Hayes, 1977).

In sum, it seems fairly safe to conclude that young children have knowledge of categories and their members, but their category members are limited in number, the core items are more restricted, and the boundaries are less well defined.

DISCREPANCY BETWEEN THE AVAILABILITY OF KNOWLEDGE AND THE ABSENCE OF ORGANIZATION

How does one resolve the discrepancy between the apparent availability of categorical knowledge in young children, the apparent similarity in the categorical structures of children and adults, and children's failure to use this knowledge in their clustering ouptuts? This discrepancy can be interpreted in two ways. First, in studies that assess knowledge directly (such as in a postquestioning task), the instruction is usually so explicit that the subject taps a specific set of links between two concepts and not necessarily the entire hierarchical or categorical structure. For example, to be able to answer correctly the question "Is a robin a bird?" one needs only to activate the link *Robin* and *Bird;* this does not necessarily imply that *Robin* is hierarchically embedded in the *Bird* category. This distinction is pointed out more explicitly in Study One (also see Chi, 1983). It is also suggested here that assessing the presence of links between things that go together is not a legitimate way to determine knowledge of semantic relations (see Study Four). Thus, this first interpretation denies the conclusion that the necessary categorical knowledge is always present on the basis of the way it has been assessed.

A second way to resolve the apparent discrepancy is to accept the assumption that young children do have categorical structures much like those in older children and adults, as is shown in the studies cited previously, except that young children's categories have fewer members than the older children's and adults'. If this premise is true, we should be able to find evidence of elevated sorting and clustering scores in young children when the material used in the recall tasks is the central members of the category.

Four kinds of experimental paradigm can provide this type of evidence. First, studies prior to the work on Rosch's notion of typical members manipulated the stimulus materials in terms of high and low associates, or good and poor exemplars, rather than typicality. If one assumes that high associates are, more or less, the central members of a category, the evidence shows that clustering occurs even in very young children (Corsale, 1978; Haynes & Kulhavy, 1976; Rossi & Rossi, 1965; Rossi & Wittrock, 1971; Vaughan, 1968). Likewise, children are also more capable of answering class-inclusion questions for good versus poor exemplars (Carson & Abrahamson, 1976). A second type of paradigm uses subject-generated members of categories. Again, if one makes a similar assumption that subject-generated members are the subject's more central members, then presumably recall, as well as clustering, should be better. This tendency occurs developmentally (Nelson, 1969; Worden, 1976). Third, if one directly manipulates the typicality of the members, then one should find that "core" members of a category should be easier to recall than the peripheral members. Bjorklund and Ornstein (1976) found that the clustering scores for the typical members were higher than for the less typical members. The results of Moely and Jeffrey (1974), using lists constructed to contain highly cohesive versus uncohesive members of the same category, may be interpreted in the same way. Six-year-olds had better recall and greater organization for the cohesive members. (Study Three may be interpreted in the same way.) Likewise, Northrop (1974) found that a list containing easy-to-sort items was recalled and organized better than a list containing items that were difficult to sort into categories. Both the cohesive members and the easy-to-sort members closely correspond to Nelson's (1974) "core" category exemplars. Finally, in a fourth kind of manipulation, children sort subordinate category members (rocking chair and captain's chair) into the "basic" level category, *Chair*. Again, young children can do this quite successfully for both natural (Rosch et al., 1976) and artificial categories (Horton & Markman, 1980).

In sum, the evidence seems fairly persuasive that there is no discrepancy between the availability of categorical knowledge and clustering if we consider recall and clustering for "core" members separately from the wider range of stimulus items, including the noncentral members, which young children do not yet have in their categorical structures. (The results of Study Four, to be reported later, can also be intepreted in the same way.) Thus, the tentative conclusion suggested here is that children's recall is elevated, and they do cluster their outputs, if the knowledge of the category members is in their knowledge structure in a form that is comparable to adults'. Hence, the issue is not one of availability/accessibility; rather, the suggestion is that children's knowledge is not usually in the form that we have assumed it to be.

ACQUISITION OF SPECIFIC RULES VERSUS KNOWLEDGE REORGANIZATION

The foregoing discussion has basically attributed children's deficiency in organization and recall to a deficiency in their knowledge base and, in particular, the representation of that knowledge. In contrast, the interpretation in the literature puts more emphasis on a deficiency in the organizational strategy at input and/or output. Thus, the interpretation centers on the children's failure to impose an organization on the incoming stimuli so that retrieval can be facilitated. Because such interpretation is based on strategic deficiency, the literature on categorized recall has not recognized that a discrepancy exists between the availability of categorical knowledge and the absence of organization in recall. The basic assumption has been that the needed knowledge of categories is present, and absence of clustering during recall is a function of the deficient organizational strategy.

The focus on an interpretation based on strategic deficiency (rather than an inability to perceive organization due to a lack of structure in semantic memory) is evident in the emergence of abundant training studies that teach children to

actively use an organizational strategy. In recall clustering tasks, most of the training studies induce children to notice the categories, for example, by blocking the stimulus presentation (Moely & Shapiro, 1971) or by providing names or labels for the categories (Nelson, 1969). These indirect training procedures have produced disappointing results. Providing labels or blocking the stimulus presentation often does not lead to greater conceptual organization in younger children.

In direct training procedures, children were taught to (1) sort the items into taxonomic categories, (2) label the categories, (3) count the members of each category, and (4) further organize recall by remembering each category. The amount of clustering was increased but only when the same stimuli were used for both training and subsequent recall tasks (Moely et al., 1969; Worden, 1975). Once again, such improvements were not dramatic when a different set of stimuli was used for the recall task (Moely & Jeffrey, 1974). There are two interpretations to these results. First, the training could have produced context- or domain-specific rules that are not generalizable to other contexts. Second, the training could have reorganized the representation of the stimuli used in training so that the categorical structure of these stimuli would be apparent during subsequent presentations. But again, such training would not be generalizable because stimuli in other domains have not undergone a representational reorganization.

Knowledge Reorganization

To elucidate the difference between the two foregoing interpretations—acquisition of specific rules and reorganization of the representation—it is instructive to see how modern cognitive theories of knowledge representation can help us understand these phenomena. Knowledge is often separated into two types, facts and rules. Factual knowledge is knowledge that we know and can talk about, such as the fact that "a robin is an animal." Rule knowledge concerns how something is done. For example, doing long division requires a set of rules, which, if followed properly, can produce the answer to a problem.

Differences between facts and rules can be captured by the formalism used to represent them. Factual knowledge is typically represented by an interrelated network of nodes and links. The nodes can be conceived of as concepts, and the links denote the relations among the nodes. A variety of node-link network structures has been proposed, beginning with Collins and Quillian's (1969) hierarchical network model. In this model, knowledge such as "a robin is an animal" is stored as two separate propositions. There are direct (isa) links between *robin* and *bird* and *bird* and *animal*, but no direct link between *robin* and *animal*. Hence, in order to verify the truth or falsity of the statement "a robin is an animal," an inference must be made. Concepts are assumed to be organized hierarchically with nonredundant storage of properties. General properties of robins that are common to all birds are stored at the most general (*Bird*) node, whereas properties specific to robins are stored directly with *Robin*. Hence, a robin is inferred to fly, sing, lay eggs, and so on (because these are properties true of all birds), but no inference needs to be made to retrieve the proposition that "a robin has red breast" (because red breast is a specific property attached to robins).

Hence, one could postulate that a canonical (and perhaps adult-like) representation is one in which the general concept (*Bird*) subsumes more specific concepts (such as *Robin* and *Sparrow*). The clustering of all types of birds into the *Bird* category necessitates a hierarchical representation in memory in which specific birds (*Robin* and *Sparrow* and so on) are subsumed under the *Bird* concept node. Thus, the reorganization interpretation provided earlier specifies that a child's original representation of conceptual knowledge may not conform to the canonical one. Training, however, could induce a new representation, thereby producing results that are consistent with adult performances because the representaion is now more adult-like. On the other hand, training fails to generalize to other domains because the representations of the other domains have not undergone any reorganization. The first study in this chapter points out that children's initial representation of factual knowledge need not conform to one an adult expects. Nevertheless, their performance variability can be understood in terms of its correspondence to the representations that exist.

Domain-Specific Rules

Knowledge of rules, on the other hand, can be represented by using the formalism of a production system. A production system is simply a set of rules, each rule having both a condition and an action side. The condition side of the rule specifies the conditions that must be satisfied before the actions can take place. The conditions must match the contents of working memory. For example, an organizational strategy can be represented as a rule that looks for similarities within a set of inputs. If the conditions are met, then the action is to group them together for storage. Thus, subsequent recall simply would retrieve the stimuli (in clusters) that have been stored in a group.

Suppose the strategic deficiency interpretation assumes that a rule that seeks categorical relations among inputs is lacking in the child. This may take the following form:

Rule I:

IF the two successively presented words come from the same category,

THEN tag them as similar, store them together, and retrieve them together.

The problem with this rule, however, is that in order for it to take effect the condition side of the rule must be satisifed by matching the incoming information with patterns in semantic memory. In order to decide whether *Robin* and *Sparrow* (the two successively presented words) come from the same category, one must out of necessity have *Robin* and *Sparrow* in the semantic network and associated in such a way that their categorical structure becomes apparent. Thus, the success of applying such a general rule rests on the existence of an appropriate semantic representation; one that has the concepts organized according to salient dimensions (as in the canonical form).

The reason we postulate that training succeeds in producing clustering is that training sometimes induces specific rules rather than general ones. The nature of specific rules is such that the condition side of the rules spells out the specific similarities that are being sought. When these are presented in the stimulus context of the experiment, the child recognizes them. In more general contexts, however, the child fails to use the learned rule, not because the child fails to apply it (a production deficiency interpretation), but because in a different context the conditions of the specific rule no longer match the new context.

To illustrate, suppose the child is told (or trained) to find and group all the birds. The child can select all the birds (such as, robin, sparrow, parrot, canary) out of a list of pictures containing other items (such as sofa, chair, bed, coat, gloves, etc.). There are two reasons why a child can easily do this task. First, as was already stated, the ability to recognize that robin, sparrow, parrot, and canary is a bird does not imply that they are represented in the canonical form. (Study One provides the evidence.) Second, young children, without any knowledge of birds, can pick out all the birds on the basis of perceptual similarity. (Evidence will be provided in Study Four.) Hence, once children have been taught to group the birds together, they may form a specific rule such as:

Rule II:

IF sparrow, robin, canary, and parrot are presented,

THEN tag them as similar, store them together, and retrieve them together.

Of course the acquisition of such a rule would not be generalizable and may also be transitory for at least two reasons. First, the rule itself may not have been learned well enough to be maintained over time. Second, the action of the rule, "storing them together," also implies that a temporary representation may be created that involves the storage of these birds in a cluster. Again, new or temporary representaions may not last and can be rather unstable. Both of these interpretations are consistent with the findings in the literature about children's failure to maintain trained strategies. Notice that if a child already has in memory a canonical representation of birds, then the actions of Rule II would be redundant. Hence, older children's learning of such a rule would be less susceptible to decay and more amenable to generalization (that is, the acquisition of Rule I), assuming that older children would more likely have the canonical representation.

Study One, following, illustrates several things. The first is that a child need not have the canonical representation that adults often think is the best. But that does not mean that children do not have a robust representation of some kind that they can and do work with. The second point is that a canonical representation is not needed in order to recognize that certain concepts are of a specific type. Nevertheless, this knowledge need not imply that certain concepts are then subsumed under their type in a hierarchical manner.

Study One: Exploring a Child's Knowledge of Friends

The goal of this study was to explore a child's representation of a specific overlearned domain and then to examine the relationship between the child's representation and how it affected classification. In order to elicit a child's knowledge of a domain (classsmates), a 5-year-old girl (M.C.) was asked to generate all her classmate's names. The results of four separate trials are shown in Table 20.1. A majority of the 23 names was generated on every trial, and the retrieved order shows a fair amount of regularity. Groups of two, three, and even four children appear across trials and tend to appear in the same location on each list. One measure of the stability of organization of these lists, at the level of pairs, is Nelson's (1969) Repeated Pairs Index (RPI). The value of the RPI for the present data of one subject is .44. By contrast, 5-year-olds in Nelson's (1969) study of free recall of lists achieved average RPIs in the range of about .2 to .25. Although we are comparing two different studies, Bjorklund and Zeman (1982) have gathered data that permit a direct comparison to corroborate this point. They found first graders' clustering scores with classmates to be around .51, whereas the same children's clustering scores on a standard taxonomic list of items was in the range of .10.

The reason for such a stable organization became apparent when M.C. was asked to sort 23 cards with the name of one classmate on each card. She completed the task in about 3 minutes and made four groups. Postquestioning revealed that her reason for this grouping was that it corresponded to the seating arrangement in class. Consultation with the teacher confirmed that this was true and the actual plan is shown in Figure 20.1. (It has since been shown by Bjorklund and Zeman, 1982, that this is a very popular way for children to represent their classmates.) The partitions of the lists in Table 20.1 correspond to these groups. Clearly, M.C. generated the lists section by section. Over four trials, only one instance occurred in which a boundary was crossed before the entire section was generated (Trial 1), and in that instance she corrected herself later and inserted the two missing names. (Notice that this finding contrasts sharply with that in the literature showing that young children are often not exhaustive in their inclusion of all the items on the list into a given category. One may now interpret that finding by assuming that children's categories are smaller; hence, they appear to be nonexhaustive by the adults' standards.)

Another way to test the reality of these sections is to look at the interitem pause times. On the average, over the four trials, the times were 6.5 seconds

TABLE 20.1
Four Trials of Generation of Classmates' Names

Trial 1	Trial 2	Trial 3	Trial 4
Michelle	Mallory	Laura	Mallory
Mallory	Michelle	Michelle	Michelle
Not Sasha	Eric	Josh	Josh
Laura	Josh	Mallory	Laura
Josh	Laura	Eric	Eric
Eric			
	Paul	Eva	Kimani
Eva	Eva	Kimani	Eva
Kimani	Leah	Oliver	Oliver
Oliver	Brian	Brian	Brian
Brian	Oliver	Tamara	Tamara
	Kimani	Leah	Leah
Terry			
Stephanie	Terry	Terry	Terry
Andrei	Stephanie	Stephanie	Stephanie
Paul	Andrei	Andrei	Andrei
Not Paul	Matthew	Nicki	Nicki
Matthew	Nicki	Matthew	Matthew
Nicki	Dana	Dana	Dana
Dana			
	Paul	Paul	Paul
Paul	Michael	Emma	Sasha
Leah	Emma	Sasha	Emma
Tamara	Sasha	Lisa	Becky
Paul	Becky	Michael	Michael
Michael		Becky	
Lisa			
Sasha			
Emma			
Becky			

between sections, whereas within-section times were 3.1 seconds. M.C. was asked to recall after she had sorted the names, because recall, as opposed to generation, is the standard procedure used to tap output organization. The set of 23 classmates' names was presented in random order and then M.C. was asked to recall them. The retrieval (which was perfect) produced the same kind of ordering, with more uniform pause times. Between-section times were 2.7 seconds, and within-section times averaged 2.4 seconds.

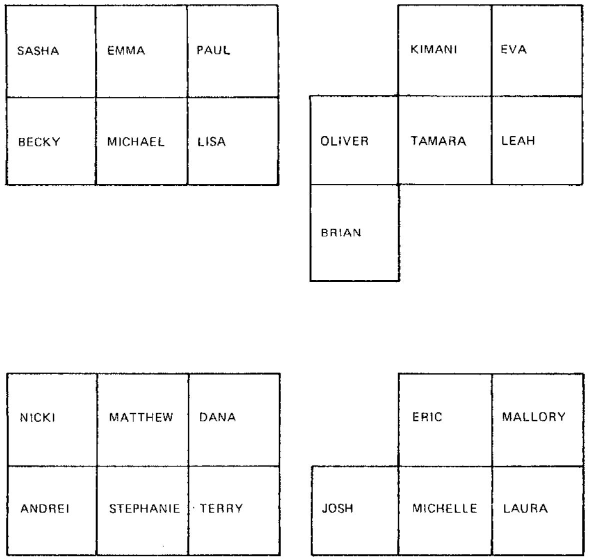

FIG. 20.1 Seating arrangement of classmates.

Although M. C. did not use the kind of taxonomic categories to organize classmates that seem salient to an adult, such as age, grade (this was a mixed classroom containing first and second graders), gender, and race, it seemed highly unlikely that she did not know these attributes for each individual classmate. To test how this knowledge might be organized, two further tasks were conducted. The first was to generate the names of classmates with certain attributes, such as second-grade boys or all the girls. Over eight trials, utilizing different subgroups of classmates, M.C.'s section-by-section organization remained stable. All members of a section satisfying the subgroup constraint were named before she moved on to the next section.

The second task was to confirm whether a given child was of the stated gender, e.g., "Andrei is a girl." The latencies for this task were measured from audio tapes, and there were no systematic differences among the times it took to verify that a child was of a given gender or not. Although measuring response latencies from aural tapes may not be very sensitive, the data are systematic in that a positive confirmation (correct gender) was faster (913 msec) than a negation (942 msec). This is consistent with data in the literature on confirmation and negation (Wason, 1959).

To summarize, the three specific results were: (1) The classmates' names were generated by seating sections, (2) specific subgroups were also generated in this

way, and (3) it took equivalent amounts of time to verify the gender of any given child. The first two results show that M.C.'s grouping by section was quite stable over time and robust under different task demands; indeed, these results were obtained over four trials of free generation, one sorting trial, two free recall trials, plus various other tasks spread over six sessions. Consistent with the hypothesis proposed here, one could conclude that a possible representation for M.C.'s classmates starts with *Classmates* as the top level, followed by *Sections* as superordinate nodes, *Names* as basic levels nodes, and *Attributes* at the lowest level linked to each basic node (see Fig. 20.2). The third result confirms this picture in the following way. If the representation took an alternative form, one in which all the girls were grouped under a *Girl* node, Rosch's (1978) results would predict that a category verification task should produce time differentials because there were 13 girls in the class and not all of them could be central members of the *Girl* category. However, the absence of time differentials in verification suggests that the task required the activation of nodes to the same depth in a hierarchy as the network (depicted in Fig. 20.2) indicates. To confirm that a named child was or was not a girl required the activation of the child node and his/her gender.

In sum, this study illustrates that the preferred mode of representation for a child is not taxonomic in the adult sense; that is, it need not conform to an adult experimenter's conception of the ideal canonical representation that may organize

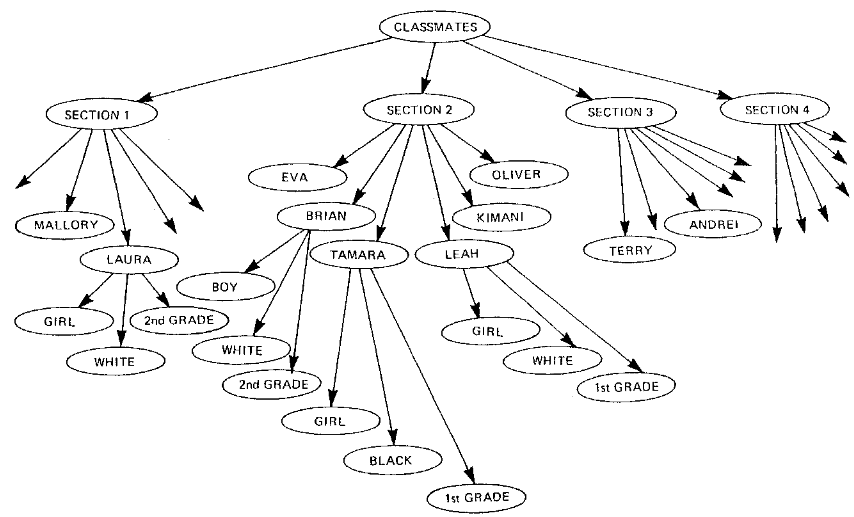

FIG. 20.2. A possible hierarchical representation for the child's knowledge of classmates.

a classroom of children according to grade, gender, or race. Nevertheless, the child's representation, consisting of children with their seating locations, constitutes a valid representation that permits an orderly and high level of recall—a finding that is also supported by Bjorklund and Zeman's (1982) data.

The second point of this study was to show that certain attributes of a concept (such as the gender of a child) may be known, and yet this does not imply that the concept is organized around that attribute as the dominant or salient dimension. This point has been made several times earlier in this chapter. Thus, assessing that a child knows that "Mallory is a girl" (or "A robin is a bird") cannot lead to the conclusion that the child possesses a canonical representation with the more inclusive category at the higher level node. It can only suggest that the specific link between the two concepts is present. Therefore, one must assess the larger integrated knowledge structure, rather than the piecemeal links, in order to ascertain that children know something.

Study Two: The Application of an Alphabetization Strategy to the Retrieval of Friends

In Study One, it was shown that M.C. had a very stable representation of her classmates, and that she retrieved those names by using a representation based on seating arrangement. The representation was postulated to be very robust because it was manifested in every opportunity to retrieve those names. The conclusion, therefore, was that the child retrieved the names in that particular order because that is how they were stored and represented in memory. The purpose of this study was to see if the child could be taught to use a strategy of retrieval that is not compatible with the way the names were represented, that is, in an alphabetical order.

This study was motivated by the theoretical analyses presented earlier concerning the two possible conditions under which the teaching of a strategy succeeds in producing the desired performance. In the one case, we postulated that in order for a strategy to take effect (Rule I), the necessary factual knowledge must already be represented in a certain way. In this study, suppose the rule of recalling by alphabetic order takes the form:

IF two names start with the same letter,

THEN store them together, and retrieve them together.

If the child already has the names stored in alphabetical order (supposing a representation such as Fig. 20.3, then alphabetic retrieval is fairly automatic. The condition of the rule will always be satisfied. On the other hand, if the names are not already stored in alphabetic order, in order for the child to manifest alphabetical recall, the child is required to form a new representation (that is, store the names in memory) so that those names with the same initial letter are

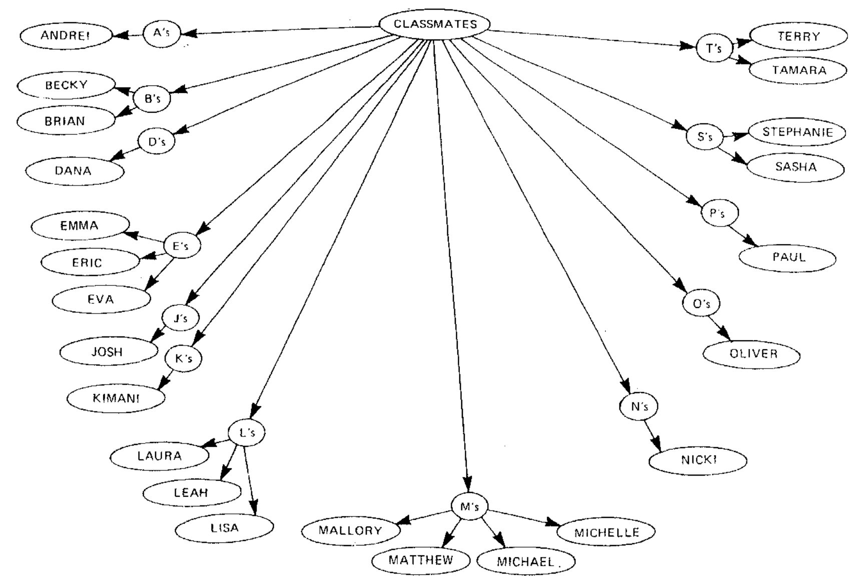

FIG. 20.3. An alphabetical representation of classmates.

stored together. Here, the specific assumption of recall is that the order of retrieval reflects the way the stimuli are organized and stored in memory after they have been encoded. One could, of course, also assume that organization occurs during retrieval, but due to the way the present study was designed, that did not happen, as is shown shortly.

Training consisted of teaching the child how to alphabetize. She was asked to alphabetize the 23 names on cards. She was able to learn the rule in one trial, although she took a while to complete the trial. After that, she was asked to recall the names in alphabetical order. Surprisingly, she did so perfectly, although she often had to stop and ask what the next letter was in the alphabet.

There was one interesting difference between the retrieval protocols of names in alphabetical order versus the retrieval according to the seating arrangement. In the latter case, retrieval occurred in quick succession, with 1- to 2-second intervals between names, and 5- to 6-second pauses between sections. In the former case, retrieval time of names within a given letter was around 2 to 3 seconds, but between letters ranged anywhere from 10 to 30 seconds. For example, it took 26 seconds to generate the name Emma after generating Dana, but only 2 seconds to then generate Eva and 3 seconds to generate Eric. In fact, because it took her so long to generate the next letter, she often would ask the experimenter what the next letter was, so that the experimenter began to prompt her with the next letter when she paused. (This is not because she did not know the alphabet sequence.) What does this timing data suggest? It suggests that a new, and perhaps temporary, representation much like that schematized in Fig. 20.4 was created (or the existing representation was reorganized) while the subject was asked to sort the names according to the alphabet.

With just one training trial, she only had time to create a representation with names grouped together by individual letters, but not in any specific (alphabetical) order. Therefore, the alphabet list was used as a pointer to retrieve the "next" cluster, and it was difficult for her to keep track of her place on the alphabet list. Once a cluster of names beginning with the same letter was entered, however, retrieval was fast. Because this representation was not ordered in a specific (alphabetic) way, it took time to jump back and forth between retrieving the content of a cluster and finding the next location on the alphabet list.

The pattern of interitem pause times is not consistent with the alternative interpretation, that is, names are searched *during* recall in alphabetical order according to the seating sections. Hence she did not search for all the A names in Sections 1, 2, 3, 4, then search for the B names in Sections 1, 2, 3, 4, and so on. To do so would mean that she did not create a new representation but used the existing one and organized her recall during retrieval. One might expect recall to be achieved by this on-line method had the child not already been asked to alphabetize the whole deck of 23 names. This initial training experience probably biased the whole organization to occur at input. The pattern of pause times suggests that recall was not on-line and supports the interpretation that one way a strategy can be taught and used is to provide an occasion when the child can create a new representation of her already familiar factual knowledge.

How successfully can a strategy be applied if a new representation cannot be easily formed? In order to test this hypothesis, the child was asked to memorize a list of names that had no immediate semantic references for her (at least not in a cohort group), even though she was familiar with each individual name. This is a matched set of 23 names with the same number of syllables and the same number of names beginning with the same letter. For example, instead of having Andrei the new list had Anna. After three sort–recall trials, including one where the child was explicitly told to alphabetize the names, the child's recall was still poor, about 11 out of 23 names, compared to the perfectly alphabetized recall of familiar names.

This study demonstrates that when the stimuli tested conform to a knowledge base that is very familiar and has a clear existing representation, a child seems to have no difficulty creating a new representation so that the new pattern of retrieval is consistent with the new representation. By this interpretation, the mechanism of retrieval operates by changing the knowledge base first (either creating a new one or rearranging the old one). This is more likely to be true in M.C.'s case because retrieval followed sorting, probably providing the opportunity to create a new representation that was more or less consistent with the alphabetization strategy. (A perfect representation would have been one where

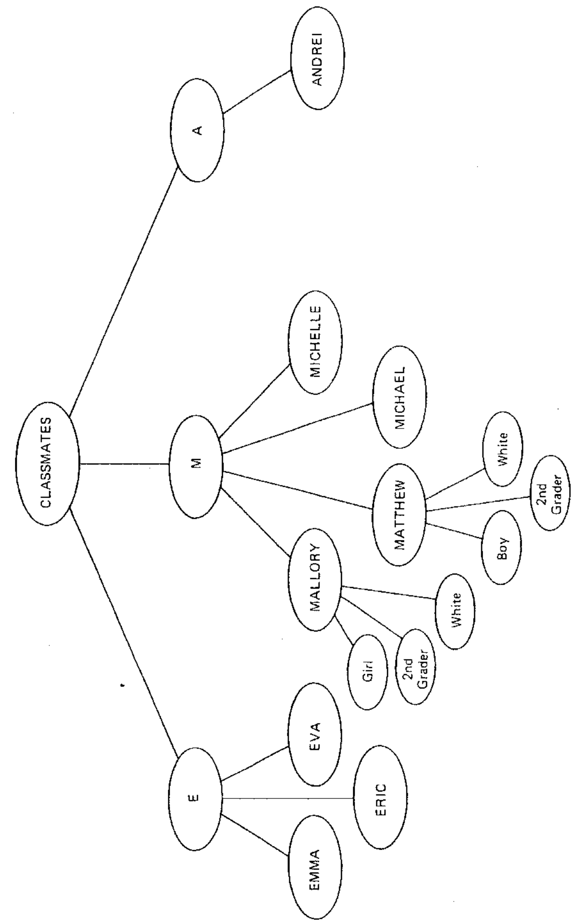

FIG. 20.4. An hierarchical organization by letter but not necessarily alphabetized.

the clusters were sequenced alphabetically.) If she had been asked to recall in alphabetical order without prior sorting, she might have had to retrieve the names in the alternative on-line mode, that is, searching for names with a given initial letter, section by section. Nevertheless, the finding that the child could readily recall her classmates in a different pattern suggests that the use of a strategy greatly interacts with the knowledge base. When the conceptual knowledge is well organized initially, a 5-year-old child can easily benefit from instruction on the use of a new strategy. Otherwise, the utility of a new strategy is more limited, as in the case of alphabetical recall of familiar names that did not correspond to an existing organized representation.

Such data give a plausible interpretation for why training studies in the use of strategies are not often maintained over time. This study suggests that the new representation may be temporary; these data also had implications for interpreting why older children seem to benefit more from training. One possibility is that older children may already have data bases analogous to M.C.'s representation of classmate names—that are organized. Younger children, however, may have data bases corresponding to this child's knowledge of a random list of familiar names that are not organized, leading to an inefficient use of strategies. In that case, the utility of a strategy was less apparent (this is what has been called a mediation deficiency).

Study Three: Classification of Dinosaurs

Study One attempted to explain why a young child did not retrieve a set of concepts in a taxonomically organized way. Instead, the organization reflected one that was learned after 1 year's experience. The presence of strong organization and the impressive number of classmates retrieved, as opposed to the frequent lack of any organization and poor retrieval in young children, may be attributed to the highly familiar nature of the stimuli. Delfosse and Smith (1979) also found preschoolers to be extremely accurate at recalling one of many companions they had played with on the previous day and week; Bjorklund and Zeman (1982) found superior recall of classmates by first, third, and fifth graders as compared to recall of the standard taxonomic categories, such as *Animals, Furniture,* and so on.

The goal of the present study was more ambitious; to show that a child is capable of taxonomic classification if the stimuli are highly familiar and are represented in memory so that they conform to a taxonomic organization that might be expected by adults. Again, it is hypothesized that such a representation is achieved through learning, which could have reorganized the earlier (more immature) representation so that the relevant attributes become the salient dimensions.

A 4½-year-old child (M.K.) was studied intensively. This child could be considered an expert in the knowledge domain of dinosaurs, because his parents had read dinosaur books to him for about 1½ years. We proceeded to explore the knowledge he had of dinosaurs, how that knowledge was represented, and how that representation affected his classification of dinosaurs. (For details see Chi & Koeske, 1983).

In order to determine which dinosaurs the child knew and what he knew about each, we began by eliciting dinosaur names from him in a production task, with the child freely generating the names of the dinosaurs he knew. Across six sessions, he generated a total of 46 dinosaurs. From this, a set of 40 was selected for further testing. When one dinosaur name elicited another, we assumed there was a link between them in memory. To determine what the child knew of the 40 dinosaurs, a clue game was played in which the "chooser" generated a list of properties and the "guesser" identified the dinosaur to which these properties belonged. By alternating roles between the experimenter and the child, the game provided information about the child's recognition and spontaneous generation of dinosaur-property links or relations.

The dinosaur–dinosaur linkages gathered in the production protocols and the dinosaur–property linkages derived from the clue game were used to map a network representation of the total set of 40 dinosaurs. In order to simplify the network, we artificially segregated the 40 dinosaurs into two groups of 20 each—one set is referred to as the better known dinosaurs and the other as the lesser known. The division was based on two external criteria: the frequency of inclusion in the child's nine dinosaur texts and the mother's independent judgment of the child's best and least known dinosaurs. Seven dinosaurs from each set of 20, henceforth referred to as the targets, were selected for detailed analyses of their structure. The targets were chosen on the amount of information (number of properties) mentioned about each dinosaur. The focus on a subset from each set of 20 was necessitated by both a theoretical reason and a methodological one. Had the structure of the entire set of 20 been analyzed, the better known set would have overwhelmed the lesser known set in terms of the sheer number of properties known about each dinosaur. Theoretically, our interest was not in the quantity of information, but in the structure of information if quantity could be held constant. The methodological reason was that the better known dinosaurs were probed with greater frequency in the clue game, thus resulting in a sampling bias.

The two sets of 20 dinosaurs were then divided into seven categories each, corresponding more or less to the way these dinosaurs were introduced in the books. As it turned out, the better known target dinosaurs fell into two of the seven categories: armored and large plant eaters. The lesser known target dinosaurs belonged to five of the seven categories: armored, small bird or egg eaters, water dwellers, duckbills, and early meat eaters.

Basically, the better known targets were better structured and formed more cohesive groups in memory than the lesser known targets, even though the same amount of information (five properties) was known about each target. This can be illustrated from the data in the following ways. First, better known target dinosaurs showed multiple links to target dinosaurs within the same category but only showed single links to target dinosaurs of other categories. Second, target dinosaurs in the better known portion of the network shared properties with target dinosaurs in the same category more often than with target dinosaurs from the other categories. Such a contrasting pattern of greater within- and lesser between-category linkages did not appear for the lesser known dinosaurs. The connections for the lesser known target dinosaurs were much more uniformly distributed among the categories. Third, when we subsequently measured M.K.'s recall of the two sets of dinosaurs, his recall outputs manifested greater clustering according to these predefined categories in the better known rather than in the lesser known set.

Would the child's classification of the 20 better known dinosaurs reflect the existence of these predefined categories? When M.K. was asked to sort the dinosaurs, he did so very quickly, without hesitation or pauses into two groups: meat eaters and plant eaters. This sorting pattern was consistent across two separate trials. The child's sorting pattern did not correspond entirely to the presumed categories in his knowledge structure. As we stated earlier, sorting and clustering should perhaps not be attributed to the same underlying processes even though their deficiencies are often correlated in young children.

Because we have argued that cohesive groups corresponding to categories existed (at least for the better known dinosaurs), this child's grouping data could be interpreted as evidence showing that he chose to use a higher level (or superordinate) relation to sort the dinosaurs; that is, one can assume that the representation can be schematized as in Fig. 20.5, with every dinosaur fitting into one of the categories that we have postulated. Furthermore, the categories can be collapsed into higher level superordinate nodes, such as *meat eaters* and *plant eaters*. *Meat eater* and *plant eater* were precisely the two abstract categories Storm (1978) had used to divide the *Animals* category. In her study, she found that third graders (about 9 years old) had difficulty sorting according to these abstract dimensions even after training. Our data would support the notion that a child can classify taxonomically if there is sufficient knowledge about the interconnections (or contingencies) to allow such groupings. Furthermore, his sorting performance is very adult-like in the sense of being fast, exhaustive, and stable across trials.

Consistent with our interpretation that the grouping of the lesser known dinosaurs are less cohesive, M.K.'s sorting performance on the lesser known dinosaurs was more variable. He could not reach a stable sort in three trials. His first sort was meat versus plant eaters; his second sort was land meat eaters, plant eaters, and water swimming; that is, he introduced two additional dimensions: habitat and locomotion. In his third sort, he changed it again into land plant eater, water meat eater, and water plant eater. His sorting performance matches those typically exhibited by young children—slow, nonexhaustive, and

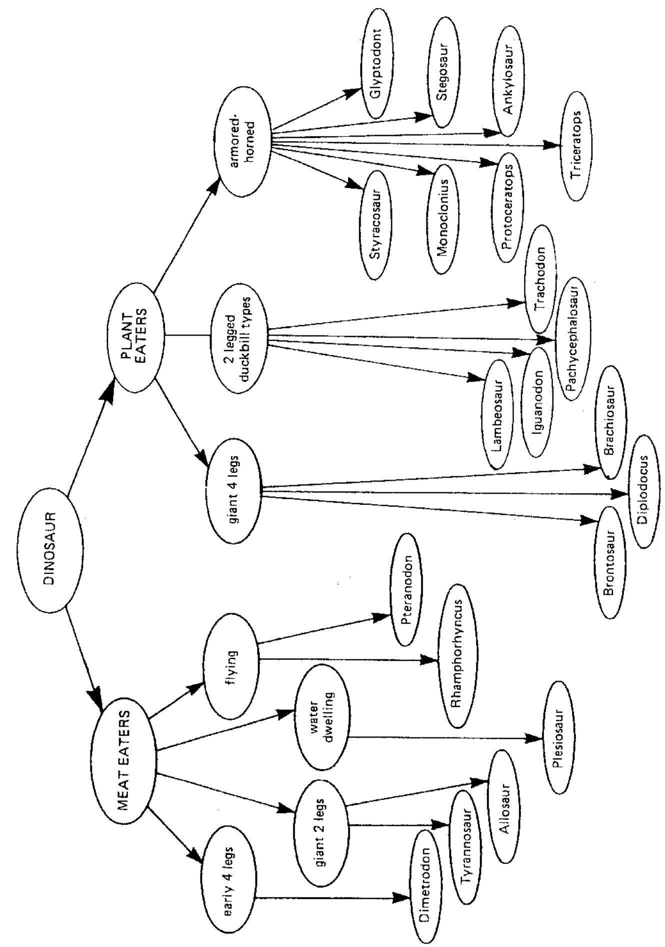

FIG. 20.5. A possible representation for dinosaur knowledge.

inconsistent. An explanation for his inconsistencies is that the lesser known dinosaurs are not as well structured and cohesive as the better known dinosaurs in terms of our criteria for patterns of interlinkages within and between groups.

To summarize, this study illustrates that a very young child is capable of sorting at a superordinate level (food habits), one that has been found by zoologists to be basic to classifications of mammals. The ability to classify at this level is not often found in the literature even for 9-year-olds (Storm, 1978). This impressive sorting performance can be attributed to the well-organized and highly enriched representation that M.K. had of dinosaurs. The enriched, well-integrated, and coherent representation, at least for the better known dinosaurs, was shown by the presence of multiple and interrelated links in a specific configuration. We hypothesize that such a well-formed representation came about from frequent exposures to dinosaurs, so that the relevant conceptual dimensions (food habits) became salient. This is why the lesser known dinosaurs were not as well represented, and sorting performance was more variable (see Chi, 1983).

Study Four: Classification of Dinosaurs by Expert and Novice Children

Study Three indicates that when a child is knowledgeable, he or she is capable of exhibiting taxonomic classification at an earlier age than has been traditionally found. Another way to examine the interaction of domain knowledge with the use of a particular classification principle is to compare and contrast expert and novice children's classification performance. The idea here is that if expert children classify in a different but more sophisticated way than do novice children, one could conclude that it is not the appearance of a classification principle (like a strategy) in the children's repertoire that makes the difference, but rather the classification outcome consists of the interaction of a particular mode of retrieval with the representation of the domain knowledge.

A set of 20 dinosaurs that could be categorized into five groups was selected. Most of the categories were determined from books about dinosaurs, and they tended to have perceptual attributes that define their similarities. For example, a common category is the duckbill dinosaurs because they all have a mouth that looks like a duck's bill. Children who knew a lot about dinosaurs, as well as children who had very little knowledge of dinosaurs, participated. They were each asked to do two tasks: (1) to tell everything they knew about a dinosaur, when a picture of it was presented, and (2) to classify the 20 dinosaurs and give explanations for their categories. Only the results of the second task are discussed here.

The data from two expert and two novice children, with a mean age of 7.2 years, are presented. Expertise was determined by a posthoc criterion: the number of dinosaurs out of 20 that a child could correctly identify by name. The two expert children each named 12 out of 20 correctly, whereas both the novices could not identify any correctly.

The sorting data are interesting in a variety of ways. First, novices could group the dinosaurs fairly accurately according to the a priori category specification. For example, novice M.C. basically grouped the dinosaurs in the way specified, perhaps with one "error." Novice A.R. had three groups. From scanning the data collected on other novices, it is fairly clear that children, without any explicit knowledge of the stimuli, can classify them based on their visual resemblance and visual similarities. This finding is consistent with both Rosch et al.'s (1976) results and Horton and Markman's (1980) results, in which they found that children can classify and easily acquire objects that are at the basic level, because at that level instances of the concept are relatively similar to each other. Hence, one could postulate that each dinosaur (see Fig. 20.5) is an exemplar of the "basic" categories such as the duckbills. Thus, based on Rosch et al.'s findings, it is not surprising that the novice children could sort the dinosaurs into their respective categories.

We can further substantiate the basis of their classification by examining children's explanations. In almost every case, the reasons provided were perceptual in nature. For example, one of the novice's reasons for grouping the duckbills together was because their heads looked alike; they had small hands, rough skin, and so on.

Note that investigators in the past have attributed semantic knowledge to children when they could sort or group things taxonomically. The present data contradict that assumption directly for natural categories where perceptual similarity and taxonomic category are correlated.

How are the sorting patterns of the experts different? We expected the categories to be salient (not only on a perceptual basis, but also because books tend to introduce them as a group), and that all the experts group them the same way. Surprisingly, the two experts grouped them pretty much the way the 4½-year-old expert (M.K.) did from the previous study: plant eaters and meat eaters. One of the experts (A.P.) had an additional group based on aggressiveness. There are two things to note about the experts' data. First, they tended to group the dinosaurs according to more abstract than perceptual features. For example, they were grouped on the basis of the diet and/or whether they were mean or not. In Rosch et al.'s (1976) taxonomy, this would correspond to sorting at the superordinate level. Secondly, we further know that the groupings were based on a more superordinate node because when both experts were asked to further subdivide the large groups (meat versus plant eaters), they created subgroupings that looked very much like the novices' initial groups (such as duckbills) and were based also on perceptual features. Hence, the adult-like sorting according to superordinate level categories was observed in 7-year-old children who were experts in a knowledge domain. This suggests that the development of classification skill interacts strongly with knowledge about the stimulus domain.

SUMMARY

This chapter began by summarizing the developmental research of the last two decades that has shown the absence of organization in young children, particularly as exhibited in the recall output. This absence of clustering is in direct contrast to the apparent capabilities of young children to sort or categorize items into their taxonomic categories when explicitly requested. This discrepancy has not been seen in this way in the literature because the interpretation has centered on a strategic (or production) deficiency explanation. It has been postulated that children have the requisite knowledge to organize the stimuli but are simply not doing so. One of the points made in this chapter is that knowledge of the stimuli is not needed at all in order to sort them properly. This can be done on the basis of perceptual similarities, as shown in Study Four. Furthermore, one could also properly sort stimuli into their respective requested categories, not because the knowledge is necessarily organized in a taxonomic way in memory, but because the task explicitly demands the assessment of specific links and not the integrated knowledge structure, as shown in Study One.

Another way to explain the occasional success of young children in sorting and clustering is by postulating that young children do have categorical knowledge much like adults', but their categories are smaller with a more restricted set of core or central members. Consequently, when an experiment uses a restricted set of central members as the stimuli, recall and clustering will be much improved. This is also shown in Studies One and Four.

Finally, this chapter makes the important point that in some cases when young children do manifest a performance that conforms to the use of a strategy, it may be a reflection of how the content knowledge was stored and represented in memory. When the memory representation takes a certain format as in Studies Two, Three, and Four, children will appear to be able to use a sophisticated strategy. When the content knowledge is not represented in a certain way, as when the child is asked to retrieve a set of names that did not belong to a cohort group (Study Two), or when a novice is asked to sort dinosaurs (Study Four), recall is more difficult and does not manifest the use of a general strategy. Hence, the relationship between strategies and knowledge is necessarily an interdependent one.

ACKNOWLEDGMENTS

This research was supported by the Learning Research and Development Center, funded in part as a research and development center by the National Institute of Education, United States Department of Education. The opinions expressed do not necessarily reflect the position or policy of NIE and no official endorsement should be inferred. The author is also grateful for funds provided by the Spencer Foundation in support of this research.

Susan Chipman's comments improved this chapter immeasurably. Comments and editing by Mary Beth Curtis and Ernest Rees are also greatly appreciated.

REFERENCES

Annett, M. (1959). The classification of instances of four common class concepts by children and adults. *British Journal of Educational Psychology, 29,* 223–236.

Bjorklund, D. F., & Ornstein, P.A. (1976). *The development of taxonomic concepts: The effects of list saliency on recall.* Unpublished manuscript, University of North Carolina at Chapel Hill.

Bjorklund, D. F., & Zeman, B. R. (1982). Children's organization and metamemory awareness in their recall of familiar information. *Child Development, 53,* 799–810.

Bousfield, W. A. (1953). The occurrences of clustering in the recall of randomly arranged associates. *Journal of General Psychology, 49,* 229–240.

Bousfield, W. A., Esterson, J., & Whitmarsh, G. A. (1958). A study of developmental changes in conceptual and perceptual associative clustering. *The Journal of Genetic Psychology, 92,* 95–102.

Carson, M. T., & Abrahamson, A. (1976). Some members are more equal than others: The effect of semantic typicality on class-inclusion performance. *Child Development, 47,* 1186–1190.

Chi, M. T. H. (1983). Knowledge-derived categorization in young children. In D. R. Rogers & J. A. Sloboda (Eds.), *Acquisition of symbolic skills.* New York: Plenum Press.

Chi, M. T. H., & Koeske, R. D. (1983). Network representation of a child's dinosaur knowledge. *Developmental Psychology, 19,* 29–39.

Cole, M., Frankel, F., & Sharp, D. (1971). Development of free recall learning in children. *Developmental Psychology, 4,* 109–123.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior, 8,* 240–247.

Corsale, K. (1978). *Factors affecting children's use of organization in recall.* Unpublished doctoral dissertation, University of North Carolina at Chapel Hill.

Delfosse, P., & Smith, P. K. (1979). Memory for companions in preschool children. *Journal of Experimental Child Psychology, 27,* 459–466.

Flavell, J. H. (1970). Developmental studies of mediated memory. In H. W. Reese & L. P Lipsitt (Eds.), *Advances in child development and behavior* (Vol. 5). New York: Academic Press.

Goldman, A. E., & Levine, M. (1963). A developmental study of object sorting. *Child Development, 34,* 649–666.

Haynes, C. R., & Kulhavy, R. M. (1976). Conservation level and category clustering. *Developmental Psychology, 12,* 179–184.

Horowitz, A. B. (1969). Effect of stimulus presentation modes on children's recall and clustering. *Psychonomic Society, 14,* 297–298.

Horton, M. S., & Markman, E. M. (1980). Developmental differences in the acquisition of basic and superordinate categories. *Child Development, 51,* 708–719.

Kobasigawa, A., & Middleton, D. B. (1972). Free recall of categorized items by children at three grade levels. *Child Development, 43,* 1067–1072.

Lange, G. (1978). Organization-related processes in children's recall. In P. A. Ornstein (Ed.), *Memory development in children.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Lange, G., & Jackson, P. (1974). Personal organization in children's free recall. *Child Development, 45,* 1060–1067.

Lange, G. W., & Hultsch, D. F. (1970). The development of free classification and free recall in children. *Developmental Psychology, 3,* 408.

Laurence, M. W. (1966). Age differences in performance and subjective organization in the free recall learning of pictorial material. *Canadian Journal of Psychology, 20,* 388–399.

Liberty, C., & Ornstein, P. A. (1973). Age differences in organization and recall: The effects of training in categorization. *Journal of Experimental Child Psychology, 15,* 169–186.

Mandler, G. (1967). Organization and memory. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Vol. 1). New York: Academic Press.

Mandler, G., & Stephens, D. (1967). The development of free and constrained conceptualization and subsequent verbal memory. *Journal of Experimental Child Psychology, 5,* 86–93.

Melkman, R., Tversky, B., & Baratz, D. (1981). Developmental trends in the use of perceptual and conceptual attributes in grouping, clustering, and retrieval. *Journal of Experimental Child Psychology, 31,* 470–486.

Mervis, C. B. (1980). Category structure and the development of categorization. In B. C. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension: Perspectives from cognitive psychology, linguistics, artificial intelligence, and education.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Moely, B. E., & Jeffrey, W. E. (1974). The effects of organization training on children's free recall of category items. *Child Development, 45,* 135–143.

Moely, B. E., Olson, F. A., Halwes, T. G., & Flavell, J. H. (1969). Production deficiency in young children's clustered recall. *Developmental Psychology, 1,* 26–34.

Moely, B. E., & Shapiro, S. I. (1971). Free recall and clustering at four age levels: Effects of learning to learn and presentation method. *Developmental Psychology, 4,* 490.

Nelson, K. J. (1969). The organization of free recall by young children. *Journal of Experimental Child Psychology, 8,* 284–295.

Nelson, K. J. (1974). Variations in children's concepts by age and category. *Child Development, 45,* 577–584.

Niemark, E., Slotnick, N. S., & Ulrich, T. (1971). Development of memorization strategies. *Developmental Psychology, 5,* 427–432.

Northrop, S. K. (1974). *The effects of organization training and list difficulty on children's free recall over varying delay intervals.* Unpublished master's thesis, Tulane University.

Olver, R. R., & Hornsby, J. R. (1966). On equivalence. In J. S. Bruner, R. R. Olver, & P. M. Greenfield (Eds.) *Studies in cognitive growth.* New York: Wiley.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. Lloyd (Eds.), *Cognition and categorization.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8,* 382–439.

Rosner, S. R. (1974). Effective list length and part–whole transfer in first graders' multitrial free recall. *Journal of Experimental Child Psychology, 17,* 422–435.

Rosner, S. R., & Hayes, D. S. (1977). A developmental study of category item production. *Child Development, 48,* 1062–1065.

Rossi, E. (1964). Development of classificatory behavior. *Child Development, 35,* 137–142.

Rossi, E. L., & Rossi, S. I. (1965). Concept utilization, serial order and recall in nursery school children. *Child Development, 36* 771–778.

Rossi, S. I., & Wittrock, M. C. (1971). Developmental shifts in verbal recall between mental ages 2 and 5. *Child Development, 42,* 333–338.

Saltz, E., & Sigel, I. E. (1967). Concept overdiscrimination in children. *Journal of Experimental Psychology, 73,* 1–8.

Saltz, E., Soller, E., & Sigel, I. (1972). Development of natural language concepts. *Child Development, 43,* 1191–1202.

Shapiro, S. I., & Moely, B. E. (1971). Free recall, subjective organization, and learning-to-learn at three age levels. *Psychonomic Science, 23,* 189–191.

Shultz, T. R., Charness, M., & Berman, S. (1973). Effect of age, social class, and suggestion to cluster on free recall. *Developmental Psychology, 8,* 57–61.

Storm, C. (1978). Acquiring principles of semantic organization. *Journal of Experimental Child Psychology, 25,* 208–223.

Tomikawa, S. A., & Dodd, D. H. (1981). Early word meanings: Perceptually or functionally based? *Child Development, 51,* 1103–1109.

Tulving, E. (1962). Subjective organization for recall of "unrelated" words. *Psychological Reports, 69,* 334–354.

Vaughan, M. E. (1968). Clustering, age and incidental learning. *Journal of Experimental Child Psychology, 6,* 323–334.

Wason, P. C. (1959). The processing of positive and negative information. *Quarterly Journal of Experimental Psychology, 11,* 92–107.

Winograd, T. (1975). Frames and the procedural-declarative controversy. In D. G. Bobrow & A. M. Collins (Eds.), *Representation and understanding: Studies in cognitive science.* New York: Academic Press.

Worden, P. (1974). Development of the category-recall function under three retrieval conditions. *Child Development, 45,* 1054–1059.

Worden, P. (1975). Effects of sorting on subsequent recall of unrelated items: A developmental study. *Child Development, 46,* 687–695.

Worden, P. (1976). The effects of classification structure on organized free recall in children. *Journal of Experimental Psychology, 22,* 519–529.