*British Journal of Developmental Psychology* (1997), 15, 495–514 *Printed in Great Britain*

# Relations between task structure and developmental changes in children's use of spatial clustering strategies

**Jodie M. Plumert*** and **David Strahan**
*Department of Psychology, 11 SSH East, The University of Iowa, Iowa City, IA 52242, USA*

Two experiments investigated how the supportiveness of the task influences children's use of spatial clustering strategies. Experiment 1 documented developmental differences in 6-, 8- and 10-year-olds' use of spatial clustering in a tour-planning and in a free recall task. Children hid objects in a dollhouse and later recalled the objects or planned a tour of the objects. Ten-year-olds, but not 6- and 8-year-olds, who planned the tour showed more spatial clustering than did their counterparts who performed the standard free recall task. Experiment 2 investigated transfer of spatial clustering strategies from the more supportive tour-planning task to the free recall task. Eight- and 10-year-olds again hid objects in the dollhouse and then performed a tour-planning or a free recall task. Immediately afterward, all children performed a free recall of the objects. Ten-year-olds, but not 8-year-olds, who performed the tour-planning task first showed significantly more spatial clustering in their subsequent free recall than did their counterparts who performed the free recall task first. Discussion focuses on factors that lead to developmental changes in children's ability to apply their spatial clustering skills to different tasks.

One of the most central, yet elusive questions about the development of recall memory is how do children acquire strategies? A variety of approaches have been used to address this question, yielding valuable insights into the factors that influence children's use of strategies. Studies of the knowledge base, for example, have led to the conclusion that developmental changes in what children know and how their knowledge is organized may be partially responsible for developmental changes in the use of organizational strategies (e.g. Best & Ornstein, 1986; Bjorklund, 1987; Chi, 1985). Likewise, investigations of meta-memory have shown that children's understanding of strategies is related to their use of those strategies in recall (Schneider, 1986; Schneider & Pressley, 1989). More recently, researchers have noted that variations in the task context also influence how children use particular strategies (e.g. Folds, Footo, Guttentag & Ornstein, 1990; Guttentag, 1984; Miller, 1990; Plumert, 1994; Woody-Ramsey & Miller, 1988).

---

* Request for reprints.

The finding that variations in the task context have a profound impact on children's strategic behaviour suggests that the task plays a critical role in the development of children's strategy use. But how might we conceptualize the role of the task context in children's strategy development? According to contextual theories of cognitive development, tasks can serve as scaffolds for the deployment of cognitive skills (Rogoff, 1990; Vygotsky, 1978). That is, tasks can provide children with a source of external support for executing their cognitive skills. Scaffolding of cognitive performance is thought to be particularly important during times of transition, sometimes referred to as the zone of proximal development (Vygotsky, 1978). During such times, children are sensitive to experiences that allow them to try out new ways of thinking and acting. More specifically, children are in a state of readiness to benefit from scaffolding that provides them with the necessary support to use their skills in novel ways. Over time, scaffolding can be modified or withdrawn as the child becomes increasingly competent at executing the skill. Developmental change results as children become less reliant on external supports to structure their cognitive performance.

This perspective on developmental change raises two fundamental questions for the study of cognitive development: (*a*) what aspects of the task context support deployment of cognitive skills at younger and older ages? and (*b*) how does experience with using skills in supportive contexts lead to changes in how those skills are used in the future? The purpose of the present investigation was to address these issues in relation to the development of children's spatial clustering strategies. The aims of this investigation were twofold: (*a*) to document developmental differences in children's ability to use spatial clustering in different tasks, and (*b*) to examine how experience with using spatial clustering in a more supportive task influences children's ability to transfer their spatial clustering skills to a less supportive task.

Spatial clustering is one of several mnemonic devices used to enhance recall. In general, spatial clustering refers to grouping objects or locations on the basis of common membership within a spatial region. Spatial regions are defined by physical or perceptual boundaries, or by proximity to salient landmarks (McNamara, 1986). For example, one might think of a table, stool and refrigerator as belonging together because they are all located in the kitchen, or one might think of a couch, rug, and rocking chair as belonging together because they are all located near the fireplace. If asked to recall the objects in one's home, a useful organizational strategy would be to recall them by spatial region. For example, one might recall all the objects in the kitchen, then all the objects in the living room, and so on. Another spatial mnemonic used to aid recall is the method of loci (Bower, 1970; Yates, 1966). The method of loci involves mentally placing objects at points along a well-known route and then mentally retrieving the items from the route during recall. For example, one might try to remember items from a grocery list by mentally placing them along the route from home to work. As a mnemonic device, the method of loci differs from spatial clustering because it is based on representation of routes rather than regions. Nonetheless, both strategies use knowledge of object *locations* to remember object *names*.

There is a small, but growing body of literature providing insight into the development of spatial clustering strategies (e.g. Cornell & Heth, 1986; Plumert, 1994; Plumert, Pick, Marks, Kintsch & Wegesin, 1994; Wellman, Somerville, Revelle, Haake & Sophian, 1984). These studies suggest that spatial clustering is a strategy that even young children are capable of using, but one that undergoes considerable change with development. A major part of this development is applying spatial clustering strategies to a broader range of tasks. One of the first ways in which children use spatial clustering is in searching for objects. Thus, 4-year-olds retrieve the objects from one cluster of locations before retrieving those in another cluster (Wellman *et al.*, 1984). Somewhat later, children begin to use their spatial clustering skills in verbal tasks such as giving directions for finding missing objects (Plumert *et al.*, 1994). By 12 years of age, children also use spatial clustering to structure their free recall of object locations. Thus, when asked to recall the locations of a set of objects, 12-year-olds recall the locations by spatial region (Plumert, 1994, Expt 2). Finally, at around 16 years of age, adolescents apply spatial clustering to structure their recall of object names. When recalling the furniture from their home, for example, 16-year-olds, but not younger children, group furniture items by room (Plumert, 1994, Expt. 1). Together, these results clearly show that developmental changes in children's use of spatial clustering strategies are task linked.

Two distinct, though not necessarily mutually exclusive explanations can be used to account for the developmental progression outlined above. One is that children use their spatial organizational skills in tasks with lower information-processing demands before they are able to use those same skills in tasks with higher information-processing demands (Guttentag, 1984; Miller, 1990). Thus, one possible reason why young children search for objects in a spatially organized fashion but do not give spatially organized directions for finding those same objects is that the task of giving directions places higher information-processing demands on children than does the task of searching for objects. In particular, direction giving requires greater representational abilities than does searching because children must take the perspective of another person and rely on their memory for the spatial layout. This explanation is consistent with recent findings showing that younger children use rehearsal and attentional strategies when the information-processing demands of the task are reduced (Guttentag, 1984; Miller, Woody-Ramsey & Aloise, 1991).

Another explanation for the developmental progression outlined above is that children first use strategies in tasks that make the relevant features of the problem more salient (Gauvain, 1993; Miller, 1990; Rogoff, 1990). When a spatial clustering strategy is the solution intended by the experimenter, children must focus on the spatial connections among the objects. In other words, children must attend to which objects belong to the same spatial region. Tasks such as searching for objects, giving directions for finding objects, and recalling the names of objects seem to differ in how explicitly they draw attention to the spatial connections among the objects. For example, a task such as giving directions to someone for finding a set of objects may readily draw younger children's attention to the spatial connections among objects by making the listener's movement through space more salient. Specifically, imagining the listener in the space may prime them to think about locations nearby the listener (Morrow, Greenspan & Bower, 1987). When faced with an unstructured task such as free recall, however, younger children may have difficulty focusing on the spatial connections among the objects because the explicitly stated goal of the task is to remember *what* the objects are, not where they are *located*. In fact, in situations in which both categorical and spatial organization are available (e.g. recalling the furniture from one's home), younger children attend more to the categorical than to the spatial relations among the items (Plumert, 1994).

An essential question at this point is how do these developmental changes in children's use of spatial clustering strategies come about? One response to this question is that searching for objects, giving directions for finding objects, recalling object locations, and recalling object names are unrelated skills that develop along independent trajectories. This answer is unsatisfying, however, because it is unparsimonious to posit that children discover spatial clustering in each of these situations independent of their earlier experiences with using spatial clustering. A more likely possibility is that during times of transition, children are sensitive to experiences that allow them to transfer their spatial skills to new problems. More specifically, children's experiences with repeatedly using spatial clustering in a more supportive task context may guide their attention to the spatial connections among the objects. Once cued about these spatial connections, children may be able to transfer their spatial clustering skills to less supportive task contexts. If so, one would predict that children who are in a transitional state can be induced to use spatial clustering in a less supportive task if given experience with a more supportive task immediately beforehand.

In fact, there is evidence showing that experience with using a skill in a more supportive task facilitates children's ability to use that same skill in a less supportive task. For example, Plumert *et al.* (1994) found that when 6-year-olds were allowed to search for objects before giving directions for finding them, they exhibited high levels of spatial clustering in their subsequent directions. These results suggest that although children apply their spatial clustering skills to searching before they apply those same skills to direction giving, experience with using spatial clustering during searching facilitates 6-year-olds' ability to apply their spatial clustering skills to the more difficult task of direction giving. Research in other domains of cognitive development also has shown that experience with using a skill in a simpler task facilitates children's ability to use that skill in a more difficult task. Marzolf & DeLoache (1994), for example, found that 2.5-year-olds were more likely to succeed on a difficult scale model task if given a simpler scale model task first. They argue that experience with the simpler task sensitized young children to the symbolic relations between the scale model and the real space. These findings are also consistent with the literature on analogical reasoning showing that young children are capable of transferring a solution to a more difficult problem if given experience with solving a simpler problem first (Brown, 1989; Gentner, 1989).

Two experiments were conducted to further investigate developmental changes in children's ability to apply their spatial clustering skills to tasks that differ in the degree of support they offer for use of spatial clustering strategies. The goal of the first experiment was to investigate developmental differences in 6-, 8- and 10-year-olds' ability to apply their spatial clustering skills to the task of planning a tour of a set of objects and to the task of performing a free recall of those same objects. These tasks were chosen because although they have similar information-processing demands, they differ in terms of how explicitly they draw attention to the spatial relations among objects. Specifically, planning a tour of a set of objects draws attention to the viewer's movement through space thereby making spatial information a salient component of the task. In this study, children helped an experimenter hide 16 unrelated objects in a dollhouse and later performed a tour-plan task or a free recall task. On the basis of previous research (e.g. Plumert, 1994; Plumert *et al.*, 1994), we expected that 6-year-olds would exhibit little spatial clustering in either the tour-planning or the free recall task. In contrast, we expected that 10-year-olds would exhibit high levels of spatial clustering in the tour-planning task but not in the free recall task.

The goal of the second experiment was to test whether giving children experience with planning a tour of a set of objects would facilitate their ability to use spatial clustering to organize their subsequent free recall of those same objects. Eight- and 10-year-olds first performed either a tour-planning task or a free recall task. Immediately afterward, all children performed a free recall task. We reasoned that if the tour-planning task cues children about the spatial connections among the objects, then children who plan a tour first should exhibit more spatial clustering in their subsequent free recall than should children who perform a free recall of the objects first.

## EXPERIMENT 1

### Method

#### *Participants*

Twenty-four 6-year-olds, 20 8-year-olds and 22 10-year-olds from predominantly middle- to upper-middle-class Caucasian families participated. The mean ages were 6 years and 4 months (range = 5 years and 11 months to 6 years and 11 months), 8 years and 1 month (range = 7 years and 8 months to 8 years and 6 months), and 10 years and 3 months (range = 9 years and 8 months to 10 years and 10 months). There were 12 6-year-olds, 10 8-year-olds and 10 10-year-olds in the tour-plan condition, and 12 6-year-olds, 10 8-year-olds and 12 10-year-olds in the free recall condition. Approximately equal numbers of males and females in each age group and experimental condition participated.

#### *Materials and apparatus*

A 122 cm long × 30 cm high × 30 cm wide dollhouse was used as the experimental space (see Fig. 1). The dollhouse was divided into four rooms: bedroom, living room, kitchen and playroom. The rooms were connected to each other through open doorways, and each room contained four pieces of furniture that were used as hiding locations. Sixteen objects were used as target items. These included a hat, wastebasket, hanger, football, mirror, guitar, book, hammer, telephone, coffee cup, teddy bear, gumball machine, skein of yarn, bunch of bananas, flower in a pot and a pair of roller skates. Table 1 lists the four hiding places in each room. Different random pairings of objects and hiding locations were used for each child. A 4.25 in. high popular action figure was used in the tour-plan condition.

#### *Design and procedure*

Children were escorted individually from their classroom to a quiet testing room. Once inside the testing room, children were shown the dollhouse and informed that they would be hiding things in the dollhouse and later trying to remember what they had hidden. At this juncture, children were familiarized with the dollhouse. Children in the *free recall* condition were told to look inside all the rooms in the dollhouse, after which the experimenter named the rooms in a random order (e.g. 'This is the playroom'). They were then asked to name the furniture in each room. The same procedure was followed with children in the *tour-plan* condition except that the experimenter explained that the toy figure lived in the dollhouse. When naming the rooms, the experimenter also mentioned the toy figure's name (e.g. 'This is Donatello's playroom').

After familiarization with the dollhouse, children hid the objects with the experimenter. The experimenter stressed that they should try to remember where they put each one because they would have to put the objects back in their places the next time. The experimenter kept the objects in a box so that they could not be seen, and handed them to the children one at a time in a random order. The experimenter pointed to the location with a pencil and provided a verbal description of the hiding place

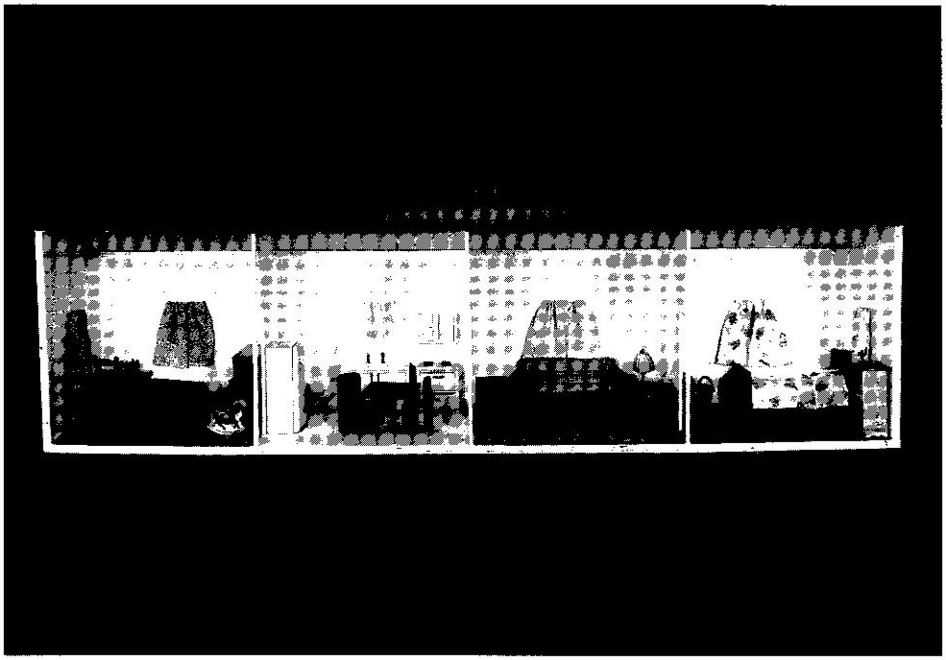

**Figure 1.** Dollhouse used as experimental space.

**Table 1.** Rooms and hiding locations used in Expts 1 and 2

| Playroom | Kitchen | Living room | Bedroom |
|---|---|---|---|
| By the sewing machine | By the stove | By the TV | By the dresser |
| On the pool table | On the refrigerator | On the coffee table | On the bookcase |
| In the rocking horse | In the cupboard | In the chair | In the laundry basket |
| Under the piano | Under the table | Under the couch | Under the bed |

(e.g. 'Hide the bananas right here under the couch'). Verbal descriptions were given to control for encoding of object names and locations.

After hiding the objects the first time, children were asked to turn around so that they faced away from the dollhouse. The experimenter then removed the objects from the dollhouse. After children turned to face the dollhouse again, the experimenter handed them the objects in a different random order and asked them to put the objects back exactly where they were before. A placement was considered correct if the child maintained the correct spatial relation between the object and landmark. For example, the object could be placed anywhere under the couch as long as it remained under the couch. If children placed an object incorrectly or could not remember where to place an object, the experimenter showed them the correct location. The experimenter also recorded which objects children placed correctly. This procedure was repeated until children reached the criterion of correctly replacing all 16 objects in a single trial. The purpose of this training procedure was to increase the likelihood that children of all ages had sufficient knowledge of the hiding locations. As it turned out, all three age groups exhibited excellent memory for the locations. The mean number of trials to reach criterion was 2.0, 2.1 and 1.9 for 6-year-olds, 8-year-olds and 10-year-olds, respectively. An age (6 years vs. 8 years vs. 10 years) × task (tour plan vs. free recall) analysis of variance (ANOVA) confirmed that there were no significant differences among the three age groups ($F(2,60) = .44$, n.s.) or between the two conditions ($F(1,60) = .43$, n.s.).

After children completed the location training procedure, the experimenter placed an opaque cover over the entire dollhouse. Children in the free recall condition then were instructed to name as many of the hidden objects as they could remember. Children in the tour-plan condition were given the following instructions:

> OK, now Donatello doesn't know about the things that you put in his house. So let's pretend that you're going to be a tour guide and show him the things that you put in there. But first I want you to come up with a plan for your tour. You tell me which one you would show him first, and second, and so on, and I'll write them down as you say each one.

For both conditions, the experimenter recorded the order in which children recalled the items and ended the session when a 10-second pause elapsed during which no more items were recalled. Children then were thanked for their participation and taken back to their classroom.

### *Coding*

A spatial clustering score was computed for each participant's tour plan or free recall to assess the degree of spatial organization present. The clustering measure used was the *adjusted ratio of clustering* (ARC) score (Roenker, Thompson & Brown, 1971). This score represents the proportion of observed number of room repetitions relative to the total possible number of repetitions corrected for chance. A score of 1.00 represents perfect clustering and a score of 0.00 represents no above chance clustering. Because scores below zero essentially represent below chance clustering and hence are difficult to interpret, all negative scores were set to zero (DeMarie-Dreblow, 1991). ARC scores in this study ranged from 0.00 to 1.00. There were two ways in which children could receive high ARC scores. One was by clustering items by room and the other was by ordering items from left to right (or right to left).

Another approach to assessing spatial clustering is to perform a Monte Carlo simulation to determine whether individual children's clustering is significantly above chance. First, the number of objects from the same room that followed each other in a given participant's recall was counted. The total number of run lengths of two, three and four items was then determined. Second, a Monte Carlo simulation was carried out to determine the probability of obtaining a particular number of runs of two, three, and four items at random. Using only the items the participant recalled, the computer program simulated 1000 randomly ordered recall trials. Each simulated trial was done without replacement of items. A participant's performance was classified as spatially organized if the number of runs of two, three, or four items was above that expected by chance (alpha = .05).

## Results and discussion

### *Organization of recall*

The primary question of interest was whether children who planned a tour of the objects would exhibit more spatial clustering than would children who performed the free recall task. We predicted that 10-year-olds in the tour-plan condition would exhibit more spatial organization in their recall than would 10-year-olds in the free recall condition. The recall task was not expected to influence the degree of spatial organization in 6-year-olds' recall.

*Spatial clustering scores.* ARC scores were entered into an age (6 years vs. 8 years vs. 10 years) × task (tour plan vs. free recall) ANOVA. This analysis yielded a significant effect of task ($F(1,60) = 13.54, p < .001$) and a significant age × task interaction ($F(2,60) = 3.14$, $p = .05$). Simple effects tests revealed no significant difference between 6-year-olds' spatial ARC scores in the tour-plan ($M = 0.29$, SD = 0.34) and free recall conditions

(*M* = 0.24, SD = 0.30), *F*(1,22) = 0.13, n.s.). The difference between 8-year-olds' ARC scores in the tour-plan (*M* = 0.61, SD = 0.36) and free recall conditions (*M* = 0.31, SD = 0.29) approached conventional levels of significance (*F*(1,18) = 4.17, *p* = .06). Finally, as predicted, 10-year-olds in the tour-plan condition (*M* = 0.68, SD = 0.37) had significantly higher spatial clustering scores than did 10-year-olds in the free recall condition (*M* = 0.17, SD = 0.21, *F*(1,20) = 16.50, $p < .001$).

*Monte Carlo analysis.* A Monte Carlo simulation was used to determine which children exhibited a greater degree of spatial clustering than would be expected by chance. Chi-square analyses then were used to determine whether the number of children at each age who exhibited more clustering than expected by chance differed by condition. As seen in Table 2, the number of 6-year-olds who exhibited more clustering than expected by chance in the tour-planning and free recall conditions did not differ ($\chi^2(1,24) = 2.27$, n.s.). Likewise, the number of 8-year-olds who exhibited a significant degree of clustering in the tour-planning and free recall conditions did not differ ($\chi^2(1,20) = 1.98$, n.s.). In contrast, more 10-year-olds in the tour-plan condition than in the free recall condition exhibited more clustering than expected by chance ($\chi^2(1,22) = 8.82$, $p < .01$).

**Table 2.** Number(%) of participants exhibiting above chance spatial clustering in Expt 1

| Age (years) | Condition | |
|---|---|---|
| | Tour plan | Free recall |
| 6 | 4 (33) | 1 (8) |
| 8 | 5 (50) | 2 (20) |
| 10 | 8 (80) | 2 (17) |

Together, the ARC score and Monte Carlo analyses clearly show that 10-year-olds used a spatial clustering strategy in the tour-planning task. In particular, 80 per cent of the 10-year-olds exhibited more spatial clustering than expected by chance in their tour plans, and the group as a whole exhibited significantly more spatial clustering in their tour plans than in their free recall. Eight-year-olds' use of spatial clustering in the tour-planning task was less consistent. Although half of the 8-year-olds exhibited more spatial clustering than expected by chance in their tour plans, the group as a whole did not exhibit significantly more spatial clustering in their tour plans than in their free recall. As expected, 6-year-olds exhibited very little evidence of spatial clustering in the tour-planning task. The finding that 6-year-olds did not exhibit spatially organized tour plans is consistent with recent work showing that their directions for finding hidden objects also tend to lack spatial organization (Plumert *et al.*, 1994).

An alternative explanation for high spatial clustering scores in this situation is that children disregarded the room boundaries and mentioned the items in a left to right (or right to left) order. If so, one would expect that when children crossed room boundaries (e.g. mentioning an item in the playroom followed by an item in the kitchen), they would mention the two items closest to one another. For example, if the last item a child mentioned from the playroom was under the piano (which was next to the wall adjacent to the kitchen), then the first item the child mentioned from the kitchen should be on the refrigerator (which was next to the wall adjacent to the playroom). To address this possibility, we first asked five adults to look at the dollhouse and rank order the 16 locations starting from the far left side and working their way to the far right side. All of the raters came up with the same rank ordering of locations (see Table 3). We then used these rankings to determine whether children's recall followed this ordering. Of particular interest was whether the order in which children mentioned items differed when they crossed room boundaries from when they stayed within rooms. Children received two separate scores for the mean rank difference between consecutively mentioned items when they stayed within rooms and when they crossed room boundaries. Consider the hypothetical example shown in Table 3. By adding together the absolute differences between consecutively mentioned pairs of items *within rooms* and dividing by the total number of such pairs, this child would receive a mean within-room score of 1.67. Likewise, by adding together the absolute differences between consecutively mentioned pairs of items that *crossed room boundaries* and dividing by the total number of such pairs, this child would receive a mean between-room score of 3.67. Note that for the perfect left to right adult ordering, the mean within-room rank difference and the mean between-room rank difference is 1.0. Thus, if children disregarded the room boundaries, their between-room and within-room scores should not differ. Because the goal of this analysis was to test an alternative explanation for *high*

**Table 3.** Adult rank ordering of items and hypothetical child rank ordering of items

| Adult ranking | Hypothetical child ranking |
|---|---|
| (1) Sewing table | (3) Pool table |
| (2) Rocking horse | (4) Piano |
| (3) Pool table | (1) Sewing table |
| (4) Piano | (2) Rocking horse |
| . . . . . . . . . . . . . . . . | . . . . . . . . . . . . . . . . |
| (5) Refrigerator | (6) Cupboard |
| (6) Cupboard | (5) Refrigerator |
| (7) Table | (8) Stove |
| (8) Stove | (7) Table |
| . . . . . . . . . . . . . . . . | . . . . . . . . . . . . . . . . |
| (9) TV | (12) End table |
| (10) Couch | (9) TV |
| (11) Chair | (10) Couch |
| (12) End table | (11) Chair |
| (13) Bookshelf | (13) Bookshelf |
| . . . . . . . . . . . . . . . . | . . . . . . . . . . . . . . . . |
| (14) Basket | (15) Bed |
| (15) Bed | (14) Basket |
| (16) Dresser | (16) Dresser |

*Note.* Dotted lines represent room boundaries.

spatial clustering scores, only children with clustering scores of .70 or higher were used in the analysis. Children with low spatial clustering scores were not included because they always had higher between-room scores than within-room scores and therefore provided a poor test of the alternative hypothesis. The average spatial clustering score of the 11 children who met the criterion was .92 (range = .73 to 1.00). Within- and between-room scores were entered into a one-way repeated measures ANOVA. This analysis indicated that the rank difference for consecutively mentioned items was higher between rooms ($M = 4.01$) than within rooms ($M = 1.49$, $F(1,10) = 29.87$, $p < .001$). Thus, high spatial clustering scores were not the result of children disregarding room boundaries and ordering items from left to right (or right to left).

### *Number of objects recalled*

*Total number of objects recalled.* The total number of objects children recalled was entered into an age (3) × task (2) ANOVA. Although older children tended to recall more items than did younger children, this analysis revealed no significant effects. The mean number of objects the 6-, 8- and 10-year-olds recalled was 11.6, 12.0 and 12.8, respectively.

*Number of objects recalled from each room.* An analysis comparing the mean number of objects recalled from each room was also carried out to determine whether children recalled more objects from the end rooms than from the middle rooms. The number of objects recalled from each room was entered into an age (6 years vs. 8 years vs. 10 years) × condition (tour plan vs. free recall) × room (bedroom vs. living room vs. kitchen vs. playroom) repeated measures ANOVA with the first two factors as between-subjects factors and the third as a within-subjects factor. This analysis yielded a main effect of room ($F(3,180) = 7.13$, $p < .001$). Follow-up tests using Tukey's HSD (Honestly Significant Difference) indicated that children recalled more items from the playroom ($M = 3.36$) than the living room ($M = 2.67$) and kitchen ($M = 2.96$), and more items from the bedroom ($M = 3.15$) than the living room ($M = 2.67$). Thus, children recalled more items from the end rooms than from the middle rooms. Quite likely, this reflects the fact that the end rooms were more distinct, and hence easier to remember, than the middle rooms.

### *Relations between organization and recall*

Correlations were conducted between ARC scores and the number of items recalled by children in each condition to examine whether children benefitted from using a spatial clustering strategy. The correlation between ARC scores and the number of items recalled was significant for children in the free recall condition ($r = .45$ and $p < .01$), but not for children in the tour-plan condition ($r = .27$, n.s.). The fact that only children in the free recall condition benefitted from using a spatial clustering strategy was unexpected. An inspection of the children in the tour-plan condition, however, revealed that three children who had very high clustering scores skipped one of the rooms. When these children were removed from the analysis, the correlation between ARC scores and number recalled reached significance ($r = .36$, $p = .05$).

We also examined whether individual differences in clustering were related to recall within each age group and experimental condition. The correlations between ARC scores and number recalled for 6-, 8- and 10-year-olds in the tour-plan condition were .29, .61 and −.04, respectively. The correlations between ARC scores and number recalled for 6-, 8- and 10-year-olds in the free recall condition were .44, .51 and .49, respectively. Thus, with the exception of 10-year-olds in the tour-plan condition, the correlations between clustering and recall were moderately high. Given the small sample sizes, however, only the correlation for 8-year-olds in the tour-plan condition reached significance ($p = .06$).

## EXPERIMENT 2

The results of Expt 1 indicate that the task of planning a tour is effective in eliciting spatial clustering from older, but not from younger children. Given the results of previous research (Marzolf & DeLoache, 1994; Plumert *et al.*, 1994), one would expect that experience with using spatial clustering in a more supportive task such as planning a tour would facilitate older children's ability to transfer their spatial clustering skills to a less supportive task such as free recall. A second experiment was carried out to test this hypothesis. Eight- and 10-year-olds again hid 16 objects in the dollhouse and then either planned a tour or performed a free recall of the objects. Immediately afterward, all children performed a free recall of the objects. We expected that 10-year-olds who planned a tour of the objects first would show high levels of spatial clustering in both their initial tours and in their subsequent free recall, but that 10-year-olds who performed the free recall task first would exhibit low levels of spatial clustering in both their initial and subsequent free recall of the objects.

### Method

#### *Participants*

Twenty-four 8-year-olds and 24 10-year-olds from predominantly middle- to upper-middle-class Caucasian families participated. The mean age of the 8-year-olds was 8 years and 1 month (range = 7 years and 5 months to 8 years and 7 months) and the mean age of the 10-year-olds was 10 years and 1 month (range = 9 years and 7 months to 11 years and 1 month). There were equal numbers of 8- and 10-year-olds in each condition. There were 8 males and 16 females in the 8-year-old group and 10 males and 14 females in the 10-year-old group.

#### *Apparatus and materials*

All materials were the same as in Expt 1 except that a doll crib was substituted for the rocking horse in the playroom.

#### *Design and procedure*

Children were tested individually in the laboratory or in a quiet room at their school. After familiarization with the dollhouse, children learned the locations of the objects. The mean number of trials to reach the learning criterion of one errorless replacement of all 16 objects was 2.04 and 1.71 for 8-year-olds and 10-year-olds, respectively. An age (8 years vs. 10 years) × condition (tour first vs. free recall first) ANOVA confirmed that there was no significant difference between the two age groups ($F(1,44) = 2.69$, n.s.) or the two conditions ($F(1,44) = 0.17$, n.s.).

After learning the object locations, children performed two tasks. Children in the *tour first* group planned a tour of the objects for a small action figure and children in the *recall first* group performed a free recall of the objects. The instructions for tour-planning and free recall tasks were identical to those used in Expt 1. Immediately after children performed the first task, both groups were asked to perform a free recall of the objects.

### *Coding*

A spatial ARC score was computed for each participant's first task and second task (Roenker *et al.*, 1971). Again, all negative scores were set to zero and ARC scores in this study ranged from 0.00 to 1.00. Using the same procedures as in Expt 1, a Monte Carlo simulation also was carried out to determine whether individual children's clustering scores were significantly above chance.

## Results and discussion

### *Organization of recall*

The primary question of interest was whether giving 8- and 10-year-olds experience with performing the tour-planning task would affect their use of spatial clustering in their subsequent free recall of those same objects. On the basis of the results of Expt 1, we predicted that 10-year-olds who performed the tour-planning task first would exhibit higher levels of spatial clustering in their subsequent free recall than would 10-year-olds who performed the free recall task first.

Two sets of planned comparisons were carried out to test these predictions. The first analyses compared the amount of spatial clustering 8- and 10-year-olds exhibited in their initial tour plans and free recall. There was no significant difference between the amount of spatial clustering 8-year-olds exhibited in their initial tour plans ($M = 0.36$, SD = 0.36) and free recall ($M = 0.25$, SD = 0.20, $F(1,22) = .88$, n.s.). As in Expt 1, 10-year-olds exhibited significantly more spatial clustering in their initial tour plans ($M = 0.59$, SD = 0.35) than in their initial free recall ($M = 0.28$, SD = 0.35, $F(1,22) = 4.79, p < .05$). The second analyses compared the amount of spatial clustering 8- and 10-year-olds exhibited in their subsequent free recall. There was no significant difference between the amount of spatial clustering that 8-year-olds in the tour first ($M = 0.32$, SD = 0.30) and free recall first ($M = 0.17$, SD = 0.21) conditions exhibited in their subsequent free recall ($F(1,22) = 2.12$, n.s.). Ten-year-olds in the tour first condition ($M = 0.78$, SD = 0.29), however, exhibited significantly more spatial clustering in their subsequent free recall than did 10-year-olds in the free recall first condition ($M = .39$, SD = .24, $F(1,22) = 13.34, p < .01$).

*Monte Carlo analysis.* Unlike the ARC score analyses, there were more 8-year-olds in the tour first condition than in the free recall first condition who exhibited a significant degree of spatial clustering in the first task ($\chi^2(1,24) = 4.44, p < .05$, see Table 4). However, the number of 8-year-olds in the tour first and free recall first conditions who exhibited a significant degree of spatial clustering in the second task did not differ ($\chi^2(1,24) = 1.20$, n.s.). These results, along with those from Expt 1, indicate that 8-year-olds are in a period of transition, with a few children engaging in high levels of spatial

**Table 4.** Number(%) of participants exhibiting above chance spatial clustering in Expt 2

| | Task and condition | | | |
|---|---|---|---|---|
| | Task 1 | | Task 2 | |
| Age (years) | Tour plan first | Free recall first | Tour plan first | Free recall first |
| 8 | 7 (58) | 2 (17) | 3 (25) | 1 (8) |
| 10 | 9 (75) | 4 (33) | 11 (92) | 5 42) |

clustering in the tour-planning task. However, across the two experiments, 8-year-olds as a group exhibited no clear evidence of spatial clustering. In contrast, consistent with the ARC score analyses, there were more 10-year-olds who exhibited a significant degree of spatial clustering in the tour-plan condition than in the free recall condition in both the first task ($\chi^2(1,24) = 4.20, p = .056$) and the second task ($\chi^2(1,24) = 6.75, p < .05$).

As in the previous experiment, we also checked whether children who had high spatial clustering scores disregarded the room boundaries and mentioned the items in a left-to-right or right-to-left order. Children received two scores for the mean difference between consecutively mentioned items when they stayed within rooms and when they crossed room boundaries. Again, only children with clustering scores of .70 or higher were used in the analyses. The average spatial clustering score of the 10 children who met this criterion for the first task was .92 (range = .76 to 1.00), and the average spatial clustering score of the 11 children who met this criterion for the second task was .88 (range = .73 to 1.00). As in Expt 1, the rank difference for consecutively mentioned items was higher between rooms ($M = 4.11$) than within rooms ($M = 1.47$) in the first task ($F(1,9) = 58.74, p < .001$). The rank difference for consecutively mentioned items also was higher between rooms ($M = 4.72$) than within rooms ($M = 1.46$) in the second task ($F(1,10) = 155.61, p < .001$). These results confirm that high spatial clustering scores were not the result of children ignoring the room boundaries and ordering items from left to right (or right to left).

The fact that 10-year-olds who planned a tour of the objects first had high levels of spatial clustering in both their initial tour plan and their subsequent free recall suggests that they were transferring a spatial clustering strategy from the tour-planning task to the free recall task. A less interesting explanation of the pattern of results is that all the children used a simple rule of applying the same strategy to both tasks. To determine whether the 10-year-olds in the tour first condition were doing something different than the children in the other groups, we assessed the degree of correspondence between the order in which they mentioned the objects in the two tasks. Almost by necessity, one would expect a high degree of correspondence in the order in which 10-year-olds in the tour first condition mentioned the objects across the two tasks. However, if this correspondence reflected only a general tendency to use the same strategy in both tasks, then 10-year-olds in the recall first condition should also exhibit a high degree of correspondence between their first and second recall, as should the 8-year-olds in the tour first and recall first conditions.

We assessed the degree of correspondence between the two tasks by calculating Spearman rank order correlations on the order in which children mentioned the objects in the first and the second task. For each child, we first identified the objects that he or she recalled in common across the two tasks and then computed the correlation on the order in which the common items were mentioned. The mean number of common items 8-year-olds and 10-year-olds mentioned in the two tasks was 10.08 and 12.79, respectively.

Seven of the 12 10-year-olds in the tour first condition had rank order correlations that were significantly above chance. However, only one 8-year-old in the tour first condition and one 10-year-old in the recall first condition had rank order correlations that were significantly above chance. The mean absolute rank order correlation between the first and second task was .33 for 8-year-olds in the tour first condition, .26 for 8-year-olds in the recall first condition, .57 for 10-year-olds in the tour first condition, and .28 for 10-year-olds in the recall first condition. Thus, only the 10-year-olds in the tour plan first condition ordered the items similarly in the two tasks. This pattern of correlations suggests that the high degree of spatial organization in the free recall of 10-year-olds in the tour first condition was not simply a reflection of a tendency to do the same thing on both tasks. Rather, it seems that the experience of planning a tour drew their attention to the spatial connections among the objects and once sensitized to these spatial connections, they were able to transfer the spatial clustering strategy to the less supportive free recall task.

### *Number of objects recalled*

*Total number of objects recalled.* The total number of objects children recalled was entered into an age (2) × condition (2) × task (2) repeated measures ANOVA with the first two factors as between-subjects variables and the third as a within-subjects variable. This analysis yielded a significant effect of age ($F(1,44) = 12.76, p < .001$), indicating that 10-year-olds ($M = 13.7$) recalled more objects than did 8-year-olds ($M = 12.0$).

*Number of objects recalled from each room.* Two analyses comparing the mean number of objects recalled from each room was also carried out to determine whether the positional distinctiveness of rooms influenced children's recall. In the first analysis, the number of objects recalled from each room in the first task was entered into an age (2) × condition (2) × room (4) repeated measures ANOVA. This analysis yielded a main effect of age ($F(1,44) = 6.77, p < .05$), indicating that 10-year-olds ($M = 3.44$) recalled more objects per room than did 8-year-olds ($M = 3.08$). More importantly, there was also a significant effect of room ($F(3,132) = 8.31, p < .0001$). Follow-up tests using Tukey's HSD revealed that children recalled more items from the playroom ($M = 3.60$) than the living room ($M = 2.81$) and kitchen ($M = 3.15$), and more items from the bedroom ($M = 3.48$) than the living room ($M = 2.81$). Thus, children found it easier to recall items from the end rooms than the middle rooms.

In the second analysis, the number of objects recalled from each room in the second task was entered into an age (2) × condition (2) × room (4) repeated measures ANOVA with the first two factors as between-subjects factors and the third as a within-subjects factor. This analysis also yielded a main effect of age ($F(1,44) = 14.86, p < .001$), indicating that 10-year-olds ($M$ = 3.43) recalled more objects per room than did 8-year-olds ($M$ = 2.94). More importantly, there was again a significant effect of room ($F(3,132) = 5.83$, $p < .001$). Follow-up tests using Tukey's HSD revealed that children recalled more items from the playroom ($M$ = 3.50) and the bedroom ($M$ = 3.31) than from the living room ($M$ = 2.83). Thus, children again found it easier to recall items from the end rooms than the middle rooms.

### *Relations between organization and recall*

Correlations were conducted between ARC scores and the number of objects recalled by children in each condition to examine whether clustering was related to recall. The correlation between clustering and recall in the task performed first was significant for children who performed the tour-planning task ($r = .66$, $p < .001$), but not for children who performed the free recall task ($r = .26$, n.s.). In contrast, the correlation between clustering scores and number recalled in the task performed second was significant for children both in the tour first condition ($r = .77$, $p < .001$) and in the free recall first condition ($r = .52$, $p < .01$).

We also examined whether individual differences in clustering were related to recall within each age group and experimental condition. The correlation between clustering and recall in the task performed first was significant for 8-year-olds who performed the tour-plan task ($r = .59$, $p < .05$), but not for 8-year-olds who performed the free recall task ($r = .46$). Likewise, the correlation between clustering and recall was significant for 10-year-olds who performed the tour planning task ($r = .68$, $p < .05$), but not for 10-year-olds who performed the free recall task ($r = .18$). The correlation between clustering scores and number recalled in the free recall task performed second was significant for 8-year-olds in both the tour first condition ($r = .66, p < .05$) and in the free recall first condition ($r = .66$, $p < .05$). Again, the correlation between clustering and recall was significant for 10-year-olds in the tour first condition ($r = .57$, $p = .05$), but not for 10-year-olds in the free recall first condition ($r = .21$). These results show that within each age group and experimental condition, children who used more spatial clustering tended to recall more items.

## GENERAL DISCUSSION

The results of this investigation clearly show that the task context plays a major role in children's strategic behaviour. Across both experiments, there were developmental differences in children's ability to apply spatial clustering strategies to different tasks. Specifically, there was a gradual increase in children's use of spatial clustering in a tour-planning task between the ages of 6 and 10. At none of the ages tested, however, did children spontaneously use spatial clustering in a standard free recall task. In Expt 1, few 6-year-olds exhibited more spatial clustering than expected by chance in either their tour plans or in their free recall, and spatial clustering scores in the tour-plan and free recall tasks did not differ significantly. Eight-year-olds exhibited a more mixed pattern of responding, however. In both experiments, approximately half of the 8-year-olds exhibited above chance spatial clustering in their tour plans, and very few 8-year-olds exhibited above chance spatial clustering in their free recall. Nonetheless, their spatial clustering scores in the tour-plan and free recall tasks did not differ significantly. In contrast, a large percentage of 10-year-olds in both experiments exhibited more spatial clustering than expected by chance in their tour plans, and a small percentage of 10-year-olds exhibited above chance clustering in their initial free recall. Likewise, 10-year-olds in both experiments who performed the tour-planning task exhibited significantly more spatial clustering than did their counterparts who performed the free recall task.

The results of Expt 2 also show that the older children can be induced to use spatial clustering in a free recall task if given experience with using spatial clustering in a tour-planning task first. Specifically, 10-year-olds who were given experience with the tour-planning task first exhibited much higher levels of spatial clustering in their subsequent free recall than did 10-year-olds who were given experience with the free recall task first. Eight-year-olds exhibited relatively low levels of spatial clustering in their subsequent free recall regardless of whether they performed the tour-planning or the free recall task first. Thus, after implementing a spatial clustering strategy in the more supportive tour-planning task, 10-year-olds transferred this strategy to the less supportive free recall task.

The analyses relating use of spatial clustering with the number of items recalled yielded somewhat mixed results. The correlations that were conducted across ages for each experimental condition indicated that children generally benefitted from using a spatial clustering strategy. However, when correlations were conducted separately for each age group and experimental condition, the relation between clustering and recall did not always reach statistical significance. This variability may simply reflect the small numbers of participants involved in these analyses or it may reflect children's difficulty with utilizing spatial clustering strategies. Recent work has shown that children's initial use of a strategy is often highly variable and ineffective (e.g. Coyle & Bjorklund, 1996; Miller, 1990; Siegler, 1995). As children become more proficient at using a strategy, they start using the strategy more consistently and start gaining more benefit from using the strategy. In the present investigation, a few of the children who had perfect spatial clustering scores also forgot one of the rooms, suggesting that utilization deficiencies played a role in some of the low correlations between clustering and recall. Quite likely, the simultaneous requirements of planning a route and remembering the objects interfered with children's ability to deploy a spatial clustering strategy effectively.

The results of these and other related studies (e.g. Marzolf & DeLoache, 1994; Plumert *et al.*, 1994; Woody-Ramsey & Miller, 1988) suggest that children use strategies in tasks that provide more supportive context before they are able to apply those same strategies to tasks that provide a less supportive context. Initially, children may only apply their spatial clustering skills to tasks that readily draw their attention to the spatial connections among the objects. As they grow older, however, they may become increasingly able to notice spatial connections among objects even when the task does not explicitly draw their attention to these spatial connections. The results of the present investigation showed that 10-year-olds used a spatial clustering strategy in their initial tours, but not in their initial free recall. When given experience with using spatial clustering to plan a tour of a set of objects, however, 10-year-olds showed high levels of spatial clustering in their subsequent free recall of those objects. These results suggest that experience with the more supportive tour-planning task cued 10-year-olds about the spatial connections among the objects. Once cued, 10-year-olds could apply a spatial clustering strategy to the less supportive free recall task.

Clearly, if younger children require more support and older children require less support to use their spatial clustering skills, then children's cognitive skills must be undergoing some kind of developmental change. What aspects of children's thinking that are relevant to using spatial clustering might be undergoing change between the ages of 6 and 10 years? First, it is important to point out that giving directions or planning a tour often involves taking a 'mental walk' (Gauvain & Rogoff, 1989; Linde & Labov, 1975). One benefit of using imagined movement to retrieve spatial information is that mentally 'seeing' one location may serve as a cue about locations of nearby objects. If younger children have difficulty with representing imagined movement, then one would also expect that the task of planning a tour would not readily draw their attention to the spatial connections among the objects. There is some evidence to support the claim that younger children have difficulty with representing imagined movement. For example, Gauvain & Rogoff (1989) found that not until 9 years of age did children's descriptions of spatial layouts contain characteristics of a mental tour. Studies of developmental changes in children's use of elaboration also have shown that older elementary school children tend to generate dynamic images to help them remember information, but younger elementary school children tend to general static images (Reese, 1977).

A second aspect of children's thinking that may be undergoing developmental change between the ages of 6 and 10 is their meta-cognitive knowledge. In particular, older children may have specific meta-cognitive knowledge about organizing tours. Although tours can be organized in many ways, they often involve taking the viewer from each location to the next closest location. Older children are more likely than younger children to have had experience with tours and hence may have a better understanding of the goals of our planning. Other research has shown that children are more likely to deploy strategies in tasks that contain a goal that is meaningful and familiar to them (Gauvain & Rogoff, 1986; Isotomina, 1975; Woody-Ramsey & Miller, 1988; for an exception see Weissberg & Paris, 1986). For example, Woody-Ramsey & Miller (1988) found that 4- and 5-year-olds were much more likely to use a selective attention strategy when the task was embedded in the context of a meaningful story. Further studies in which children's meta-cognitive knowledge is directly assessed may shed light on how meta-cognitive knowledge interacts with the characteristics of the task to produce developmental changes in how children apply their spatial clustering skills.

A third aspect of children's thinking that may be undergoing developmental change is their ability to encode spatial relations among locations. That is, older children may be better at noticing and encoding spatial relations among locations and therefore may not require the same degree of task support as do younger children. Numerous investigations of developmental changes in children's spatial knowledge have shown that older children's representation of location is more sophisticated than that of younger children (e.g. Acredolo, Pick & Olsen, 1975; Cohen, Weatherford, Lomenick & Koeller, 1979; Hardwick, MacIntyre & Pick, 1976). In the present investigation, we attempted to control for age differences in the knowledge base by bringing all age groups to the same criterion of learning the object locations during encoding. However, it is possible that the older children were better able than younger children to encode both the individual object locations and the spatial relations among objects within rooms. If so, the fact that

10-year-olds used a spatial clustering strategy in some tasks but not in others even though the objects and locations remained the same across tasks suggests that the task may interact with the organization of the knowledge base to determine children's ability to access their spatial knowledge in a systematic manner.

The finding that children recalled more items from the end rooms than from the middle rooms suggests that the structure of the physical space also plays an important role in children's recall. Presumably, the end rooms were more memorable because they were more physically distinctive than the middle rooms. In addition, children may have remembered end rooms better because they were easier to code egocentrically (i.e. 'to my left and to my right'). Other studies also have shown that 5- to 7-year-old children are more likely to remember the end positions than the middle positions of a spatial array (Siegel, Allik & Herman, 1976). At this point, however, it is unclear how the distinctiveness of the spatial regions affects the organization of children's recall. In particular, are younger children more likely to use a spatial clustering strategy when spatial regions are highly distinct? Further research is needed to understand whether children also become less reliant on aspects of the physical context as their spatial clustering skills develop.

From a general standpoint, the results of the present investigation emphasize both continuity and discontinuity in the development of children's strategic behaviour. Clearly, spatial clustering is a skill that even young children are capable of using, but one that undergoes considerable refinement with development. A major part of this development is changes in children's ability to apply their spatial clustering skills to a wider range of situations. As Folds *et al.* (1990) recently have pointed out,

> Demonstrations of context specificity could be viewed as production deficiencies and perhaps dismissed as frequent examples of this ubiquitous (and presumably uninteresting) concept. However, to do so would be to ignore important information concerning the development of children's skills. Rather than being bored or distressed by young children's differing performance across settings, we suggest that this variability offers unique opportunities for charting the course of mnemonic growth and for learning about the factors that may be of critical developmental importance. In particular, we argue that children's memory skills should be discussed in terms of a profile of performance in contrasting contexts, and that developmental changes in memory abilities should be measured in terms of variations in the profile across age (p. 85).

The present investigation represents a step forward in charting such developmental changes in children's ability to apply their spatial clustering skills to different tasks, and in understanding how children's experiences with using their spatial clustering skills in one task context affects their ability to use those same skills in another task context.

## Acknowledgements

This research was supported in part by a seed grant from the College of Liberal Arts at the University of Iowa. The authors wish to thank Damien Ihrig, Jennifer Kreps, Kim Steward, Susan Totten and Azure Welborn for their assistance in coding and data collection, and Lisa Oakes for her helpful comments on the manuscript. The authors also would like to express appreciation to Regina Elementary School in Iowa City, IA.

## References

Acredolo, L. P., Pick, H. L. Jr. & Olson, M. G. (1975). Environmental differentiation and familiarity as determinants of children's memory for spatial location. *Developmental Psychology*, **11**, 495–501.

Best, D. L. & Ornstein P. A. (1986). Children's generation and communication of mnemonic organizational strategies. *Developmental Psychology*, **22**, 845–853.

Bjorklund, D. F. (1987). How age changes in knowledge base contribute to the development of children's memory: An interpretive review. *Developmental Review*, **7**, 93–130.

Bower, G. H. (1970). Analysis of a mnemonic device. *American Scientist*, **58**, 496–510.

Brown, A. L. (1989). Analogical learning and transfer: What develops? In S. Vosniadou & A. Ortony (Eds), *Similarity and Analogical Reasoning*. Cambridge: Cambridge University Press.

Chi, M. T. H. (1985). Interactive roles of knowledge and strategies in the development of organized sorting and recall. In S. Chipman, J. Segal & R. Glaser (Eds), *Thinking and Learning Skills: Current Research and Open Questions*, vol. 2, pp. 457–485. Hillsdale, NJ: Erlbaum.

Cohen, R., Weatherford, K. L., Lomenick, T. & Koeller, K. (1979). Development of spatial representations: Role of task demands and familiarity with the environment. *Child Development*, **50**, 1257–1260.

Cornell, E. H. & Heth, C. D. (1986). The spatial organization of hiding and recovery of objects by children. *Child Development*, **57**, 603–615.

Coyle, T. R. & Bjorklund, D. F. (1996). The development of strategic memory: A modified microgenetic assessment of utilization deficiencies. *Cognitive Development*, **11**, 295–314.

DeMarie-Dreblow, D. (1991). Relation between knowledge and memory: A reminder that correlation does not always imply causality. *Child Development*, **62**, 484–498.

Folds, T. H., Footo, M. M., Guttentag, R. E. & Ornstein, P. A. (1990). When children mean to remember: Issues of context specificity, strategy effectiveness, and intentionality in the development of memory. In D. F. Bjorklund (Ed.), *Children's Strategies: Contemporary Views of Cognitive Development*. Hillsdale, NJ: Erlbaum.

Gauvain, M. (1993). The development of spatial thinking in everyday activity. *Developmental Review*, **13**, 92–121.

Gauvain, M. & Rogoff, B. (1986). Influence of the goal on children's exploration and memory of large-scale space. *Developmental Psychology*, **22**, 72–77.

Gauvain, M. & Rogoff, B. (1989). Ways of speaking about space: The development of children's skill in communicating spatial knowledge. *Cognitive Development*, **4**, 295–307.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds), *Similarity and Analogical Reasoning*. Cambridge: Cambridge University Press.

Guttentag, R. E. (1984). The mental effort requirement of cumulative rehearsal: A developmental study. *Journal of Experimental Child Psychology*, **37**, 92–106.

Hardwick, D. A., McIntyre, C. W. & Pick, H. L., Jr. (1976). The content and manipulation of cognitive maps in children and adults. *Monographs of the Society for Research in Child Development*, **41** (3, Serial No. 166).

Isotomina, Z. M. (1977). The development of voluntary memory in preschool-age children. In M. Cole (Ed.), *Soviet Developmental Psychology*, pp. 5–64. White Plains, NY: Sharpe.

Linde, C. & Labov, W. (1975). Spatial networks as a site for the study of language and thought. *Language*, **51**, 924–939.

McNamara, T. P. (1986). Mental representations of spatial relations. *Cognitive Psychology*, **18**, 87–121.

Marzolf, D. P. & DeLoache, J. S. (1994). Transfer in young children's understanding of spatial representations. *Child Development*, **65**, 1–15.

Miller, P. H. (1990). The development of strategies of selective attention. In D. F. Bjorklund (Ed.), *Children's Strategies: Contemporary Views of Cognitive Development*. Hillsdale, NJ: Erlbaum.

Miller, P. H., Woody-Ramsey, J. & Aloise, P. A. (1991). The role of strategy effortfulness in strategy effectiveness. *Developmental Psychology*, **27**, 738–745.

Morrow, D. G., Greenspan, S. L. & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language*, **26**, 165–187.

Plumert, J. M. (1994). Flexibility in children's use of spatial and categorical organizational strategies in recall. *Developmental Psychology*, **30**, 738–747.

Plumert, J. M., Pick, H. L. Jr., Marks, R. A., Kintsch, A. S. & Wegesin, D. (1994). Locating objects and communicating about locations: Organizational differences in children's searching and direction-giving. *Developmental Psychology*, **30**, 443–453.

Reese, H. W. (1977). Imagery and associative memory. In R. V. Kail & J. W. Hagen (Eds), *Perspectives on the Development of Memory and Cognition*. Hillsdale, NJ: Erlbaum.

Roenker, D. L., Thompson, C. P. & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin*, **76**, 45–48.

Rogoff, B. (1990). *Apprenticeship in Thinking*. New York: Oxford University Press.

Schneider, W. (1986). The role of conceptual knowledge and metamemory in the development of organizational processes in memory. *Journal of Experimental Child Psychology*, **42**, 318–336.

Schneider, W. & Pressley, M. (1989). *Memory Development Between 2 and 20*. New York: Springer-Verlag.

Siegel, A. W., Allik, J. P. & Herman, J. F. (1976). The primacy effect in young children: Verbal fact or spatial artifact? *Child Development*, **47**, 242–247.

Siegler, R. S. (1995). How does change occur: A microgenetic study of number conservation. *Cognitive Psychology*, **28**, 225–273.

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Weissberg, J. A. & Paris, S. G. (1986). Young children's remembering in different contexts: A reinterpretation of Isotomina's study. *Child Development*, **57**, 1123–1129.

Wellman, H. M., Somerville, S. C., Revelle, G. L., Haake, R. J. & Sophian, C. (1984). The development of comprehensive search skills. *Child Development*, **55**, 427–481.

Woody-Ramsey, J. & Miller, P. H. (1988). The facilitation of selective attention in preschoolers. *Child Development*, **59**, 1497–1503.

Yates, F. A. (1966). *The Art of Memory*. Chicago: University of Chicago Press.

*Received 29 September 1994; revised version received 10 December 1996*