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The interaction of symmetry and verbal codability in children's reconstruction of spatial configurations

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Abstract. Although the physical organization of spatial information clearly influences how it is recognized, recalled, and mentally transformed, few studies have explored how different *levels* of organization interact. This study focused on 4- and 6-year-old children's memory for spatial configurations and examined the relative influence of two levels of organization: symmetry (vertical, horizontal, or none) and codability (verbal or nonverbal). We predicted that the influence of symmetry would be less pronounced among the older children for whom the patterns were more codable. The results partially supported this prediction: Older children's reconstructions were accurate regardless of pattern symmetry; younger children's reconstructions of vertically-symmetric patterns were more accurate than their reconstructions of horizontally-symmetric and asymmetric patterns. Taken together, the results revealed an interaction between age and symmetry on the accuracy of children's reconstructions, suggesting that younger children were more sensitive than older children to differences in pattern symmetry. Thus, different levels of organization may influence children's ability to recall spatial information and the relative influence of these levels may change during development.

Key words: codability, memory, spatial configuration, symmetry

Given the impossibility of processing all available sensory information, people must often search for organization in the environment. We define organization, in general, as any regular relationship within a pattern that adds structure by providing an additional reference frame or context for perceiving, encoding, or thinking about the individual pattern components. The purpose of this paper is to examine the relative influence of different *levels* of spatial organization on the development of spatial cognition.

Numerous studies of adult cognition have shown that multiple levels of organization can influence how easily information is perceived and remembered. These studies also suggest that when different levels of organization are available simultaneously they do not exert equal influence. Suzuki and Cavanaugh (1995), for example, showed that both local and emergent features can influence performance on a perceptual task. Using six-item search arrays in which a search item consisted of a triplet of arcs, they demonstrated that both low-level features (whether an individual arc pointed up or down) and high-level features (whether a triplet of arcs together formed a happy or sad facial expression) influenced the time required to find the odd item in an array. Furthermore, they found that while the presence of facial organization speeded performance on a normally difficult conjunctive search task (e.g., detecting a single happy face among five sad faces), facial organization *slowed* a feature search task which requires search for a low-level feature (e.g., detecting a single oddly positioned arc in the array). These findings suggest that when a high-level feature is available, perceptual processes may operate on it even when searching for a local feature would be more efficient. In other words, the presence of a high level of codability can subsume the influence of lower-level features in perception.

Similar evidence also indicates that different levels of organization influence how spatial information is remembered. Tversky and Schiano (1989) demonstrated that when subjects were presented with curves that were nearly symmetric, there was a robust perceptual bias to perceive and remember the curves as being more symmetric than they actually were. The introduction of a conceptual factor, however, attenuated this perceptual bias. Interestingly, one of the curves that was negatively skewed and presented on the vertical axis was spontaneously identified by many subjects as a "nose;" this was the only curve (of the eight used) that failed to elicit the expected perceptual bias toward symmetry. This result provides further evidence that the presence of a highly codable organizational scheme may subsume the influence of a lower level of organization such as symmetry.

In the present work, we also focused on symmetry because it is an important example of low-level spatial organization and has been studied extensively. For example, symmetry facilitates the perception, recognition, and recall of spatial patterns (Attneave 1955; Bornstein and Stiles-Davis 1984; Uttal 1994). Although considerable previous work has clearly established that very young children can detect the presence of pattern symmetry (Bornstein and Krinsky 1985; Fisher et al. 1981), symmetry influences learning from infancy through childhood. For example, Bornstein and Stiles-Davis (1984) found that preschoolers learn to reconstruct and discriminate vertically-symmetrical figures before horizontally- and obliquely-symmetrical figures. Uttal (1996) further demonstrated that symmetry facilitates not only the direct reconstruction of a spatial configuration but also the reconstruction of larger- and smaller-scaled versions of spatial configurations. The extension of the advantage to scaling is noteworthy because scaling requires that a mental transformation take place before reconstruction (Uttal 1994). When the additional demand of scaling is made on memory, pattern symmetry appears to constrain the placement of the toys within the larger or smaller scale of the new configuration. Thus, symmetry is a powerful level of organization that becomes available early in development and continues to influence children's memory for spatial locations during development.

In contrast to symmetry, higher-level types of organization become important later in development. These types of organization represent a level of pattern structure derived from the similarity of the pattern to a familiar concept outside the pattern itself. For example, encoding a group of stars as a constellation such as the Big Dipper provides a meaningful way of perceiving what might otherwise be a random array of stars. That is, children who note the similarity between a configuration of stars and the shape of a cup can benefit from this type of higher-level organization when they are asked to find that group of stars in the sky. Similarly, the triplets of curves used by Suzuki and Cavanaugh (1995) were found to be easier to perceive when they were facelike and, therefore, were easily coded as something meaningful.

Higher-level organization also influences children's ability to learn and remember spatial information (Mandler and Day 1975). Most recently, Uttal et al. (unpublished manuscript) showed that a highly codable arrangement of hiding locations facilitates children's search for a hidden object. Children learned the location of a sticker on a small map and were asked to find the sticker in its corresponding location on a large carpet. The 27 hiding locations were arranged in the shape of a dog, a fact that was highlighted for half of the children whose small map depicted lines connecting the hiding spots. The other half viewed a map that showed the same locations but without lines connecting the hiding spots. Children, therefore, could not easily see the pattern that the dots formed. Five-year-old (but not 4-year-old) children's performance was better when the dog was emphasized than when it was not. Thus, children were more successful at finding the sticker when the conceptual organization of the 27 locations was highlighted.

In the present study, we attempted to show that a meaningful pattern could facilitate performance on a reconstruction task as it does on a search task. We predicted that low and high levels of organization such as symmetry and codability would not exert equal influence on children's ability to reconstruct a spatial configuration. Although the symmetric properties of a pattern may be perceived *directly* by observing the relationship between its two halves, the codability of a pattern depends on perceiving the pattern to be similar to something outside the pattern itself. For example, children who are unfamiliar with the shape of a dipper may not recognize that the stars in the Big Dipper form a meaningful configuration. These children, however, should be sensitive to levels of organization inherent to the pattern such as its symmetrical properties. Our aim is to make these two levels of organization available simultaneously and to trace their relative influence for children of different ages.

We investigated the relative influence of low-level (symmetry) and high-level (conceptual codability) types of pattern organization by examining how they together affect children's reconstruction of spatial configurations. We composed a set of dot patterns that crossed three levels of symmetry (vertical, horizontal, and asymmetry) and two levels of codability (verbal and nonverbal). We asked children to remember and reconstruct these patterns at a larger scale.

We predicted that the relative influence of symmetry on children's reconstruction success would be moderated by their age. Because older children have had more exposure to letters in school than younger children, they should rely less on the symmetry properties when the patterns resemble letters and are verbally codable. On the other hand, because younger children are in the process of learning the alphabet, they might find both verbal and nonverbal patterns to be difficult to code. Consequently, we predicted that younger children's memory for both verbal and nonverbal patterns would be influenced more by symmetry. Thus, our predictions can be summarized as follows: Children who are less able to code the conceptual information depicted in the patterns will rely more heavily on features inherent to the pattern itself such as symmetry. Children who do perceive the patterns to be verbally codable, however, should be less influenced by the symmetry properties of the patterns.

Method

For the verbal patterns, we chose six capital letters of the Roman alphabet because letters are usually highly salient stimuli for school-age children. Of the six letters, two were vertically-symmetrical (A and Y), two were horizontally-symmetrical (E and K), and two were asymmetrical (F and Z).[1] We also constructed a set of letter-like stimuli that were perceptually-equivalent to these six letters but were nonverbal and less codable.

The nonverbal stimuli preserved the "critical features" (Gibson 1969) of the letter patterns. Critical features are common structural properties such as symmetry or the presence of diagonal lines that are either present or absent in different letters of the alphabet. The nonverbal stimuli were constructed by vertically or horizontally translating one or more of the critical features of the letter patterns.[2] For example, the letter A is vertically symmetrical and composed of two diagonal lines intersecting one horizontal line; its nonverbal counterpart was constructed by sliding the crossbar of the A up toward the

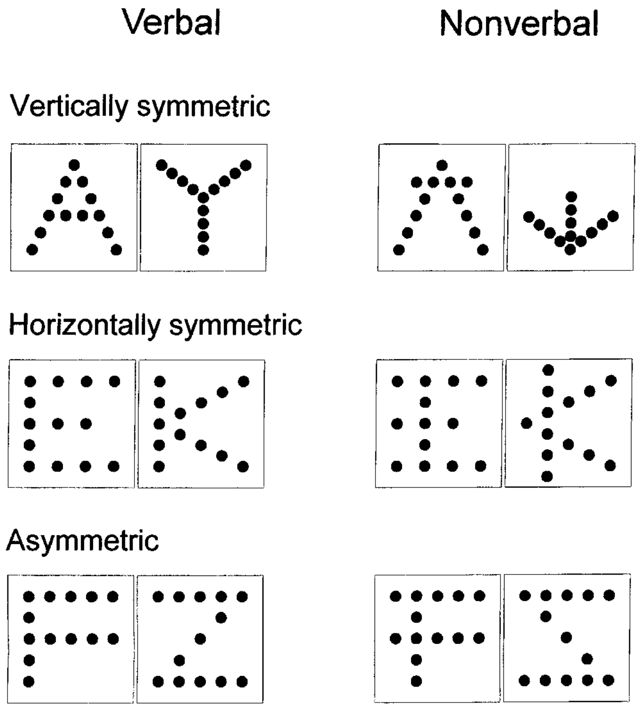

Figure 1. The twelve dot patterns used in the study grouped by symmetry and codability.

vertex. Similarly, the nonverbal counterpart to the K was constructed by sliding the vertical bar to the right, thus preserving the horizontal symmetry and the intersecting vertical and diagonal lines found in the letter.

Participants

Twenty-five 4-year-old children (12 boys and 13 girls, mean age = 54.3 months) and 24 6-year-old first-graders (12 boys and 13 girls, mean age = 77.8 months) were brought to the test site by their parents. These age groups were chosen to bracket the time period during which many children become familiar with letters. The children were recruited through direct mail, newspaper, and magazine advertising.

Materials

Test materials consisted of 10×10 cm white flash cards. Each flash card depicted one of the twelve patterns shown in Figure 1. White metal boards (30×30 cm) were used in the scaling-reconstruction task. The larger scale of the boards allowed children to manipulate and place the magnets easily during

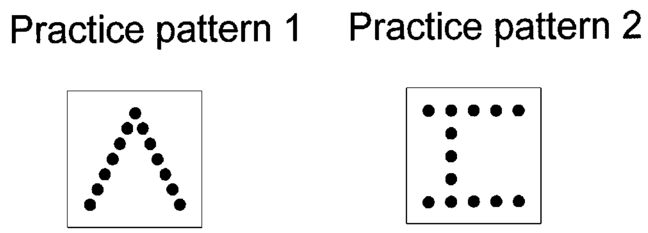

Figure 2. The practice patterns used in the study.

the reconstruction task. To create large versions of the dots depicted by the dot patterns, black dots (2.5 cm in diameter) were constructed by covering circular magnets with black felt.

Design and procedure

Children were tested individually. During each session, children were seated at a child-size table across from a female experimenter while their parents waited in an adjacent room.

Scaling and reconstruction. The experimenter displayed a turned-over flash card next to a blank magnetic board and pointed out the similarities between the card and the board. She said, “See, the small board is white and the big board is white too. The small board has four sides and the big board has four sides too.”

The experimenter then turned over the card to reveal the first of two practice patterns (Figure 2). The experimenter said, “See the small board has thirteen dots on it. This big board is the same as the small board, only it is bigger and it doesn’t have dots yet.” Children were presented with thirteen felt dots, which were placed next to the magnetic board on the table. The experimenter said, “Here are the dots for the big board. See how they look the same as the dots for the small board only they are bigger? What you do is place the big dots onto the big board so that they look like the dots on the small board.” Children were then instructed to reconstruct the pattern with the flash card present.

The experimenter then displayed the second practice card. She said, “Now I’m going to make it a little harder. Look at the small board until you think you can remember it. Then I’m going to take it away and you’re going to put the dots on the big board until it looks like the small board. That means you won’t be able to look back at the small board.” Children then reconstructed the second practice pattern. During practice trials, if children forgot the pattern, they were instructed to think back to the small pattern and try to picture it in their mind. If they were still unable to remember, they were allowed to look back at the pattern and reminded that they should study the pattern so that they would not forget it later.

Children received the verbal and nonverbal patterns in two randomized blocks, with order of blocks counterbalanced between subjects. The experimenter measured the amount of time each child spent studying each pattern until he or she placed it back on the table. Children then reconstructed the pattern by placing the magnets on the board. In cases where children failed to use all thirteen magnets, the experimenter encouraged them to place the remaining magnets. If they still refused, the magnets were set aside and not included in the reconstruction. The study-reconstruction process was repeated until children reconstructed all twelve dot patterns.

Identification test. After the reconstruction task, the experimenter brought out the flash cards again and asked, “Did you notice anything special about the dot patterns on the small boards?” Children were then shown the flash cards, one at a time, and were asked what they saw while the experimenter recorded their responses by hand.

Scoring and data reduction

Children’s reconstructions were translated onto paper by measuring the x-y coordinates of each magnet placed and entering these coordinates into a spreadsheet. Each reconstruction was then printed on a separate sheet of paper using computer-generated circles to represent the positions of magnets placed. The graphical representations were produced at the same scale as the flashcards (i.e., 10×10 cm) so that they would fit on standard typing paper. Examples of children’s reconstructions are shown with their corresponding target patterns in Figure 3.

Two independent sets of undergraduates (25 total) judged the accuracy of the reconstructions. The students were asked to rate the similarity between children’s reconstructions and the target patterns they studied. Each judge was randomly assigned to four subjects (two from each age group) such that each judge had a unique combination of four subjects. Each judge then rated all the reconstructions made by each of those four subjects (48 reconstructions total). Reconstructions were blocked by subject, with four- and six-year-old blocks occurring alternately. Order of age (four- vs. six-year-old first) was counterbalanced for the two sets of judges.

Judges were instructed to disregard any translations, transformations of size, and rotations. In cases in which a child failed to use all the dots provided (only 5% of all cases), judges based their ratings on the dots present. Judges rated the similarity of each reconstruction to its target on a scale of 1 to 7, where 1 corresponded to an *extremely poor* representation of that target

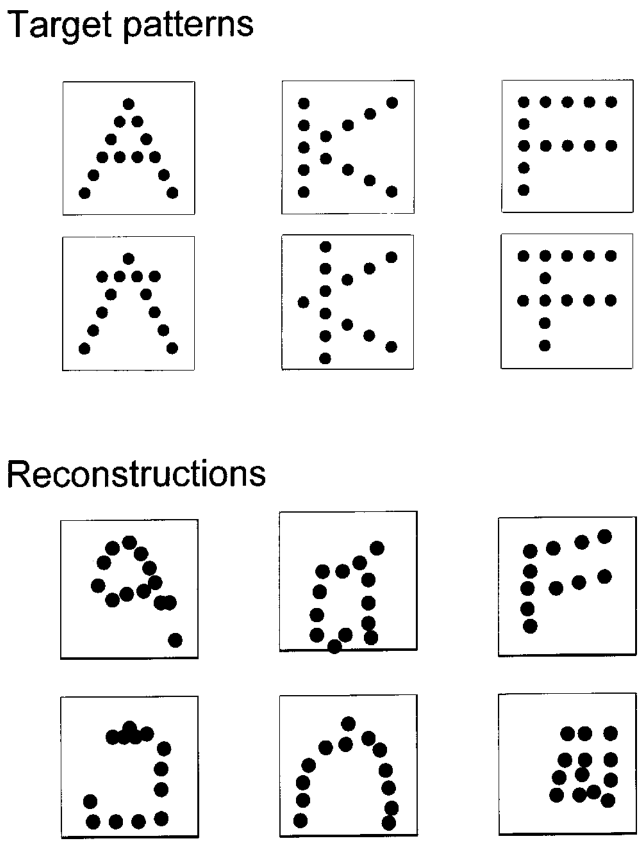

Figure 3. Examples of randomly selected reconstructions of the target patterns shown.

and 7 corresponded to a *perfect* reconstruction of all components of the target.

The ratings of the two sets of judges agreed moderately well (r = 0.68). The two sets of ratings were averaged to yield a single similarity rating for each reconstruction. Because we were interested in comparing the relative magnitude of scores across the two age groups, scores were standardized about a grand mean calculated from all of the scores. Standardizing the scores facilitates the comparison of judges' ratings across the two age groups by centering the scores about a single grand mean. All subsequent analyses of similarity-to-target ratings refer to these standardized scores. The standardized ratings were used to compute the average rating per symmetry group for verbal and nonverbal patterns. For example, the ratings for A and Y were averaged to yield a single rating for vertically-symmetric, verbal patterns.

Results

We predicted that age would be an important determinant of children's success in reconstructing the patterns. We expected that older children would perceive the letter patterns to be verbally codable and would be able to remember these patterns regardless of their symmetry properties. For the younger children, for whom the letter patterns were less codable, we predicted that the vertically-symmetric patterns would be easier to remember and reconstruct than the horizontally-symmetric and asymmetric patterns. Finally, we predicted that both groups of children would have more difficulty remembering the nonverbal patterns than the verbal patterns, although we expected that this difference would be more pronounced among the younger children.

Reconstruction ratings

The standardized ratings of children's reconstructions were entered into a 2 (Age) × 2 (Sex) × 2 (Order of verbal and nonverbal blocks) × 2 (Codability) × 3 (Symmetry) ANOVA, with symmetry as a repeated measure. An alpha level of 0.05 was used for all analyses.

As predicted, older children ($M = 0.53$, $SD = 0.82$) were significantly better at reconstructing the dot patterns than younger children ($M = -0.53$, $SD = 0.88$), $F(1,42) = 55.89$, $MSe = 1.44$, $p < 0.001$. In addition, all children were more successful at reconstructing verbal patterns than nonverbal patterns $F(1,42) = 65.75$, $MSe = 0.23$, $p < 0.001$. Reconstructions of verbal patterns ($M = 0.23$, $SD = 1.01$) received higher similarity-to-target ratings than nonverbal patterns ($M = -0.23$, $SD = 0.93$).[3]

More importantly, we found a significant Age × Symmetry interaction, indicating that the pattern of ratings across symmetry type differed for the two age groups, $F(2,84) = 4.01$, $MSe = 0.19$, $p < 0.05$. As shown in Figure 4, younger children received significantly higher similarity ratings for their reconstructions of vertically-symmetrical patterns than horizontally-symmetric or asymmetric patterns; older children, however, reconstructed the three pattern symmetries equally well, Tukey's HSD, *p*s < 0.05.

Our analysis of the reconstruction ratings supports our prediction that the relative influence of pattern symmetry on children's memory for spatial configurations changes during development. Although older children reconstructed patterns equally well regardless of symmetry type, younger children's reconstruction of vertically-symmetric patterns was superior to their reconstruction of the other two symmetry types. This result is consistent with other developmental studies that have found a clear advantage of vertical symmetry (e.g., Bornstein and Krinsky 1985). To determine whether these

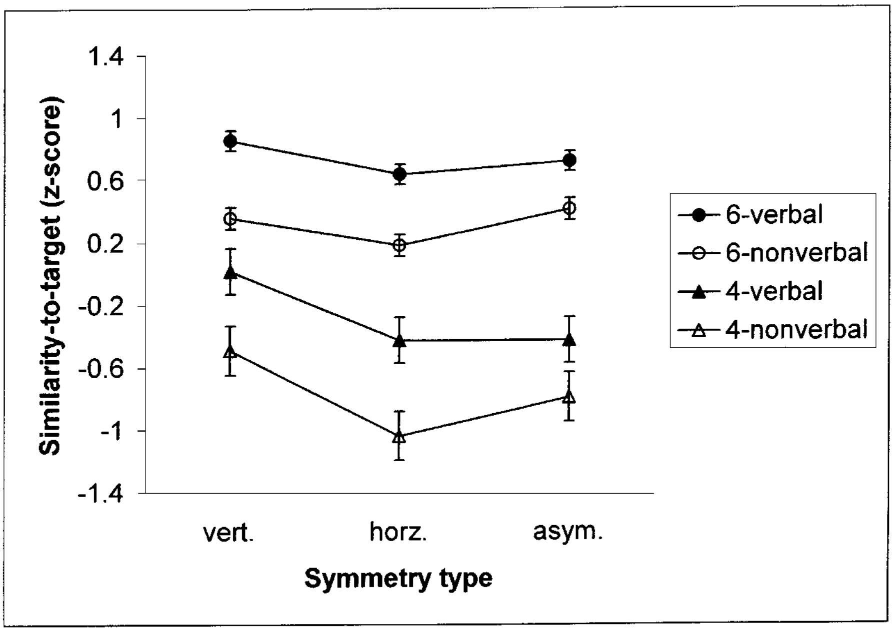

Figure 4. Rated similarity between children's reconstructions and the target patterns as a function of age, symmetry, and verbal codability.

differences in reconstruction quality could be attributed to differences in the time children spent looking at the patterns, we compared children's study times for different pattern types.

Study time

Study times longer than two standard deviations from the mean were trimmed from the data. This amounted to 5.7% of all observations. Overall, the length of time children spent studying the different patterns reflected the difficulty they had in reconstructing them. Children studied nonverbal patterns significantly longer than verbal patterns, $F(1,37) = 16.71$, $MSe = 24.88$, $p < 0.001$. Children spent an average of 10.20 sec ($SD = 6.82$) studying the nonverbal patterns and, on average, only 7.58 sec ($SD = 5.89$) studying the verbal patterns.

Like the reconstruction ratings, children's study times also varied as a function of symmetry and age. A significant Codability × Symmetry × Age interaction revealed that study times for verbal patterns did not vary across the three symmetry groups for either age group, $F(2,74) = 7.95$, $MSe = 8.49$, $p < 0.01$. However, for nonverbal patterns, older (but not younger)

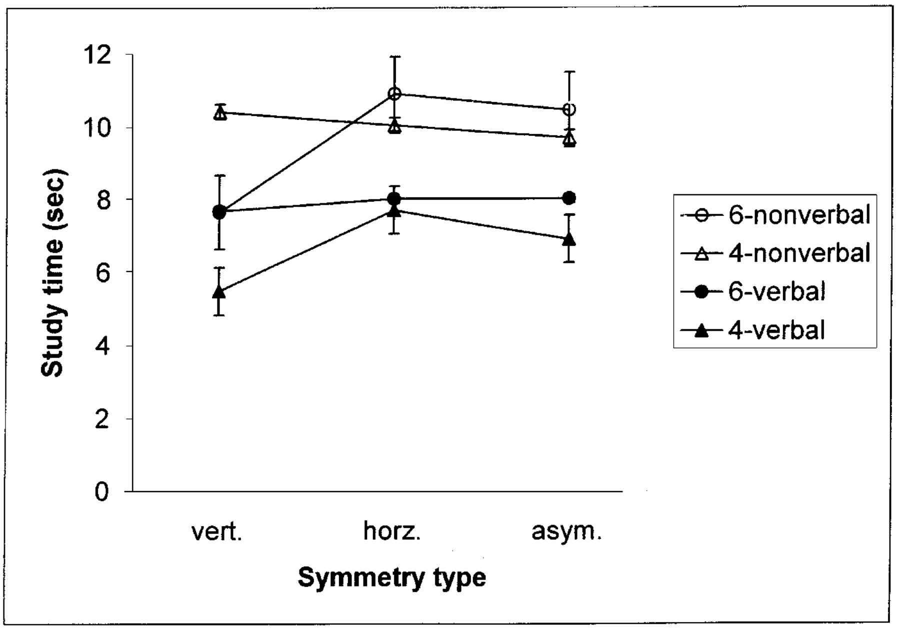

Figure 5. Self-imposed study time for the reconstruction task as a function of age, symmetry, and verbal codability.

children studied horizontally-symmetric and asymmetric patterns longer than vertically-symmetric patterns, Tukey's HSD, *p*s < 0.05. As shown in Figure 5, older children's study times for the nonverbal patterns increased as a function of increasing symmetry difficulty while younger children's study time of the nonverbal patterns did not vary with across the three types of symmetry, Tukey's HSD, n.s. Thus, although both older and younger children's study times reflected the difference between verbal and nonverbal patterns, only older children's study times reflected any differences in symmetry.

Taken together, our analyses of the reconstruction and study time measures revealed that both older and younger children studied the verbal patterns equally regardless of symmetry. This may suggest that both age groups recognized that some of the dot patterns could be construed as letters. However, only the older children were also able to use this information to help them reconstruct the patterns. Although older children reconstructed the three types of patterns equally well, younger children's reconstructions clearly were better when the patterns were vertically symmetric. To ascertain that the differences in reconstruction performance could be attributed to age-related differences in the codability of the letter patterns, we analyzed a direct measure of the level of children's experience with different letters of the alphabet.

Interview data. In the final interview, we assessed children's ability to identify correctly the different letters depicted by the dot patterns. Responses to the two pattern types were analyzed separately. For the verbal patterns, responses were counted as correct if children correctly identified the letters depicted. We predicted that older children, who would have more experience with letters, would correctly identify more of these patterns than younger children.

The results are consistent with our prediction. Older children were significantly more familiar with the letters of the alphabet than younger children, $F(1,46) = 16.98$, $MSe = 0.03$, $p < 0.001$. Older children ($M = 0.98$, $SD = 0.14$) correctly identified a higher proportion of the letter patterns than younger children ($M = 0.65$, $SD = 0.48$). As with the study time measure, however, neither older nor younger children's ability to identify the verbal patterns varied as a function of symmetry. This suggests that both age groups were equally acquainted with letters of the three symmetry types.

We performed a parallel analysis of children's responses to the nonverbal patterns. Children's responses to the nonverbal patterns were coded as "correct" if they identified the letter from which the pattern was derived. As with the verbal patterns, we found that older children ($M = 0.69$, $SD = 0.46$) correctly identified a higher proportion of the nonverbal patterns than the younger children $M = 0.34$, $SD = 0.48$, F(1,46) = 25.07, $MSe = 0.19$, $p < 0.001$. This suggests that the older children were better able to perceive the relation of the nonverbal patterns to letters of the alphabet.

For the nonverbal patterns, we also found a significant Age $\times$ Symmetry interaction, suggesting that children's success in identifying the nonverbal patterns was dependent on the symmetry properties of the patterns, $F(2,92) = 4.59$, $MSe = 0.06$, $p < 0.05$. The smallest proportion of correct pattern identifications occurred with vertically-symmetric patterns for both older and younger children (Figure 6).

A closer look at children's responses suggests a possible explanation for this result. For the cases in which children did not name the correct letter, we looked for popular alternative responses that might suggest whether children were using an alternative strategy for remembering these patterns. We found that children displayed an overwhelming tendency to label the nonverbal Y as an "arrow." When arrow was recoded as a correct response to the nonverbal Y, symmetry was no longer a significant factor and the pattern of results was the same as that obtained from the verbal patterns, with age being the only significant factor, $F(1,46) = 22.89$, $MSe = 0.23$, $p < 0.001$.

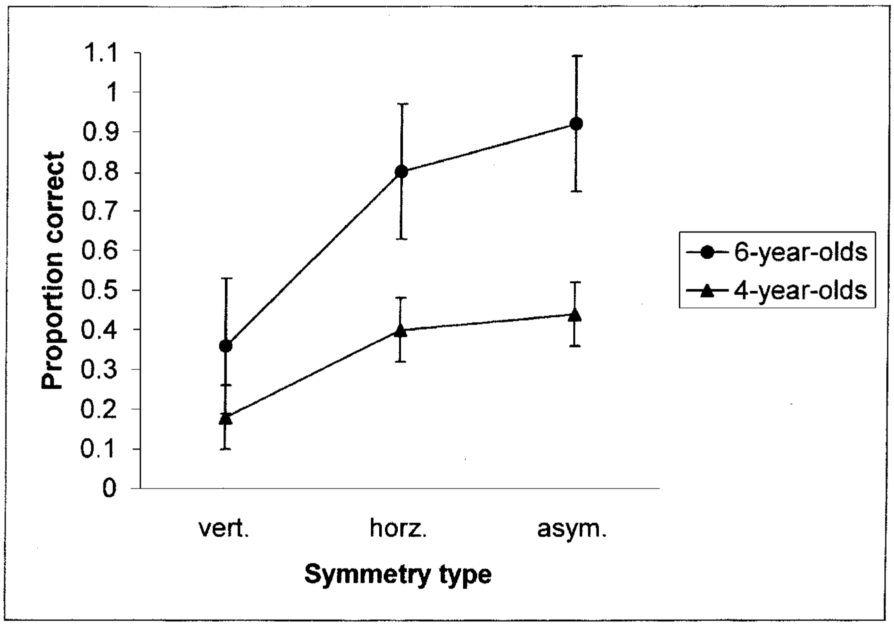

Figure 6. Proportion of correctly identified nonverbal patterns as a function of age and symmetry.

When responses to verbal and nonverbal patterns were analyzed together (with "arrow" counted as a correct response), we found only significant main effects of codability and age; the Age × Symmetry interaction was no longer significant. Not surprisingly, children correctly identified significantly more verbal patterns ($M = 0.82$, $SD = 0.39$) than nonverbal patterns, $M = 0.64$, $SD = 0.48$, $F(1,42) = 29.61$, $MSe = 0.08$, $p < 0.001$. In addition, older children ($M = 0.91$, $SD = 0.29$) identified significantly more patterns than younger children, $M = 0.55$, $SD = 0.50$, $F(1,42) = 22.50$, $MSe = 0.38$, $p < 0.001$. Thus, these results converge with the reconstruction findings suggesting that younger children, overall, found the patterns used in the study to be less codable than older children did. As with the reconstruction ratings, however, the Age × Codability interaction failed to reach significance, suggesting that the degree to which the verbal patterns were easier to identify than nonverbal patterns was the same for both older and younger children.

Discussion

The results of our three measures suggest that an age-related increase in children's knowledge of letters occurs with an age-related decrease in children's reliance on symmetry. Taken together, these findings support our prediction that different levels of organization may not exert equal influence on spatial memory during development. Although there was an overall age-related difference in performance on the reconstruction task and the letter identification task, verbal patterns were easier to remember than nonverbal patterns for both older and younger children. In other words, the higher-level organization that defined the verbal patterns appeared to provide a powerful organizing tool that was available to both age groups.

An alternatative account for this age-related difference in performance is that counting strategies, rather than familiarity per se, was responsible for older children's success on the reconstruction task. This account would suggest that the older children were more able to count the dots within the patterns and that this information improved the accuracy of their reconstructions. We argue that this is not the case because the judges were specifically instructed to rate the *overall* similarity of the reconstructions to the targets without regard to the specific number of dots used to compose the individual pattern elements. Thus, older children would not have gained any specific advantage by being able to count the dots that composed the patterns and younger children would not have been penalized for inaccuracies in how they distributed the dots among the pattern elements.

Among the younger children who, overall, were less familiar with the verbal and nonverbal patterns, it appeared that properties inherent to the pattern such as symmetry were important in determining children's reconstruction performance. Although recognizing the verbal codability of the letter patterns provided them with an advantage over nonverbal patterns that was statistically significant, the accuracy of their reconstructions, on average, was still influenced by the symmetry properties of the individual patterns.

The absence of a statistically significant three-way interaction does not necessarily rule out the existence of an interaction between codability and symmetry. First, there was clearly a difference in the extent to which symmetry influenced older and younger children's reconstructions. Although older children's reconstructions of nonverbal patterns did not vary with symmetry as predicted, older children had more difficulty with the nonverbal patterns than the verbal patterns and their reconstructions were still superior to those of younger children. Older children simply may have been so familiar with their letters that they were able to regard both the verbal and nonverbal patterns as codable. In other words, the older children were able to verbally code the nonverbal patterns such that there was no longer a difference in difficulty among the three symmetry types represented. The possibility that older children used verbal codes to remember the nonverbal patterns is supported by our data: Older children were more successful than younger children at identifying the letters from which the unfamiliar patterns were derived.

It is possible to argue that children who fail to identify a pattern correctly during the interview task would not be necessarily precluded from reconstructing the pattern successfully. For example, one could imagine a scenario in which a young child could draw a letter A without knowing its identity as a letter. We argue, however, that this hypothetical situation does not speak to our results for two reasons. First, being able to copy the letter is not the same as being able to reproduce it from memory. Although children might be capable of mechanically copying a letter pattern without knowing about its identity as a letter, it seems less likely that they would also be able to recall the pattern from memory. Second, our results do not support the idea that the younger children were reconstructing the patterns successfully without having knowledge of the letters themselves. Rather, our results suggest that younger children's inferior performance on the reconstruction task was paralleled by their inferior ability to identify letters and nonletters.

Several other findings also merit attention. First, although symmetry appeared to influence younger children's ability to *reconstruct* spatial patterns, differences in pattern symmetry did not influence how long they *studied* these patterns or their ability to *identify* these patterns. Although younger children identified a significantly lower proportion of the nonverbal patterns relative to the older children, their level of identification performance was similar across symmetry types. Furthermore, neither age group's study times of the familiar patterns varied as a function of symmetry. This may suggest that symmetry exerts its primary influence during retrieval, rather than at encoding, for school age children. This interpretation is consistent with Uttal's (1996) finding that symmetry improves performance in reconstruction by constraining the placement of objects in a configuration.

Second, although both age groups studied the verbal patterns equally, only the older children adjusted their study times of nonverbal patterns to reflect difference in difficulty due to pattern symmetry. This may suggest that the lack of difference among symmetry groups for the nonverbal patterns may be due, in part, to older, but not younger, children's ability to adjust their study times to reflect pattern difficulty. We suggest that this pattern of findings may be explained by age-related differences in children's understanding of how memory strategies should be adjusted to accommodate changes in task demands. Lovett and Flavell (1990) showed, for example, that third graders and adults were more likely than first graders to differentiate between effective and ineffective strategies that could be used for remembering a list of words.

Finally, our pattern of results suggests that our initial concept of what constitutes a higher level of organization may be too narrow. Older children were adept at identifying our nonverbal, letter-like patterns by name. We also found that most children spontaneously *imposed* an organizational label on the nonverbal pattern shaped like an arrow. This suggests to us that what makes a pattern meaningful may not be limited to its relation to a single concept. Older (and in some cases younger) children are able to relate unfamiliar patterns to patterns they have previously learned.

Our findings that older children were more adept at finding a higher level of organization in the nonverbal patterns are consistent with work in cognitive development that has demonstrated that children become increasingly sensitive to higher-order levels of organization. Gentner and Rattermann (1991) suggested that young children preferentially attend to shared object attributes when judging the similarity between two objects but as they grow older they undergo a relational shift in which they increasingly attend to the shared relations between the objects.

The relational shift is useful in explaining change in children's interpretations of spatial configurations. For example, when children are presented with a face constructed out of pieces of fruit and asked what they see, younger children will focus on the individual parts and report that they saw only fruit while older children were more likely to report seeing both the fruit and the face (Elkind et al. 1964; Whiteside et al. 1976). Consistent with the relational shift hypothesis, as children grow older, they are increasingly likely to see the "fruit face" because they are more likely to realize that the relations between the pieces of fruit correspond to the relations between the features of a face. This result is consistent with our findings that older children are better able to meaningfully organize a pattern by relating it to something they know well.

In conclusion, we have demonstrated that multiple levels of organization in a pattern may influence how the pattern is remembered. When a higher level organization is elusive (as it was to our 4-year-old participants), basic organizing principles such as symmetry seem to be an important determinant of ease of remembering. When patterns are verbally codable, however, our results suggest that the effects of lower levels of organization may become less important determinants of successful remembering.

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Notes

1 Although the letter Z is symmetrical about the origin, it was classified as asymmetrical because we believed that symmetry about the origin would be difficult for the children in the study to detect visually. Previous work on the acquisition of symmetry discrimination has not addressed, specifically, this particular type of symmetry, but Bornstein and Stiles-Davis (1984) showed that children learn to discriminate and remember oblique symmetry much later than vertical or horizontal symmetry. We believed that symmetry about the origin would be as, if not more, difficult for young children to detect than oblique symmetry. Letters that were totally asymmetrical (e.g., J or L) were ruled out because they either contained curved elements that may have posed other difficulties in reconstruction that unrelated to symmetry or they did not contain a number of elements comparable to the other letters used in the study. The letter Z thus was the best compromise between several constraining factors.

2 In our first attempt to devise a set of nonverbal stimuli that shared the symmetry properties of the letter stimuli, we simply rotated the letter patterns by 180°. Although this manipulation preserved the symmetry properties and the combination of critical features (Gibson 1969) present in the letters, we found that 8-year-old children were extremely adept at identifying these "nonverbal" patterns as letters turned upside-down. Thus, the results of this pilot study indicated that rotation is too transparent a transformation to effectively disguise the letter patterns. Visual "compensatory rectifying mechanisms" may exist such that rotated letters are nevertheless recognized as their upright counterparts (Kolers and Perkins 1975). In addition, because the 8-year-olds seemed to be extremely proficient at identifying the transformed letters, younger children were tested in this study.

3 To rule out the possibility that verbal reconstructions received higher ratings because of a bias on the part of the judges, we had a third set of judges rate children's reconstructions against the opposite targets (henceforth called *mismatched* ratings). These judges rated the similarity of nonverbal reconstructions to verbal targets and vice versa. If the original judges were, in fact, biased to give higher ratings when they were judging similarity to a verbal target, then we would also expect the similarity-to-target ratings of the nonverbal reconstructions to be inflated when these reconstructions were judged against verbal targets. To test

this possibility, we entered the original ratings and mismatched ratings into 2 (Matched or mismatched targets) × 2 (Verbal or nonverbal reconstruction target) ANOVA. We found that the mismatched ratings were significantly lower than the original ratings (i.e., those obtained when judging to the correct target), $F(1,49) = 19.19$, $MSe = 0.33$, $p < 0.001$. Moreover, a significant Match × Codability interaction revealed that judges' ratings favored verbal targets only when the judge's target matched the child's target, $F(1,49) = 4.75$, $Mse = 0.06$, $p < 0.05$. Thus, when judges were asked to judge reconstructions against the opposite pattern, their ratings were equally low, regardless of whether their target was a verbal or nonverbal pattern. The absence of rating inflation in either of the mismatched conditions suggests that judges were not simply finding it easier to find similarities between children's reconstructions and the verbal targets. Rather, children's reconstructions of verbal patterns more closely resembled their targets than did their reconstructions of nonverbal patterns.

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