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The Emergence of Strategic Knowledge Activation in Categorical Clustering during Retrieval

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Elementary school children's free recall clustering has recently been explained as an automatic by-product of their developing knowledge base. In contrast, it is claimed that as children get older they become aware of the usefulness of category organization as a memory strategy that enables them to *strategically* activate category knowledge even during retrieval. To test this hypothesis an experimental procedure was developed where Ss first had to learn items in a noncategorical order to the criterion of two perfect serial recall trials. After a 12- to 15-min retention interval Ss unexpectedly received either serial or free recall (or—in Experiment 1—cued recall) instructions. In three experiments with second and fourth graders it was shown that (1) fourth graders' recall exceeded that of second graders only in the free, but not in the serial (or cued), recall condition, (2) higher levels of clustering were observed for fourth graders in the free recall condition, and (3) the grade effect on free recall data was eliminated when the influence of metamemory and categorical clustering statistically was partialled out (Experiments 1 and 3). This pattern of results proved robust against variants in which a metamemory question was asked or omitted prior to recall (Experiment 2) and manipulations in which age differences in categorical knowledge were minimized (Experiment 3). The results were interpreted as demonstrating fourth graders' strategic competence in activating category knowledge during retrieval and second graders' automatic knowledge activation.

For over two decades, children's strategic activities have been a topic of central interest in the area of memory development. In the early 1970s the primary focus centered on the description and measurement of strategic memory behavior, and a distinction was made between *acquisition* and *retrieval* strategies to characterize the locus of mnemonic activities in a subject's information processing flow (cf. Kobasigawa, 1977). In the

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last decade, interest has shifted to pertinent theoretical questions concerning the mechanisms involved in memory strategies and related developmental changes (cf. Naus & Ornstein, 1983). As a consequence, controversial positions about the defining characteristics of strategies have recently emerged. However, it seems widely accepted to define them as goal-directed and effort-consuming processes that enhance task performance and are, at least, potentially conscious and controllable (cf. Flavell, 1985; Schneider & Pressley, 1989).

Categorical organization in free recall has, for some time, been interpreted as a typical deliberate memory strategy that emerges in school age children. Ten years ago, two possible explanations of age differences in categorical organization were advanced (cf. Lange, 1978; Moely, 1977; Ornstein & Corsale, 1979): (a) the increasing availability of knowledge about the usefulness of organizational memory strategies (*metamemory hypothesis*) and (b) the child's growing knowledge about the world (*knowledge base hypothesis*).

Bjorklund (1985, 1987) proposed an elaborate version of the knowledge base hypothesis. He argued that the increase in category clustering during children's free recall is mediated by mechanisms representing unconscious and automatic side effects of age differences in semantic memory. In Bjorklund's view, spontaneous and deliberate (i.e., strategic) organization does not arise before adolescence. According to him, the shift from automatic to strategic organization occurs at a transitional stage during preadolescence, when children become aware of their automatic organizational behavior and its facilitating effects (Bjorklund, 1985; Bjorklund & Jacobs, 1985).

However, the position that only automatic side effects of the developing knowledge base are responsible for children's increasing category clustering in free recall during elementary school years may be called into question for several reasons. First, although empirical evidence strongly suggests that age differences in knowledge base (especially conceptual knowledge) contribute significantly to developmental changes in clustering (e.g., Bjorklund & de Marchena, 1984; Bjorklund & Jacobs, 1985; Frankel & Rollins, 1985; Schneider, 1986), this contribution might rest not only on purely automatic side effects of the developing knowledge base but also on the emergence of strategic competencies. Although a necessary condition for category organization, knowledge base is, perhaps, sufficient only in preschool and early elementary school years. When children grow older, strategic elements of knowledge activation also must be taken into account.

This line of reasoning is supported by the rapidly increasing metamemorial knowledge concerning the usefulness of clustering as a free recall strategy during elementary school years (cf. Justice, 1985; Schneider, 1986; Schneider & Pressley, 1989, Chap. 5). Moreover, Schneider

and Pressley (1989) reported a number of studies with significant correlations between task-specific metamemory and category clustering in third and fourth graders. Thus, a primary hypothesis of the present experiments was that some of the age differences between second and fourth graders' retrieval behavior in free recall are attributable to increasing metamemory. This would be indicative of an emerging strategic mechanism.

Second, the empirical elaboration of Bjorklund's position suffers from not precisely separating *input* organization during information acquisition and *output* organization during recall (cf. Ornstein, Baker-Ward, & Naus, 1988; Schneider & Pressley, 1989). By and large, Bjorklund and colleagues analyzed output organization. It thus remains unclear whether the results of their studies are due to encoding, to retrieval processes, or to an interaction between them.

To solve this problem, some recent studies (e.g., Frankel & Rollins, 1985; Schneider, 1986; Schneider, Borkowski, Kurtz, & Kerwin, 1986) relied on sort/recall tasks, where both sorting during encoding (input organization) and clustering during recall (output organization) were recorded. One of the main results was that output organization was a better predictor of younger children's recall, while input organization (sorting) made a significant contribution to predicting third and fourth graders' recall. In addition, Schneider (1986) found that task-specific metamemory was correlated with fourth graders' sorting behavior. This gives some credit to the assumption that strategic elements contribute to fourth graders' clustering at least at the encoding stage.

Although superior to other methods in the analysis of category organization during free recall, the sort/recall task has some disadvantages of its own. For example, the sort instruction may evoke children's spontaneous clustering behavior (Chi & Ceci, 1987). Furthermore, age differences in input organization may affect those in output organization. Thus it is difficult to disentangle the impact of encoding and retrieval processes on subjects' recall clustering in sort/recall tasks.

The most likely place for strategic use of organization is during acquisition. In fact, the intentional use of organization during encoding has been demonstrated by consistently significant correlations between metamemory and input organization among fourth graders (Andreassen & Waters, 1989; Schneider, 1986). However, the argument here is that even when important strategic efforts at input are suppressed, fourth graders' strategic competence will be powerful enough to initiate an effective categorical retrieval strategy.

To test this hypothesis developmental changes in category organization during *retrieval* were studied in a memory task where subjects had to encode in a noncategorical serial way. A basic procedure was developed to minimize the possibility of categorization at input and to control for

age differences in item acquisition. This procedure includes three phases: the acquisition phase, the retention interval, and the retrieval phase. In the *acquisition phase,* children had to learn four items from each of four different categories (A, B, C, D) in the following serial order, where no two items of the same category succeeded one another (arrows indicate the order of presentation):

$$\begin{aligned} &A1 \rightarrow B1 \rightarrow C1 \rightarrow D1 \\ \rightarrow\ &A2 \rightarrow B2 \rightarrow C2 \rightarrow D2 \\ &A3 \rightarrow B3 \rightarrow C3 \rightarrow D3 \\ \rightarrow\ &A4 \rightarrow B4 \rightarrow C4 \rightarrow D4 \end{aligned}$$

When the child had learned both the first (A1 to D2) and the second eight-item string (A3 to D4) to the criterion of two perfect serial recall trials, a *retention interval* of 12 to 15 min followed where subjects had to work on some distractor tasks. In the final *retrieval phase,* children were asked to recall the items either in the learned order (serial recall) or in any order they preferred (free recall).

This basic procedure was applied to second and fourth graders in three experiments. In contrast to second graders most fourth graders were expected to have sufficient metamemorial knowledge about category organization as a memory aid to strategically activate their category knowledge during retrieval. Accordingly, a specific grade-by-retrieval-condition-interaction was expected: In the free recall condition grade 4 children were expected to show better recall than grade 2 children, whereas opposite grade differences or no grade differences were expected for the serial recall condition. These expectations were based on the following line of reasoning: If fourth graders do have sufficient knowledge about clustering as a memory strategy, they will make use of it and will thus outperform second graders in the free recall condition. In the serial recall condition fourth graders may also try to make use of the categorical structure within the learned list of items, but they are explicitly instructed to refrain from doing so. As a consequence, a kind of interference between serial and categorical retrieval processes may impair the serial recall performance in fourth graders. In contrast, most second graders were not expected to have sufficient metamemorial knowledge to initiate categorical retrieval activities in the free recall condition. Instead, they may start to recall those items just coming into their mind, and mere chance may dictate whether they discover and use the encoded serial organization, the categorical structure, or neither. On the other hand, the serial recall instruction might serve for most second graders as an explicit cue to use the serial order provided during encoding as a retrieval strategy. As a consequence, the serial but not the free recall demand may work as an effective retrieval cue for second graders which enables them to recall more items in the serial as compared to the free recall condition.

EXPERIMENT 1

In the first experiment the procedure described was supplemented by a third retrieval condition in which labels for stimulus categories were provided as retrieval cues. This *cued recall* condition was added to assess children's recall and clustering behavior after the categorical relationships among the items had been made explicit and the optimal retrieval structure was thus available. However, it should be noted that this condition was similar to the "directive cue" condition used by Kobasigawa (1974), where Ss were directed to recall all items from one category before proceeding to the next. Superior performance was expected for cued recall as opposed to serial recall for both age groups based on the effectiveness of categorical retrieval structures compared with serial search and reconstruction processes. A similar difference between cued and free recall performance was expected for second graders but not for fourth graders, because the latter were anticipated to spontaneously make use of organizational retrieval strategies.

A second purpose of Experiment 1 was to study the impact of task-specific metamemory and short-term processing capacity, or *functional* memory capacity (Flavell, 1985, p. 86f), on children's free recall behavior. According to the hypothesis of strategic knowledge activation outlined above the expected age differences in free recall performance should be influenced more by the superior metamemory and clustering behavior of fourth graders than by their greater memory capacity.

METHOD

Subjects and design. Subjects were 96 volunteers, 48 each from the second (mean age = 8 years, 3 months; SD = 6 months) and fourth (mean age = 10 years, 3 months; SD = 6 months) grades. These children attended suburban public elementary schools near Hannover in West Germany, with most children coming from middle- or upper-middle-class homes. An equal number of boys and girls were chosen at each grade level. The basic design was a 2 (grade levels) × 2 (sex) × 3 (retrieval conditions) factorial combination. Sixteen subjects (8 boys and 8 girls) of either grade level were randomly assigned to the three experimental conditions.

Materials. In the recall task stimuli were colored drawings of common objects, including four instances each from four different categories: ANIMALS: *Schwein* (*pig*), *Hund* (*dog*), *Schaf* (*sheep*), *Pferd* (*horse*); BUILDINGS: *Hütte* (*cottage*), *Schloss* (*castle*), *Schule* (*school*), *Kirche* (*church*); CLOTHING: *Jacke* (*jacket*), *Pulli* (*sweatshirt*), *Strümpfe* (*socks*), *Schal* (*scarf*); FRUITS: *Birne* (*pear*), *Nüsse* (*nuts*), *Trauben* (*grape*), *Melone* (*melon*). Each picture was drawn on a 4.2 by 4.2-cm card, with the object's name printed under the drawing.

Metamemory was assessed by slightly modified version of a procedure

developed by Andreassen & Waters (1989). For this purpose two display cards were prepared, showing nine black and white line drawings of items belonging to three distinct categories. These items were different from those represented in the stimulus list for the recall task (pliers, hammer, saw; table, cabinet, stool; car, bus, bicycle). On one display card the pictures were presented in three rows by category. On the other one the same drawings were randomly arranged in three rows, with no two items of the same category in the same row.

To assess the children's functional memory capacity, a tape-recorded version of the WISC digit span test was used. In this version, a female voice presented the digits at a rate of one digit per second.

Procedure. The subjects were tested individually in a 25-min session. At the beginning, children were told that the experimenter would play some memory games with them. In the first game they should try to remember some pictures in serial order. The experimenter put the item series: "pig–cottage–jacket–pear" as a first row on the desk in front of the child and named the items twice in serial order. Then the pictures were covered and the child had to try to name them in the same order. Once the child had successfully done so, the next row of cards ("dog–castle–sweatshirt–nuts") was placed below the first one and the experimenter named all eight objects in their serial order, covered them again, and asked the child to recall the eight items in the correct order. This procedure was repeated until the child had correctly recalled the items twice. Likewise the last eight items ("sheep–school–socks–grape," "horse–church–scarf–melon") were presented until the child had reached the same learning criterion. The experimenter recorded the time the child required to complete the acquisition phase and explicitly praised his/her success in this first "memory game" to make the child believe that the task had now been completed.

During the 12-min retention interval, digit span and task-specific metamemory were assessed. First, the digit sequences of the span test were presented by tape recorder. While the individual score for the digit span was the number of digits in the longest sequence the subject was able to recall correctly, the child was credited half a point when she/he reproduced both digit sequences of this length without mistake. At the end of the retention interval each subject was asked the metamemory question. The two display cards described above were presented to the child and the experimenter asked, "Suppose a friend of yours is going to play this memory game and he asks you about the best way to do it. Would you tell him to try remember the pictures this way (experimenter points to the display card on which the items were presented in three rows by category), or that way (experimenter points to the randomly arranged display card), or wouldn't it matter which way he tried?" If the child correctly chose the categorically organized display card, she/he

was asked for the reason. Only when the child's answer gave evidence that she/he had realized the usefulness of the category organization was the metamemory point granted.

In the undeclared final retrieval phase the children were requested to recall the items learned at the beginning of the session either in the same serial order (serial recall condition) or in any order they preferred (free recall condition); or the experimenter said, "I will tell you something that might help you remember the picture list. Some of the pictures were animals, some buildings, some clothing, and some fruits! Now, first tell me all the animals you remember . . ." (cued recall condition). Irrespective of the retrieval condition, recall performance was scored by the number of items recalled correctly.

RESULTS

In all experiments the interactions in the analyses of variance were interpreted further by means of analyses of simple effects, and individual pair-wise differences were determined by Newman–Keuls analyses, and planned t test comparisons. The significance level of all tests was $\alpha = .05$, unless otherwise noted.

An initial Grade (2) × Sex (2) × Retrieval Condition (3) factorial analysis of variance on the learning time data (i.e., time to reach the acquisition phase learning criterion) yielded neither significant main effects nor any significant interaction. Thus in all subsequent analyses, the subjects' learning time ($M = 5.42$ vs. 5.29 min for second and fourth graders, respectively) could be ignored.

Recall. The Grade (2) × Sex (2) × Retrieval Condition (3) analysis of variance of the recall data revealed a main effect for retrieval condition, $F(2, 84) = 5.45$, $p < .01$. This main effect was qualified by an interaction between grade and retrieval condition, $F(2, 84) = 6.50$, $p < .01$, indicating that fourth graders' recall was superior to second graders' recall in the free recall condition, and inferior to second graders' recall in the serial recall condition, while in the cued recall condition there was no difference between second graders' and fourth graders' recall (see Table 1 for the relevant means and standard deviations). Thus, the expected pattern of recall differences within the grade by retrieval condition design was confirmed. Since recall performance was negatively correlated with learning time for fourth graders ($r(46) = -.30$, $p < .05$) but not for second graders ($r(46) = -.06$, ns) the impact of this grade difference on the reported recall results was also analyzed. A 2 × 2 × 3 analysis of covariance, with learning time as a significant covariate ($F(1, 83) = 5.18$, $p < .05$), again revealed only the main effect for retrieval condition ($F(2, 83) = 5.82$, $p < .01$) and the grade by retrieval condition interaction ($F(2, 83) = 6.27$, $p < .01$).

Recall clustering. Bousfield's (1953) Ratio of Repetition (RR) was used

TABLE 1

EXPERIMENT 1: MEAN RECALL, RECALL CLUSTERING (RR), SERIAL RETRIEVAL ORGANIZATION (SRR), AND METAMEMORY SCORES BY GRADE AND RETRIEVAL CONDITION (STANDARD DEVIATIONS IN PARENTHESES)

	Condition		
	Cued recall	Free recall	Serial recall
Recall			
Grade 2	10.63 (1.45)	8.50 (1.46)	9.94 (2.49)
Grade 4	11.13 (1.67)	10.81 (2.81)	8.50 (2.07)
Clustering			
Grade 2	.68 (.06)	.25 (.20)	.06 (.12)
Grade 4	.69 (.07)	.38 (.16)	.17 (.20)
Serial retrieval			
Grade 2	.09 (.13)	.23 (.19)	.49 (.28)
Grade 4	.04 (.07)	.16 (.13)	.40 (.25)
Metamemory			
Grade 2	.44 (.51)	.38 (.50)	.50 (.52)
Grade 4	.69 (.48)	.69 (.48)	.63 (.50)

to assess the subjects' level of retrieval clustering. The definition of the RR measure is $r/(n - 1)$ where r refers to the intracategory repetitions, and n refers to the total number of items recalled. This measure had been reported to be independent of the absolute level of recall (Murphy, 1979). The chance value of the RR is .20 for the selected item set, and the maximum (given perfect recall) is .80 (for calculation of these values, see Murphy, 1979, p. 60). Mean Ratio of Repetition scores are also shown in Table 1.

The high levels of RR for both grades in the cued recall condition suggest that nearly all children who were directed to recall items by category did so. The remaining two retrieval conditions (free recall and serial recall) were considered in a 2 (grade) × 2 (sex) × 2 (retrieval condition) analysis of variance on the clustering data. Only significant main effects of grade, $F(1, 56) = 7.76$, $p < .01$, and retrieval condition, $F(1, 56) = 20.15$, $p < .001$, were obtained. No other effect reached the chosen level of significance.

As a rather trivial result, the level of clustering in the free recall condition was higher ($M = .31$) than in the serial recall condition ($M = .12$). More interestingly, analyses of simple effects showed that fourth grade clustering exceeded second grade clustering only under free ($t(30) = 2.15$, $p < .05$), but not under serial, recall ($t(30) = 1.88$, $p < .10$). Comparisons of mean levels of clustering in the free recall condition with the chance value indicated a significant level of category organization during retrieval only in fourth grade ($t(14) = 4.50$, $p < .001$, one-tailed), but not in second grade ($t(14) = 0.99$, ns).

Serial retrieval organization. To assess subjects' degree of serial organization during retrieval a *ratio of serial repetitions* (SRR) analogous to Bousfield's (1953) ratio of intracategory repetitions was used. The ratio of serial repetitions was defined as $sr/(n - 1)$ where sr refers to the number of bidirectional repetitions according to the serial input order, and n refers to the total number of items recalled.

A grade (2) by sex (2) by retrieval condition (3) factorial analysis of variance yielded only a significant main effect of retrieval condition, $F(2, 84) = 31.41$, $p < .001$. Simple effects analyses revealed that serial retrieval organization under serial recall was superior to that in the free recall condition, which in turn was superior to that in the cued recall condition. The grade effect (in favor of the second graders) did not reach statistical significance ($F(1/84) = 2.90$, $p < .10$).

Metamemory and memory capacity. A grade (2) × sex (2) × retrieval condition (3) analysis of variance on the dichotomously scored metamemory data yielded only the expected main effect of grade, $F(1, 84) = 4.84$, $p < .05$, indicating that the task-specific metamemory of fourth graders ($M = .67$, $SD = .48$) exceeded that of second graders ($M = .44$, $SD = .50$). All other effects were not significant ($Fs < .60$).

The equivalent 2 × 2 × 3 analysis of variance on the digit span revealed a similar grade effect, $F(1, 84) = 17.36$, $p < .001$. Mean levels of digit span were 3.88 ($SD = .67$) and 4.52 ($SD = .82$) for second and fourth graders, respectively.

Individual types of retrieval organization. To clarify the internal causes of the observed grade × retrieval condition interaction on recall, subjects' individual type of retrieval organization was examined. Four types of individual retrieval organization were discerned. Children were classified as *serial organizers* if either their ratio of serial repetition was above chance *and* their ratio of intracategory repetition was below chance level (SSR > .20 and RR < .20) or the serial score was much higher than the categorical one (SRR = RR + .20). *Categorical organizers* were defined in an analogous manner (either RR > .20 and SRR < .20 or RR = SRR + .20). Children's retrieval organization was classified as being *both* serial and categorical when the serial and the categorical ratios of repetition were above chance and did not differ substantively (SRR > .20 and RR > .20 and |SRR − RR| < .20). Only if the ratios of serial and categorical repetitions were equal to or less than .20 were children classified as *nonorganizers*.

Table 2 presents the number and percentage of subjects classified as serial, categorical, serial and categorical, and nonorganizers by grade and retrieval condition. Nearly all subjects in both grades demonstrated categorical retrieval organization under cued recall. In the free recall condition, most fourth graders were categorical organizers. This was not true for second graders. Under serial recall most children at both grade

TABLE 2

EXPERIMENT 1: NUMBER AND PERCENTAGE OF SUBJECTS CLASSIFIED AS SERIAL, CATEGORICAL, SERIAL AND CATEGORICAL (BOTH), OR NONORGANIZERS BY GRADE AND RECALL CONDITION

Type of organization	Cued recall		Free recall		Serial recall	
	Grade 2	Grade 4	Grade 2	Grade 4	Grade 2	Grade 4
Serial	—	—	7 (43%)	1 (6%)	13 (82%)	10 (63%)
Categorical	15 (94%)	16 (100%)	6 (38%)	10 (63%)	1 (6%)	4 (25%)
Both	1 (6%)	—	1 (6%)	4 (25%)	1 (6%)	1 (6%)
None	—	—	2 (13%)	1 (6%)	1 (6%)	1 (6%)

levels were classified as serial organizers. However, the percentage of serial types was greater in second grade, while the percentage of categorical types was greater in fourth grade.

Explorations of determinants of the age-difference in free recall performance. Additional analyses of covariance were done to further explore whether the observed age difference in free recall performance was determined more by nonstrategic factors such as children's increasing functional capacity, or by strategic factors like metamemory and related category clustering. In the grade (2) × sex (2) analysis of covariance on the free recall data with digit span as a covariate ($F(1, 27) = 1.57$, ns) the grade effect remained significant, $F(1, 27) = 6.55$, $p < .05$. On the other hand, the grade effect *was* eliminated with free recall as the dependent variable, and clustering ($F(1, 26) = 2.65$, ns) and metamemory ($F(1, 26) = 1.25$, ns) as the covariates, $F(1, 26) = 4.11$, $p > .05$.

DISCUSSION

The confirmed expectation that fourth graders' free recall but not their serial recall performance was superior to that of second graders may for several reasons be attributed to their emerging deliberate use of retrieval strategies based on category organization.

First, the free recall difference between second and fourth graders disappeared when the organizational retrieval structure was made explicit. Moreover, fourth graders' recall performance was the same in the free and cued recall condition, while second graders' recall was significantly higher in the cued recall as compared with the free recall condition.

Second, fourth graders were more apt to produce categorical clustering during retrieval in the free recall condition. This categorical retrieval activation may be responsible for fourth graders' superior free recall compared to second graders.

Third, fourth graders' higher level of free recall performance was not only accompanied by their greater amount of recall clustering, the higher percentage of individuals classified as categorical organizers, and their

more mature metamemory. The age difference in free recall was also eliminated when the level of clustering and metamemory was statistically controlled in an analysis of covariance.

Fourth, more fourth graders than second graders were classified as categorical organizers in the serial recall condition. This may be indicative of the internal interference in fourth grade serial recall. Perhaps, because of their budding awareness of the usefulness of strategic clustering, the demand for serial retrieval processes competed with their attempt to initiate categorical search processes, resulting in a rather poor serial recall performance.

At first glance the superiority of serial over free recall for second graders seems to reflect a striking anomaly. Why did the younger children not use the serial retrieval strategy they effectively demonstrated in the serial recall condition? The most likely explanation for this anomaly seems to be a kind of interference between attempts to reconstruct the serial order presented at acquisition and the automatic activation of category relatedness knowledge described by Bjorklund (1987). This interference may be more influential in the free recall condition because here the explicit cue to recall in the serial order was not given.

In summary, the pattern of results in Experiment 1 seems to fit well with the outlined hypothesis of the emergence of strategic knowledge activation during retrieval. However, one serious problem still remains. Since Andreassen and Waters (1989) have demonstrated mutual relationships between answering a metamemory question and actual strategic memory behavior, older children might have learned something about strategy use before final recall as a consequence of posing the metamemory question during retention interval. Given this possibility, fourth graders' pattern of behavior may alternatively be interpreted as an artifact of applying the metamemory question before final recall. This problem was addressed in Experiment 2.

EXPERIMENT 2

Experiment 2 was designed to rule out the possibility that the grade × free versus serial recall interaction is a function of asking the metamemory question before or after final recall.

Method

Subjects and design. Forty-eight second graders (mean age = 8 years, 3 months; *SD* = 6 months) and 48 fourth graders (mean age = 10 years, 3 months; *SD* = 4 months) from middle- and upper-middle-class homes participated in the experiment. All the children attended a rural public elementary school in the Hannover district, West Germany. The design was a 2 (grade) × 2 (sex) × 2 (retrieval condition) × 2 (metamemory question condition) factorial combination with 12 subjects (6 males and

6 females) randomly assigned to the 2 (free versus serial recall) by 2 (metamemory question before versus after final recall) experimental conditions.

Materials. All the materials used in Experiment 1 were again used in Experiment 2.

Procedure. The procedure was the one used in Experiment 1, with three exceptions. First, the cued recall condition was omitted. Second, within each grade 50% of the subjects in each retrieval condition were asked the metamemory question *after* completion of the retrieval phase. The other 50% had to answer this question immediately *before* starting recall. Third, the retention interval was extended from 12 to 15 min in order to produce slightly higher forgetting rates. Again, digit span was assessed for all Ss in the retention interval.

RESULTS

Contrary to the findings of Experiment 1, the initial four factor analysis of variance on the learning time data yielded a significant effect of grade, $F(1, 80) = 10.67$, $p < .01$, indicating that second graders needed more time ($M = 6.15$ min, $SD = 1.24$) to complete the acquisition phase than fourth graders ($M = 5.38$ min, $SD = 1.00$). No other effect was significant.

Recall. Recall was analyzed by a $2 \times 2 \times 2 \times 2$ analysis of variance. As expected, the only significant effects were a main effect of grade, $F(1, 80) = 7.65$, $p < .01$, and the two-way interaction between grade and retrieval condition, $F(1, 80) = 7.74$, $p < .01$. Subsequent analyses of the simple effects (see Table 3 for the relevant means and standard deviations) indicated a significant recall superiority of grade 4 children only in the free recall condition, while no grade difference was revealed under serial recall. Like all remaining effects, the effect for the metamemory question condition did not approach significance ($F(1, 80) = 2.43$, $p > .10$). A very similar pattern of results was found in the $2 \times 2 \times 2 \times 2$ analysis of covariance with learning time as a significant covariate ($F(1, 79) = 7.27$, $p < .01$). Again only the grade effect ($F(1, 79) = 4.15$, $p < .05$) and the grade by retrieval condition interaction ($F(1, 79) = 8.26$, $p < .01$) were significant.

Recall clustering. Mean ratio of repetition (RR) scores are presented by grade and conditions in Table 3. The 2 (grade) $\times$ 2 (sex) $\times$ 2 (retrieval condition) $\times$ 2 (metamemory question condition) analysis of variance of these data produced significant main effects of grade, $F(1, 80) = 4.26$, $p < .05$ (grade 2 < grade 4), and retrieval condition, $F(1, 80) = 14.20$, $p < .001$ (serial recall < free recall). There were no other significant effects in the analysis of clustering data.

Serial retrieval organization. Again the ratio of serial repetition (SRR) was used to assess subjects' serial organization during retrieval. The

TABLE 3

EXPERIMENT 2: MEAN RECALL, RECALL CLUSTERING (RR), SERIAL RETRIEVAL ORGANIZATION (SRR), AND METAMEMORY SCORES BY GRADE, RETRIEVAL CONDITION, AND METAMEMORY (MM) QUESTION CONDITION (STANDARD DEVIATIONS IN PARENTHESES)

	Free recall		Serial recall	
	MM Before	MM After	MM Before	MM After
Recall				
Grade 2	6.92 (1.51)	8.17 (1.34)	8.58 (2.11)	9.00 (2.80)
Grade 4	9.58 (1.51)	9.75 (1.86)	8.50 (1.68)	9.08 (1.68)
Clustering				
Grade 2	.19 (.14)	.28 (.22)	.15 (.17)	.16 (.18)
Grade 4	.37 (.14)	.36 (.15)	.22 (.21)	.14 (.15)
Serial retrieval				
Grade 2	.26 (.15)	.16 (.17)	.43 (.28)	.42 (.20)
Grade 4	.23 (.15)	.25 (.26)	.40 (.30)	.33 (.25)
Metamemory				
Grade 2	.17 (.39)	.25 (.45)	.25 (.45)	.25 (.45)
Grade 4	.67 (.49)	.75 (.45)	.67 (.48)	.58 (.51)

grade (2) × sex (2) × retrieval condition (2) × metamemory question condition (2) analysis of variance yielded only a significant main effect of retrieval condition, $F(1, 80) = 13.89$, $p < .001$, indicating that serial retrieval organization in the free recall condition was lower than in the serial recall condition. No other effect approached statistical significance ($Fs < 1.00$).

Metamemory and memory capacity. Mean metamemory scores are presented in Table 3 by grade and conditions. The 2 × 2 × 2 × 2 analysis of variance on these data yielded only the expected grade effect, $F(1, 80) = 23.13$, $p < .001$ indicating that fourth graders' metamemory ($M = .69$, $SD = .47$) exceeded that of second graders ($M = .23$, $SD = .42$).

The corresponding 2 × 2 × 2 × 2 analysis of variance on digit span data similarly revealed only a grade effect, $F(1, 80) = 8.72$, $p < .01$. Mean levels of digit span were 4.20 ($SD = .57$) and 4.60 ($SD = .72$) for second and fourth graders, respectively.

Individual types of retrieval organization. Based on the definitions developed in Experiment 1, children were classified as serial, categorical, serial and categorical, or nonorganizers. Initial analyses indicated no difference in the distribution of serial and categorical organizers as a function of the metamemory question condition. Thus, Table 4 presents number and percentage of subjects classified as serial, categorical, both, or nonorganizers as a function of retrieval condition and grade, collapsed across the metamemory question condition.

TABLE 4

EXPERIMENT 2: NUMBER AND PERCENTAGE OF SUBJECTS CLASSIFIED AS SERIAL, CATEGORICAL, SERIAL AND CATEGORICAL (BOTH), OR NONORGANIZERS BY GRADE AND RECALL CONDITION (COLLAPSED ACROSS METAMEMORY QUESTION CONDITION)

Type of organization	Free recall		Serial recall	
	Grade 2	Grade 4	Grade 2	Grade 4
Serial	7 (29%)	3 (13%)	15 (62%)	11 (46%)
Categorical	9 (38%)	14 (58%)	3 (13%)	6 (25%)
Both	2 (8%)	6 (25%)	5 (21%)	4 (16%)
None	6 (25%)	1 (4%)	1 (4%)	3 (13%)

As in Experiment 1 more second graders than fourth graders were classified as serial organizers, and more fourth graders than second graders were classified as categorical organizers, irrespective of retrieval condition.

Further analyses. The impact of functional memory capacity and strategic elements in knowledge activation was explored by additional analyses of covariance on the free recall data. A grade (2) × sex (2) × metamemory question condition (2) analysis of covariance with digit span as covariate ($F(1, 39) = 0.10$, ns) did not remove the grade effect reported above ($F(1, 39) = 19.88$, $p < .001$). This result indicates the negligible impact of functional capacity on fourth graders' superior free recall performance. But even in the 2 × 2 × 2 analysis of covariance using clustering ($F(1, 38) = 10.69$, $p < .01$) and metamemory ($F(1, 38) = 7.95$, $p < .01$) as covariates, a statistically significant main effect of grade was obtained, $F(1, 38) = 7.35$, $p < .05$. It should be noted, however, that a substantial reduction of the F-value was achieved by controlling for age differences in metamemory and clustering.

DISCUSSION

The potential objection that the results of Experiment 1 do not indicate the suggested emergence of a spontaneous strategy activation of categorical knowledge, but are rather an artifact of asking the metamemory question before final recall, can obviously be rejected by the outcome of Experiment 2. Although not all the findings of Experiment 1 were replicated, not a single significant effect was found for the metamemory question condition. Instead, the main findings of Experiment 1 were replicated without any qualification by the metamemory question condition.

First, the grade × retrieval condition interaction on recall performance was again found. However, in contrast to Experiment 1, no age difference for serial recall was obtained. Only fourth graders' superiority on free

recall was replicated. Second, fourth graders showed higher levels of clustering under free recall. Although this superiority of categorical clustering was not confirmed in the serial recall condition, more fourth graders compared to second graders were classified as categorical organizers under both retrieval conditions. Third, most fourth graders, but only few second graders, were aware of the usefulness of categorical clustering as an effective memory strategy. Although these results are open to alternative interpretations, it is proposed here to highlight the deliberate use of category knowledge as a retrieval strategy.

EXPERIMENT 3

While the basic predictions derived from the hypothesis of emerging strategic knowledge activation in late elementary school years were confirmed by the results of Experiments 1 and 2, Experiment 3 was designed to explore whether this emerging strategic behavior is limited to highly familiar item materials where automatic effects of knowledge base may release a category retrieval strategy. Recently, similar knowledge-strategy interactions were discussed (e.g., Chi & Ceci, 1987; Ornstein et al., 1988; Rabinowitz & Chi, 1987; Schneider & Pressley, 1989) emphasizing the key role of children's category knowledge. Undoubtedly, age differences in children's degree of knowledge concerning category relations exist (e.g., Bjorklund, Thomson, & Ornstein, 1983; Posnansky, 1978). Furthermore, studies where children's knowledge of categorical relations was manipulated by norms of category typicality (e.g., Bjorklund, 1988; Frankel & Rollins, 1985; Schneider, 1986) revealed that children's categorical clustering in free recall is a function of the typicality of stimulus items.

Bjorklund (1985, 1987) concluded that most age differences in recall and clustering can be explained solely in terms of age differences in the strength of relationships between category exemplars and category labels, without having to propose age differences in strategy implementation. Relating this position to the development of categorical retrieval studied in the present experiments, one might expect that the pattern of results reported in Experiments 1 and 2 could be restricted to typical stimulus items where age differences in the degree of category knowledge are very likely.

Thus, the primary goal of Experiment 3 was to test whether the pattern of results obtained in both previous experiments could be replicated using stimulus materials in which age differences in categorical knowledge were minimized by using atypical exemplars as stimulus items. Furthermore, the supportive function of interitem associations on fourth graders' retrieval behavior should be explored, since the observed categorical organization may, in addition, depend on the automatic activation of associative interitem relations (cf. Bjorklund & Jacobs, 1985).

METHOD

Subjects and design. Fifty-six second graders (mean age = 8 years, 2 months; *SD* = 8 months) and 56 fourth graders (mean age = 10 years, 4 months; *SD* = 8 months) participated in the experiment. The children came from two rural public elementary schools near Göttingen, West Germany. The design was a 2 (grade) × 2 (sex) × 2 (retrieval condition) × 2 (interitem associativity) factorial combination with 14 subjects (7 boys and 7 girls) randomly assigned to each of the 2 (free versus serial recall) × 2 (high versus low interitem associativity) experimental conditions.

Materials. Two recall lists with either high or low within-category interitem associations were generated. Only categorically atypical items for both grade levels (proportions lower than .20 according to the Posnansky (1978) norms) were used to minimize age differences in category knowledge on recall behavior. Each list was composed of four stimuli from each of four categories. Stimuli were black and white line drawings of common objects adapted from Schneider (1986). In the list with high interitem associations from each category, two pairs of high associated exemplars were chosen. The items in each category were (dashes between the high associates) ANIMALS: *Ziege* (*goat*)–*Schaf* (*sheep*), *Büffel* (*buffalo*)–*Nilpferd* (*hippopotamus*); CLOTHING: *Gürtel* (*belt*)–*Shorts* (*shorts*), *Handschuh* (*glove*)–*Schal* (*scarf*); BODY PARTS: *Knöchel* (*ankle*)–*Knie* (*knee*), *Ellbogen* (*elbow*)–*Schulter* (*shoulder*); HOUSE PARTS: *Zaun* (*fence*)–*Tor* (*gate*), *Treppe* (*steps*)–*Geländer* (*railing*). Only low associates were chosen for the list with low interitem associations. The items were ANIMALS: *Seehund* (*seal*), *Krokodil* (*crocodile*), *Kamel* (*camel*), *Eichhörnchen* (*squirrel*); CLOTHING: *Gürtel* (*belt*), *Schal* (*scarf*), *Unterhemd* (*undershirt*), *Pullover* (*sweater*); VEHICLES: *Traktor* (*tractor*), *Hubschrauber* (*helicopter*), *Schlitten* (*sled*), *Rakete* (*rocket*); FURNITURE: *Kühlschrank* (*refrigerator*), *Schaukelstuhl* (*rocker*), *Bücherregal* (*bookcase*), *Ofen* (*stove*). Since no suitable German association norms were available, association values were selected from the Marshall and Cofer (1970) and Palermo and Jenkins (1964) norms and validated by associative strength ratings from an independent sample of 23 third graders, using a five-point rating scale similar to that used by Bjorklund and Jacobs (1985).

The display cards used in the previous experiments to assess metamemory were modified slightly in order to avoid the same categories being represented in both the recall lists and the metamemory assessment displays. Therefore, six of the nine stimulus drawings on the display cards were replaced. The objects presented on the new display cards were pliers, hammer, saw; pear, grape, melon; castle, school, church.

Procedure. The procedure was identical to the one used in Experiment 1, except for the retention interval. Instead of working on the digit span

task, subjects had to work on two simple distractor tasks, involving the repetition of word-triplets spoken by the experimenter.

RESULTS

An initial 2 (grade) × 2 (sex) × 2 (retrieval condition) × 2 (interitem associativity) analysis of variance on the learning time data yielded only a significant main effect of grade, $F(1, 96) = 13.29$, $p < .001$ (grade 2, $M = 6.84$, $SD = 1.89$; grade 4, $M = 5.71$, $SD = 1.75$). Furthermore, a significant three-way interaction between grade, associativity, and sex, $F(1, 96) = 7.17$, $p < .05$, was obtained. Analyses of simple effects revealed that grade differences in learning time were less pronounced for boys in the low associativity condition, and for girls in the high associativity condition.

Preliminary analyses of sex effects on the remaining data to be presented revealed that sex had no significant effect, and the data were collapsed across this variable in all subsequent analyses.

Table 5 contains the mean recall, clustering (ratio of repetition), serial retrieval organization, and metamemory scores as a function of grade, retrieval condition, and interitem associativity.

Recall. The 2 × 2 × 2 analysis of variance on recall data yielded only a significant two-way interaction between grade and retrieval condition, $F(1, 104) = 4.73$, $p < .05$, indicating that fourth graders outperformed second graders under free recall, and no significant grade difference occurred in serial recall. Similarly, a three-factor analysis of covariance with learning time as covariate ($F(1, 103) = 1.79$, ns) revealed

TABLE 5

EXPERIMENT 3: MEAN RECALL, RECALL CLUSTERING (RR), SERIAL RETRIEVAL ORGANIZATION (SRR), AND METAMEMORY SCORES BY GRADE, RETRIEVAL CONDITION, AND ASSOCIATIVITY (STANDARD DEVIATIONS IN PARENTHESES)

	High associativity		Low associativity	
	Free recall	Serial recall	Free recall	Serial recall
Recall				
Grade 2	7.50 (1.95)	8.07 (2.53)	7.36 (2.27)	8.07 (1.44)
Grade 4	8.79 (1.85)	7.36 (2.06)	8.36 (1.55)	7.50 (1.61)
Clustering				
Grade 2	.34 (.23)	.07 (.14)	.21 (.15)	.16 (.14)
Grade 4	.42 (.14)	.17 (.18)	.30 (.17)	.12 (.13)
Serial retrieval				
Grade 2	.18 (.15)	.40 (.21)	.26 (.15)	.28 (.17)
Grade 4	.12 (.12)	.42 (.29)	.21 (.22)	.31 (.22)
Metamemory				
Grade 2	.29 (.47)	.50 (.52)	.36 (.50)	.21 (.43)
Grade 4	.64 (.50)	.71 (.47)	.57 (.51)	.64 (.50)

only a significant effect of the grade × retrieval condition interaction ($F(1, 103) = 7.00$, $p < .01$).

Recall clustering. The 2 (grade) × 2 (retrieval condition) × 2 (interitem associativity) analysis of variance of the RR-scores produced significant main effects of grade, $F(1, 102) = 4.01$, $p < .05$, and retrieval condition, $F(1, 102) = 33.28$, $p < .001$. The latter effect was qualified by a two-way interaction between retrieval condition and interitem associativity, $F(1, 102) = 6.64$, $p < .05$, indicating a significant effect of associativity in the free recall, but not in the serial recall condition.

T-comparisons of mean levels of free recall clustering with those expected by chance ($k = .20$) revealed significant levels of clustering only for the list with high associates in grade 2 but for both lists in grade 4 ($ts > 2.20$).

Serial retrieval organization. The grade (2) × retrieval condition (2) × associativity (2) analysis of variance on subjects' ratio of serial repetition (SRR) revealed a significant main effect only for retrieval condition, $F(1, 102) = 21.16$, $p < .001$. This main effect was qualified by a two-way interaction between retrieval condition and associativity, $F(1, 102) = 5.77$, $p < .05$. Analyses of simple effects revealed that serial retrieval organization was higher under low associativity in free recall, and under high associativity in the serial recall condition.

Metamemory. Mean metamemory scores are presented in Table 5 by grade and conditions. The 2 × 2 × 2 analysis of variance on these data yielded only the expected main effect of grade, $F(1, 102) = 10.89$, $p < .001$, indicating fourth graders' ($M = .64$, $SD = .48$) general superiority over second graders' metamemory ($M = .34$, $SD = .48$).

Individual types of retrieval organization. Again, individual types of retrieval organization were classified by the same criteria used in both previous experiments. The results of this classification are presented in Table 6 as a function of retrieval condition, grade, and interitem associativity.

Irrespective of grade, more children were classified as categorical organizers in the high compared to the low associativity condition. However, even in the low associativity condition, 57% of the fourth graders were categorical organizers. In contrast, in this condition 43% of the second graders were classified as serial organizers. Although these results demonstrate the supportive function of high interitem associations on fourth graders' use of categorical clustering, the hypothesized strategic knowledge activation seemed to be initiated by more than 50% of the grade 4 children even when the possibility of knowledge base support was minimized. This interpretation is sustained by the finding that six of the eight fourth graders that were classified as categorical organizers in the free recall/low associativity condition, but only two of the remaining

TABLE 6

EXPERIMENT 3: NUMBER AND PERCENTAGE OF SUBJECTS CLASSIFIED AS SERIAL, CATEGORICAL, SERIAL AND CATEGORICAL (BOTH), OR NONORGANIZERS BY GRADE AND ASSOCIATIVITY, SEPARATED BY RECALL CONDITION

Type of organization	Grade 2 Associativity		Grade 4 Associativity	
	Low	High	Low	High
	(a) Free recall			
Serial	6 (43%)	1 (7%)	4 (29%)	—
Categorical	4 (29%)	6 (43%)	8 (57%)	10 (71%)
Both	3 (21%)	3 (21%)	1 (7%)	4 (29%)
None	1 (7%)	4 (29%)	1 (7%)	—
	(b) Serial recall			
Serial	8 (57%)	12 (86%)	8 (57%)	7 (50%)
Categorical	3 (22%)	1 (7%)	1 (7%)	1 (7%)
Both	1 (7%)	—	1 (7%)	4 (29%)
None	2 (14%)	1 (7%)	4 (29%)	2 (14%)

six children, demonstrated task-specific strategic knowledge in the metamemory question.

As can be seen from Table 6b, in the serial recall/high associativity condition 29% of fourth grade children, but none of the second grade children, were classified as both serial and categorical organizers. This may be interpreted in terms of the postulated interference between serial and categorical retrieval processes in grade 4 children. This interference seems to be a function of the associative strength between items.

The impact of metamemory and clustering on free recall performance. In order to determine whether fourth graders' free recall superiority may be explained by their emerging strategic competence, a grade (2) $\times$ associativity (2) analysis of covariance with metamemory and clustering as covariates was conducted. As expected, the grade effect was eliminated ($F(1, 50) = 2.97$, $p > .05$). However, neither covariate was significant ($Fs(1, 50) < 2.20$, ns).

DISCUSSION

Again, the pattern of results interpreted as evidence of fourth graders' strategic use of category clustering during retrieval was replicated. First, the recall superiority of fourth graders as compared to second graders was limited to the free recall condition in which children had enough degrees of freedom to make use of their strategic competence. Second, fourth graders exceeded second graders with regard to free recall clustering. Although the amount of clustering was affected by interitem associativity, the level of clustering in grade 4 proved to be above chance

for the list with low associates, too. Similarly, more fourth graders than second graders in the free recall condition were classified as categorical organizers. Moreover, these categorical organizers were found to have a better task-specific metamemory than their non-category-organizing peers. Third, fourth graders' superiority in free recall performance was eliminated in an analysis of covariance using metamemory and clustering as covariates.

Taken together, the basic pattern of results expected from the strategic knowledge activation hypothesis was obtained regardless of the manipulation of the knowledge base. Thus, fourth graders' spontaneous free recall clustering in the procedure developed here is *not reducible to effects of automatic knowledge activation.*

Independent of this clear evidence for the strategic knowledge activation hypothesis presented, the supportive function of knowledge base in the child's development of organizational retrieval strategies was also demonstrated. Similar to previous findings regarding clustering during encoding (Frankel & Rollins, 1985; Schneider, 1986), associative relations also played a substantial role in mediating category clustering during retrieval. This supports the view of an interaction between knowledge base and strategic competence in memory development.

GENERAL DISCUSSION

The series of experiments described above was designed to test the hypothesis that increasing category clustering in free recall during elementary school years is determined by an emerging strategic competence, and is not only an automatic by-product of children's developing knowledge base. Children first had to learn items presented in a noncategorical order to a strong criterion of two perfect serial recall trials. A 12- to 15-min retention interval followed, filled with some distractor tasks. Two alternative retrieval conditions, with either an unexpected serial or an unexpected free recall instruction, were given.

Assuming that fourth graders are in a transitional state concerning the flexible and deliberate use of memory strategies in a great variety of situations (e.g., Frankel & Rollins, 1985; Ornstein et al., 1988; Schneider, 1986), it was hypothesized that unlike second graders, most fourth graders are aware of the usefulness of category organization as a retrieval strategy and thus begin deliberately to activate category knowledge as a memory strategy during retrieval. The following pattern of results replicated within the series of experiments presented supports this theoretical view: (1) the interaction between grade and free versus serial recall instructions on children's recall data indicates that fourth graders' free recall, but not their serial recall, exceeded that of second graders, (2) fourth graders' higher levels of category clustering in free recall as compared to second graders, (3) the removal of the grade effect on free

recall performance when using metamemory and clustering as covariates in an analysis of covariance.

However, a few additional findings indicate that this strategic competence is not yet a mature one among grade 4 children. For example, only 2/3 of the children at grade 4 are aware of the utility of category organization as a memory aid. In addition, only in two of the three experiments could fourth graders' free recall superiority be eliminated by the statistical control of differences in metamemory and clustering.

Moreover, the supportive function of associativity on free recall clustering provides evidence for the interaction between knowledge base and strategic competence. Late elementary school children's increasing categorical clustering during retrieval seems to be best explained by the emergence of strategic knowledge activation. However, continuing theoretical work seems necessary to disentangle the complexity of developmental interactions between knowledge base and strategic competence.

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