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Children's reasoning about spatial relational similarity: The effect of alignment and relational complexity

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ABSTRACT

We investigated 4- and 5-year-old children's mapping strategies in a spatial task. Children were required to find a picture in an array of three identical cups after observing another picture being hidden in another array of three cups. The arrays were either aligned one behind the other in two rows or placed side by side forming one line. Moreover, children were rewarded for two different mapping strategies. Half of the children needed to choose a cup that held the same relative position as the rewarded cup in the other array; they needed to map left–left, middle–middle, and right–right cups together (aligned mapping), which required encoding and mapping of two relations (e.g., the cup left of the middle cup and left of the right cup). The other half needed to map together the cups that held the same relation to the table's spatial features—the cups at the edges, the middle cups, and the cups in the middle of the table (landmark mapping)—which required encoding and mapping of one relation (e.g., the cup at the table's edge). Results showed that children's success was constellation dependent; performance was higher when the arrays were aligned one behind the other in two rows than when they were placed side by side. Furthermore, children showed a preference for landmark mapping over aligned mapping.

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Introduction

One of humans' most powerful cognitive tools for mental organization is reasoning by analogy—the perception and use of like relational patterns across contexts. This ability has even been argued to be the driving force behind humans' mental prowess (Gentner, 2003). An analogy reveals common structure between two situations (a known situation and a novel situation) and, based on these similarities, enables one to draw an inference from the known situation to the novel situation.

Theories of analogy have divided the phenomenon into several individual processes: retrieval, mapping, evaluation, abstraction, and re-representation (Gentner & Colhoun, 2010). Arguably the most crucial one among them is mapping. Mapping describes the alignment of the representational structure of two situations in order to deduct similarities between them, which in consequence will allow for inferences from the base situation to the target situation (Gentner & Rattermann, 1991). The ontogeny of mapping abilities is characterized by the so-called "relational shift"—a shift from attending primarily to surface or featural similarity when comparing two objects or situations to attending to the relational similarity (Gentner & Rattermann, 1991). Early in ontogeny, children judging similarity of two scenes attend solely to overall similarity or to object-level commonalities. Only from 3 or 4 years of age onward do they start to appreciate relational similarities, although at that age they still find it hard to inhibit reacting on the basis of object similarity when it is pitted against relational similarity (Markman & Gentner, 1990; Paik & Mix, 2006, 2008; Rattermann & Gentner, 1998). Children's ability to solve analogies is also constricted by their working memory capacity, which limits the number of relations children (and adults) can process in parallel (Halford, Wilson, & Phillips, 1998; Richland, Morrison, & Holyoak, 2006). The number of relations that need to be compared simultaneously represents the relational complexity of a problem, and the higher the relational complexity, the higher the memory processing load. In addition, a progression from an easier problem to a more difficult problem increases children's performance on the difficult problem (Kotovsky & Gentner, 1996).

One of the domains in which a developmental pattern of relational mapping becomes apparent in young children is the spatial domain. In most spatial mapping tasks, children are required to find a hidden object in a target array of hiding places after they have observed an experimenter hide the same object in a different array. To be able to infer the location of a hidden object in the target constellation based on knowing the position of a similar object in the base constellation, they need to recognize similarities in spatial organization between the two arrays (e.g., Loewenstein & Gentner, 2005). Children's ability to recognize spatial relational similarity is supported by several factors: previous experience with easier (more similar) examples (Loewenstein & Gentner, 2001), proximity of the corresponding items (Haun & Call, 2009), high surface similarity between the two comparing spatial scenes (DeLoache, de Mendoza, & Anderson, 1999; DeLoache, Kolstad, & Anderson, 1991), and an alignment or the same orientation of the two scenes that need to be mapped (Blades & Cooke, 1994; Bluestein & Acredolo, 1979; Paik & Mix, 2008; Presson, 1982; Vasilyeva & Bowers, 2006). Moreover, the amount and type of instructions also have an influence on children's performance on the mapping task (DeLoache et al., 1999; Loewenstein & Gentner, 2005). Loewenstein and Gentner (2005) argued that hearing relational words, such as "on", "in", and "under", facilitated children's mapping performance.

Recently, the ability to map spatial relations has been investigated in our closest living phylogenetic relatives, the other great apes: bonobos (*Pan paniscus*), chimpanzees (*Pan troglodytes*), gorillas (*Gorilla gorilla*), and orangutans (*Pongo pygmaeus*) (Haun & Call, 2009; Hribar, Haun, & Call, 2011). In a spatial mapping task, apes, like children, have also been found to be influenced by prior experience with the easier problem and by proximity of the corresponding items (Haun & Call, 2009). Moreover, apes' performance was highly dependent on the relative positioning of the base and target arrays; they performed best when the two arrays were aligned one behind another and performed worst when the arrays were in one line. This indicated a degree of inflexibility in their mapping abilities (Hribar et al., 2011). In addition, Hribar and colleagues (2011) reported that apes did not map together the cups that held the same relative position within the arrays (i.e., the left, middle, and right cups); instead, they appeared to encode the baited cup in the base array in a relation to a nearby spatial feature or a landmark (i.e., table's edge) and then chose a cup from the target array that was also near that same landmark. Hribar and Call (2011) later demonstrated that, indeed, when apes are presented with a linear array of identical-looking cups placed on a platform, they encode the rewarded cup by its relation to the table's edge and not by its relation to other cups.

Therefore, we propose that there are two different mapping strategies that participants could use in a spatial mapping task: the aligned and landmark strategies. The aligned mapping strategy predicts that cups of one array hold special relations to one another. As a result, each cup (location) is defined by two relations. For example, the left cup is left of the middle cup and left of the right cup. The landmark mapping strategy predicts that cups hold relations to some elements that are external to the cup array (i.e., the table's edge). Thus, to encode the left cup, for example, only one relation needs to be encoded—the cup next to the table's edge. Hence, the difference between the aligned and landmark mapping strategies is in the relational complexity—in the number of relations that need to be encoded and mapped. The question then becomes, which mapping strategy do young children use or prefer when they engage in a spatial mapping task?

Children's strategies to encode space, their relative reliance on certain cues over others, and their use of spatial frames of reference change throughout childhood (Haun, Call, Janzen, & Levinson, 2006; Haun, Rapold, Call, Janzen, & Levinson, 2006; Learmonth, Newcombe, & Huttenlocher, 2001; Nardini, Burgess, Breckenridge, & Atkinson, 2006; Newcombe & Huttenlocher, 2000). At 2 years of age, children can encode a correct box out of four identical plain boxes with the help of a single landmark (e.g., a chair) standing in its vicinity (DeLoache & Brown, 1983). At 4 years of age, children are successful in differentiating between two identical objects by their relation to a nearby landmark (being close or far), a platform's edge (next to it or in the middle of the platform), and a platform edge's length (at the shorter edge or at the longer edge) (Vasilyeva, 2002). However, at the same age, they fail when they need to encode a hiding container in relation to two other containers in the array—one identical to the hiding container and one unique, which could potentially be used as a landmark (Lee, Shusterman, & Spelke, 2006), but children can learn through repeated trials that a reward is always hidden in the middle of two landmarks (Simms & Gentner, 2008; Spetch & Parent, 2006; Uttal, Sandstrom, & Newcombe, 2006). Hence, it appears that 4-year-olds readily encode the location of a hiding place in relation to a single landmark but still have great difficulty in encoding location in terms of two relations.

The main objective of the current study was to investigate children's relational mapping in a spatial mapping task while minimizing the effect of language and to more directly compare children's responses with those in previous studies with nonhuman great apes (Hribar et al., 2011)—thus, to search for similarities and differences in flexibility and preferences in spatial mapping strategies that might indicate homologies between species irrespective of a higher overall performance in humans. More precisely, we addressed the following three points. First, we investigated how alignment of the arrays affects children's mapping performance. We presented children with two three-cup arrays, which were either aligned one behind another in two rows or placed next to each other forming a line. Based on previous studies finding that children and apes performed better on the mapping tasks when the two arrays were aligned and when the corresponding items were also the closest items, we expected that children in our study would find the task easier when the two arrays were placed in two rows than when they were in one line. Second, we were interested to see whether those children who were first presented with the easier constellation (i.e., two rows) would consequently perform better on the more difficult constellation (i.e., one line) than children who were first presented with the one line constellation. Experience in comparing aligned spatial scenes should allow children to recognize the relational similarity in a subsequent unaligned constellation (Kotovsky & Gentner, 1996; Loewenstein & Gentner, 2001). Third, we investigated which spatial relations children would find easier to map—relative position within the array (e.g., left–left cups), thereby needing two relations to encode each cup, or relative position on the table (e.g., cup at the edge–cup at the edge), thereby needing only one relation to encode the rewarded cup. Because 4-year-olds still have difficulty in encoding locations using two relations, we should expect that 4-year-olds would be better when rewarded for the landmark mapping, whereas 5-year-olds should perform well on the landmark as well as on the aligned mapping.

Method

Participants

In total, 24 4-year-old children (mean age = 48.2 months, *SD* = 1.7, range = 45.7–51.0) and 24 5-year-old children (mean age = 60.8 months, *SD* = 1.6, range = 57.4–62.7) participated in this study. Half of the children in each age group were girls, and the other half were boys. All children were recruited from local kindergartens. They were tested individually in a familiar room in their kindergarten. Children could stop participating at any time, and 1 child stopped. The sample size reported above is the final number after exclusion.

Materials

We used two arrays of three identical metal square cups (8.5 × 8.5 cm). Each array was placed on a yellow plastic tray (32 × 12.5 cm) resting on a wooden testing table (50 × 80 cm). In both conditions, the distance between the trays, as well as the distance between the cups within each array, was 3.5 cm. We used small (3.5 × 3.5 cm) cartoon animal pictures as rewards.

Procedure

After a short warm-up time in a group, each child was taken to a separate room in the kindergarten where the apparatus was set up. The child sat at the middle of the testing table opposite to the experimenter. The experimenter then showed the child some animal pictures and explained that they would play a game in which the experimenter would hide pictures underneath the cups and the child could then search for them. If the child found a picture, he or she could keep it. There was no specific mention that two pictures would be hidden—one underneath each array. There was also no mention that pictures would be under the same positioned cups in both arrays or that the child would need to find a pattern or rule of the game. After this short introduction of the game, the experiment started.

There were two conditions. In the Two Rows condition, both arrays were placed on the left half of the table, aligned one behind another, 6 cm from the table's left edge. In the One Line condition, the

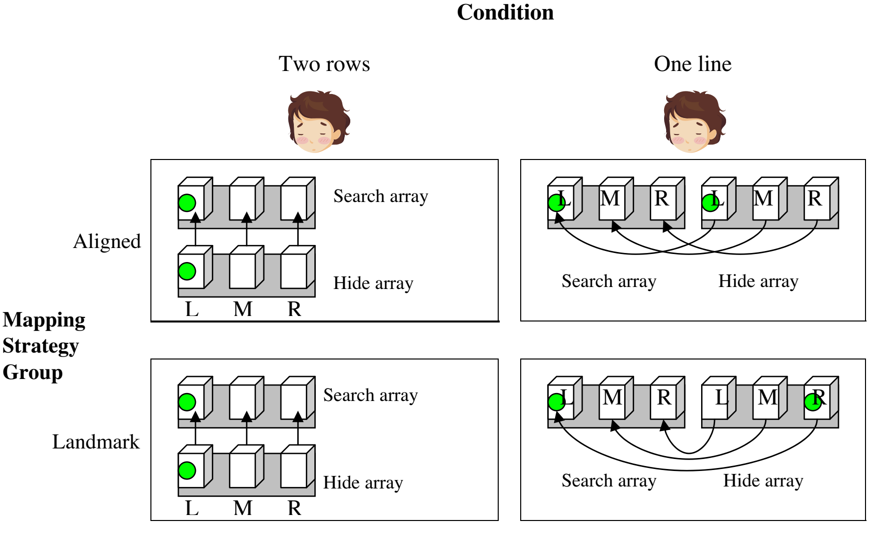

Fig. 1. Experimental setup: positioning of the two arrays in the two rows and one line conditions. The arrows indicate the corresponding cups.

arrays were placed side by side, each resting on the opposite halves of the table, the left array resting 6 cm from the left edge and the right array resting 6 cm from the right edge (see Fig. 1). For both conditions, the procedure was the same. One of the arrays was designated as a Search array, and the other was designated as a Hide array. In the Two Rows condition the Search array was the array closer to the child, and in the One Line condition it was the left array (from the experimenter's view). At the beginning of each trial, all six cups were empty and laying on their sides, with the openings facing the child. An occluder was put on the table between the child and the arrays, so that the child could see that the experimenter was hiding one picture but could not see underneath which cup. After the experimenter had hidden a picture underneath one of the cups (called the hiding cup) in the Search array, all three cups in the Search array were upturned (closed) and the occluder was removed. The cups in the Hide array were still opened, and the child could observe the experimenter first close two of the cups and then place a picture underneath the cup that remained open in the Hide array before closing that cup as well. Finally, the experimenter pushed forward the tray with the Search array for one tray's width ($\sim$12.5 cm; note that in the One Line condition this means that the two arrays were not forming a continuous line anymore) and asked the child where the picture was. If the child indicated a cup in the Hide array, the experimenter pushed the Search array tray back and forward again and said, "Yes, but where do you think the picture is here?" The child could either point to or lift the chosen cup. If the child was correct, he or she kept the picture and the experimenter opened all of the remaining cups and removed the picture from the Hide array. If the child was wrong, the experimenter opened all of the cups and took both pictures away without making any reference to the position of the pictures.

Each child received one block of 12 trials of each condition (24 trials total) in one session. There was a short break ($\sim$5–10 min) between the blocks. Half of the children started with the Two Rows condition, and the other half started with the One Line condition. Each position (left, middle, or right) was rewarded four times per condition, with the order of the position being semi-randomized; the same position was not rewarded on more than 2 consecutive trials.

There were two different mapping strategies for which children could be rewarded: *aligned* and *landmark* strategies. For the aligned strategy, the two cups hiding a picture had the same relative position within their array. Thus, if the hiding cup in the Hide array was left, middle, or right, then the rewarded cup in the Search array was also left, middle, or right, respectively. For the landmark strategy, the two hiding cups in the two arrays had the same relation to a landmark (i.e., table's spatial feature) next to them. Thus, in the Two Rows condition, the cups that were in the same relative position also had the same landmark next to them (e.g., both of the left cups were at the table's edge). In the One Line condition, however, if the hiding cup in the Hide array was the cup in the middle of the table (the left cup), then the rewarded cup in the Search array was also the cup in the middle of the table (the right cup). Therefore, in the Two Rows condition both strategies led to the same cup, whereas in the One Line condition they did not (except for the middle cup) (see Fig. 1). Half of the children were assigned to one strategy, and the other half were assigned to the other strategy.

Scoring and data analysis

All sessions were videotaped, and scoring was done live as well as subsequently from the videos. We scored which cup (left, middle, or right) children chose, and the dependent measure was the percentage of correct trials. A second coder scored 20% of the trials of each condition and strategy group to assess interobserver reliability, which was perfect (Cohen's kappa = 1).

In the Two Rows condition, both mapping strategies (aligned and landmark) led to the same cups (left–left, middle–middle, or right–right). In the One Line condition, on the other hand, the two strategies led to different cups (except for the middle cup). Therefore, we decided to analyze the two conditions separately with the following factors: age (4 or 5 years), rewarded mapping strategy (aligned or landmark), order of condition administration (first or second), and position of the rewarded cup (left, middle, or right). We conducted a 2 (Age) $\times$ 2 (Strategy) $\times$ 3 (Position) $\times$ 2 (Order) analysis of variance (ANOVA) on the percentage of correct responses separately for the two conditions. Position was a within-participants variable, and age, strategy, and order of conditions were between-participants variables. To compare children's performance against chance (33%), we conducted a one-sample *t* test; to compare the performance on the two conditions, we used a paired-samples *t* test (two-tailed); and to compare individual performance against chance, we used a binomial test.

Apes in Hribar and colleagues' (2011) study tended to use the landmark strategy in the One Line condition even though they were always rewarded only for the aligned strategy. Therefore, we were interested to see whether children from the aligned group also tended to choose cups following the landmark strategy (even though they were not rewarded for it). We coded the aligned group's responses irrespective of their success and compared their percentage of choices following the landmark strategy against chance (33%) with a one-sample *t* test.

Results

Fig. 2 presents the percentage of correct responses for each condition and strategy group as a function of age. In the Two Rows condition, the 4-year-olds from both strategy groups chose the correct cup more often than expected by chance: aligned group (48.6%), $t(11) = 2.45$, $p = .03$, $d = 0.71$; landmark group (60.4%), $t(11) = 3.23$, $p = .008$, $d = 0.93$. In the One Line condition, on the other hand, the 4-year-olds from both strategy groups performed at chance levels: aligned group (34.0%), $t(11) = 0.27$, $p = .79$, $d = 0.08$; landmark group (43.1%), $t(11) = 1.65$, $p = .13$, $d = 0.48$. The 5-year-olds from both strategy groups performed above chance in both conditions: aligned group—Two Rows condition (77.8%), $t(11) = 5.72$, $p < .001$, $d = 1.65$; One Line condition (51.4%), $t(11) = 2.20$, $p = .05$, $d = 0.64$; landmark group—Two Rows condition (73.5%), $t(11) = 4.95$, $p < .001$, $d = 1.43$; One Line condition (54.9%), $t(11) = 3.15$, $p = .009$, $d = 0.91$. Children's retrieval accuracy was higher in the Two Rows condition than in the One Line condition, $t(47) = 5.16$, $p < .001$, $d = 0.76$.

A 2 (Age) × 2 (Strategy) × 3 (Position) × 2 (Order) ANOVA of the Two Rows condition revealed main effects of age (4-year-olds: 54%; 5-year-olds: 76%), $F(1, 40) = 8.42$, $p = .006$, $\eta^2_p = .17$, and order (Two Rows condition presented first: 56%; Two Rows condition presented second: 74%), $F(1,40) = 5.92$, $p = .02$, $\eta^2_p = .13$, and no significant interactions. The ANOVA of the One Line condition revealed main effects of age (4-year-olds: 38.5%; 5-year-olds: 53%), $F(1,40) = 5.21$, $p = .03$, $\eta^2_p = .12$, and

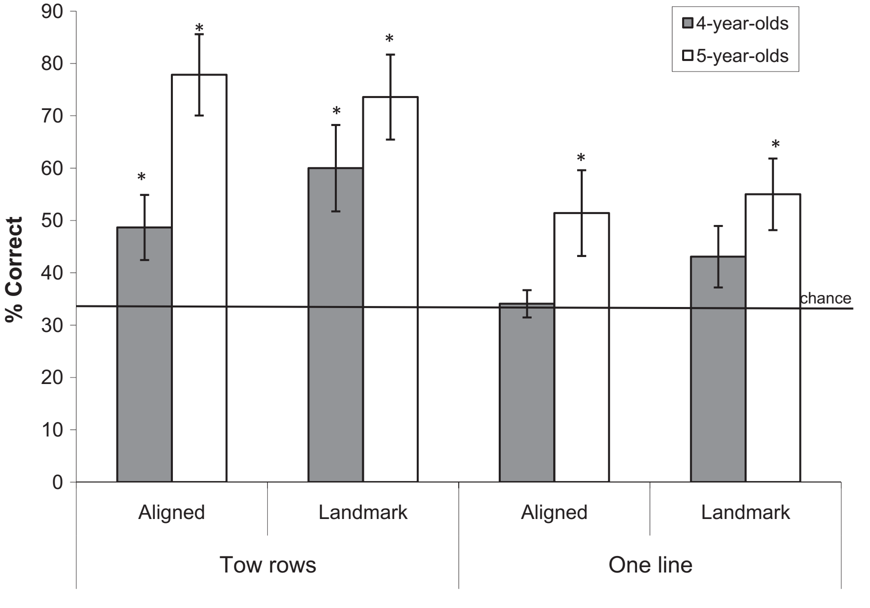

Fig. 2. Percentage of correct responses for each condition and rewarded mapping strategy as a function of age. Each asterisk (∗) denotes above chance performance ($p < .05$). Bars represent standard errors.

position (left: 37%; middle: 57%; right: 44%), $F(2,80) = 6.62$, $p = .002$, $\eta_p^2 = .14$. There was also a significant interaction between Strategy and Position, $F(2,80) = 3.16$, $p = .05$, $\eta_p^2 = .07$. To investigate the pattern of the interaction, we conducted an ANOVA with a rewarded cup's position as a within-participant factor separately for the two strategy groups. The performance of the aligned group differed on the three cups (left: 33%; middle: 62%; right, 33%), $F(2,46) = 8.45$, $p = .001$, $\eta_p^2 = .27$, whereas the performance of the landmark group did not (left: 40%; middle: 53%; right: 54%), $F(2,46) = 2.08$, $p = .14$, $\eta_p^2 = .08$.

Individual analysis revealed that in the Two Rows condition, 8 4-year-olds (4 from each rewarded strategy group) and 17 5-year-olds (9 from the aligned group and 8 from the landmark group) selected the rewarded cup above chance. In the One Line condition, 2 4-year-olds (both from the landmark group) and 9 5-year-olds (4 from the aligned group and 5 from the landmark group) selected the rewarded cup above chance (all *ps* < .05) (see Table 1).

We were interested in whether children's performance became better over the trials in each condition. We compared the success on the first 6 trials with the success on the last 6 trials of each condition. There was no learning effect for the Two Rows condition, $t(47) = 1.88$, $p = .07$, $d = 0.27$, but there was a learning effect for the One Line condition, $t(47) = 4.23$, $p < .001$, $d = 0.61$.

The ANOVAs did not show a difference in the overall performance between the landmark and aligned groups in either of the conditions, but there was a difference between the strategy groups in their success on the three cups in the One Line condition (see Table 2). The difference between the aligned and landmark strategies can be seen only in the One Line condition, more specifically, only when the left or right cup was rewarded (see Fig. 1); when the middle cup was rewarded, both strategies led to the same cup—the middle cup. Therefore, we decided to exclude the trials where the middle cup was rewarded and to compare the two strategy groups in the One Line condition again. The results showed that now the difference in the performance of the landmark and aligned groups approached significance, $t(46) = 1.96$, $p = .056$, $d = 0.57$.

Moreover, as already mentioned above, when all trials were included in the analysis, the 5-year-olds from both strategy groups performed above chance in the One Line condition. However, if we exclude the middle trials, then the aligned group's performance in the One Line condition is not above chance anymore, $t(11) = 0.81$, $p = .43$, $d = 0.23$, whereas the landmark group still found the reward more often than expected by chance, $t(11) = 3.62$, $p = .004$, $d = 1.04$.

We also investigated whether children from the aligned group tended to choose cups following the landmark strategy. Indeed, in the One Line condition, children who were rewarded for the aligned strategy chose the cups in the Search array following the landmark strategy more often than expected by chance, $t(23) = 2.62$, $p = .015$, $d = 0.53$. Individual analyses revealed that 3 5-year-olds from the aligned group selected the cups after the landmark strategy at above chance levels (*p*s < .05). Similarly, we tested whether children from the landmark group preferred to choose the cups after the aligned strategy, and we found no significant result, $t(23) = 1.01$, $p = .32$, $d = 0.20$. Moreover, none of the children from the landmark group preferentially chose the cups following the aligned strategy.

Table 1
Percentages of correct choices for the two conditions when presented first or second.

	Aligned group		Landmark group	
Order of presentation	Two Rows	One Line	Two Rows	One Line
First				
4-year-olds	41.7 (0)	37.5 (0)	48.6 (1)	41.7 (1)
5-year-olds	73.6 (4)	52.8 (2)	61.0 (3)	47.2 (2)
Mean	58	45	55	44
Second				
4-year-olds	55.6 (4)	30.6 (0)	72.2 (3)	44.4 (1)
5-year-olds	81.9 (5)	50.0 (2)	86.1 (5)	62.5 (3)
Mean	69	40	79	53

Note: Numbers of children who passed the condition are in parentheses.

Table 2
Percentages of correct choices across the three positions.

		Position of reward		
		Left	Middle	Right
Aligned strategy				
Two Rows	4-year-olds	38	54	54
	5-year-olds	77	79	77
	Mean	56.5	65.5	64.5
One Line	4-year-olds	23	50	29
	5-year-olds	44	73	38
	Mean	33.5	61.5	33.5
Landmark strategy				
Two Rows	4-year-olds	54	56	70
	5-year-olds	67	90	65
	Mean	60.5	73	67.5
One Line	4-year-olds	29	52	48
	5-year-olds	50	54	60
	Mean	39.5	53	54

Discussion

Children were presented with a spatial mapping task in which the two spatial arrays could be positioned in two rows or in one line. We rewarded them for two different types of mapping: aligned and landmark mapping. The study showed that children's mapping performance was very similar to the performance of the great apes in Hribar and colleagues' (2011) study. First, similar to prior results with apes, children's retrieval accuracy was higher when the two arrays were positioned in two rows compared with when they formed a line. Second, against our expectations, the experience with the Two Rows condition did not increase children's performance in the One Line condition. Third, in the One Line condition, children tended to perform better when they needed to use the landmark mapping—the mapping spontaneously applied by the other great apes in a nearly identical situation—than when they needed to use the aligned mapping. Moreover, some children who were rewarded for the aligned mapping strategy actually came to engage in the landmark mapping strategy, whereas none of the children rewarded for the landmark mapping preferred to use aligned mapping.

We propose three possible factors (that could also work in combination) that could increase children's performance in the Two Rows condition in comparison with the One Line condition: surface similarity of the two arrays, alignment of the arrays, and proximity of the corresponding cups. Surface similarity has been shown to have an effect on children's performance in relational mapping tasks (Chen, 1996; Chen, Sanchez, & Campbell, 1997; Holyoak, Junn, & Billman, 1984; Paik & Mix, 2006). In the Two Rows condition, the Search array could be considered as more similar to the Hide array than in the One Line condition because the two arrays in the Two Rows condition had nearly identical surroundings (e.g., on their left the table ended and on their right the table continued), whereas the arrays in the One Line condition did not. Moreover, similarity between two spatial scenes that need fewer changes to become identical is higher than that between two scenes that require more change (Bruns & Egenhofer, 1997). Another difference between the two conditions could be that in the Two Rows condition the two arrays were perfectly aligned one behind the other. Children's mapping success is higher when the two comparing scenes are aligned or oriented in the same direction (Blades & Cooke, 1994; Bluestein & Acredolo, 1979; Paik & Mix, 2008; Presson, 1982; Vasilyeva & Bowers, 2006). Some authors have suggested that this alignment allowed children to potentially use the help of egocentric cues to solve the task and that, therefore, the trials with nonaligned scenes provided a more reliable measure of the ability to map spatial relations (Blades & Cooke, 1994; Vasilyeva & Bowers, 2006). In addition, it is conceivable that memory in the One Line condition was worse than in the Two Rows condition because the former resulted in a greater change of view of the Hide array when children shifted their gaze to the Search array than the latter where the gaze shift was minimal and the Hide array stayed within the field of view at all times. Such difference may have negatively affected retrieval accuracy in the One Line condition.

Finally, in the Two Rows condition, the corresponding cups from the two arrays were also the most proximate cups and, therefore, children might have chosen the cup from the Search array that was closest to the picture reward they saw hidden in the Hide array. The proximity of the corresponding cups has been shown to have an effect on children's spatial mapping (Haun & Call, 2009). However, children did not show a preference to pick the closest cup in the One Line condition, which would always be the same cup—the right cup—irrespective of the position of the rewarded cup in the Hide array. Thus, the higher overall similarity of the arrays, their alignment one behind the other, and the proximity of the corresponding cups might have increased children's performance in the Two Rows condition compared with the One Line condition.

The second finding was that we did not find any order effect for the One Line condition, meaning that presenting children with a simpler problem (the Two Rows condition) did not help them to solve the harder problem (the One Line condition). Surprisingly, children performed better in the Two Rows condition after they were presented with the One Line condition. Prior studies have shown that presenting children with a simpler task first improved their performance in the subsequent more difficult task (Kotovsky & Gentner, 1996; Loewenstein & Gentner, 2001). We propose the following explanation for these results. As mentioned earlier, children might have solved the Two Rows condition by using egocentric or proximity cues rather than the relational mapping, and as a consequence this strategy was not beneficial to them later when they were presented with the One Line condition. On the other hand, if they started with the One Line condition, there was no (easier) alternative strategy available to them. This might have caused them to spend more time comparing the two arrays in search of a "game rule." Indication for this would be children's improvement over trials in the One Line condition and their increased performance in the Two Rows condition if it was presented after the One Line condition. Vasilyeva and Bowers (2010) found that when children compare scenes that are to some degree different, they are more likely to focus on common relations than on common surface features. In contrast, when children compare highly similar scenes, they are more likely to focus on common features.

The third finding was that the landmark group's retrieval accuracy was higher than that of the aligned group in the One Line condition (recall that this analysis does not apply to the Two Rows condition because there both strategies led to the same cups). Interestingly, both age groups showed this pattern of results; however, the younger group was not above chance in the One Line condition irrespective of the rewarded mapping strategy, whereas the older group was above chance (when the middle cup was excluded) only when rewarded for the landmark mapping. Vasilyeva (2002) showed that 4-year-olds, when presented with only two identical objects placed on a platform, could encode the target object's location with respect to its distance to a nearby landmark, or to a platform's edge, and they could also transfer this information to another identical spatial layout and indicate to an object in the same location. Nardini and colleagues (2006), however, showed that when children were presented with 12 identical hiding places, only those 5 years of age and older could encode a location of the hidden toy with respect to the surrounding landmarks on the platform, the platform edges, and the configuration of the array. Thus, they encoded a hiding cup in relation to nearby special features. In our study, the platform's edge could serve as a nearby special feature. A platform's edge and a symmetry axis of the platform (i.e., the middle of the platform) are very salient cues and affect adults' and children's spatial recall (Batty, Spetch, & Parent, 2010; Bullens et al., 2010; Huttenlocher, Newcombe, & Sandberg, 1994). Therefore, it is conceivable that children in our study in the One Line condition (and possibly in the Two Rows condition as well) encoded the hiding cup from the Hide array in relation to nearby special features and that they then mapped this relation to the Search array. In summary, overall 4- and 5-year-olds found the mapping of spatial relations in the One Line condition to be much easier when they needed to encode and map only one relation (landmark mapping) instead of two (aligned mapping).

However, children could solve this task by using other strategies as well. For example, children could map together the cups that held a similar relation to themselves as a central landmark—the cups that were farthest away from them, the cups that were closest to them, and the cups that were halfway. Alternatively, if in the One Line condition children saw the two arrays as one continuous line, they might have mapped together the two endings of the line (the right cup in the Hide array and the left cup in the Search array) and the two middle parts of the line. However, note that before the children were allowed to choose a cup, the Search array was pushed forward, and so the continuous line that the two arrays formed was broken.

Unlike most previous studies, we did not provide children with explicit instructions that they should compare the two arrays and search in the same place; neither did we use relational language (i.e., "left", "middle", and "right"). Both have been shown to improve children's mapping performance (DeLoache et al., 1999; Loewenstein & Gentner, 2005). The 4-year-olds in Loewenstein and Gentner's (2005) study (Experiment 1, baseline condition), who were presented with a very similar task to our Two Rows condition and were given a full description of the task without relational terms (e.g., "on", "in", "under"), found the reward in 64% of the cases. Interestingly, the retrieval accuracy of the 4-year-olds in our study who were presented with the Two Rows condition first was 45%, whereas the retrieval accuracy of the 4-year-olds who got the Two Rows condition second was 64%. These results suggest that children who received detailed instructions possessed some advantage over those who did not, but the advantage disappeared after the children without instructions gathered experience with the task. However, future studies are needed to address this question directly.

To summarize, the results we obtained with this study are very similar to the results that Hribar and colleagues (2011) obtained with great apes. Both apes and children spontaneously used information about the location of a reward hidden in the Hide array to find the reward located in the Search array. Children did so without any verbal instructions, whereas apes did so without any prior training. However, both apes and children were affected by the constellation of the arrays; they performed better when the two arrays were aligned in two rows than when they were presented in a single row. Moreover, neither apes nor children successfully engaged in the aligned mapping strategy that demanded encoding of two relations when the two arrays were presented in one line; they both appeared to prefer mapping together the cups in relation to the nearby table's spatial features.

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