Geometric Maps as Tools for Different Purposes in Early Childhood

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Abstract

This study examined whether and how young children make spontaneous use of geometric maps for two different purposes: to determine and to represent the locations of objects. A total of 64 2.5-, 3-, 3.5-, and 4-year-old children solved a task with two phases in counterbalanced order: they had to use a map to locate a toy hidden in a referent space (retrieval), and to indicate on the symbol with a sticker the location of the hidden toy (map making). Results show that there is a clear developmental progression with 2.5-year-olds failing both phases, 3- and 3.5-year-olds succeeding only in map making, and 4-year-olds succeeding in both map making and retrieval phases. The differences between making use of maps to represent locations or to locate objects in space allow for a closer comprehension of map-reading as a progressive, sequenced process, and the factors at play as children develop symbolic understanding.

*Keywords:* geometric maps, map use, retrieval, map making

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**Introduction**

In literate cultures, maps are symbolic tools used for thinking, communicating, and orienting ourselves among different places in the world. Maps free us from the bounds of our own direct experience. They allow complex information about large extensions to be represented in a simple and compact manner, making possible ways of thinking, elaborating and conveying spatial information to others that would be impossible or at least much more difficult without them. For these reasons, the comprehension and use of maps is a central issue in the study of symbolic development and spatial cognition. The present study focused on the first steps of children’s ability to use maps for two different purposes: to determine and to represent the locations of objects.

Learning how to interpret and use spatial symbols such as maps is a long and challenging process (Liben & Downs, 2015; Uttal, 2000; Uttal & Yuan, 2014). At early starting points, ‘reading’ a map relies on at least two skill sets: (i) the ability to recognize that each element in the map (a two-dimensional representation) has a one-to-one relation to an element in the referent (a three-dimensional real space); and (ii) the ability to establish correspondence of spatial relations (the relations among elements in the map have a correspondence to spatial relations in the space). These skills let children understand and use simple maps (usually large scale plans with limited content) as representations of an immediate small space (often a room or a playground) and emerge sometime around the end of the third year of life (DeLoache, 2004; Huttenlocher, Newcombe, & Vasilyeva, 1999; Marzolf & DeLoache, 1994; Uttal, 2000; Vasilyeva & Bowers, 2006).

DeLoache and her associates (e.g., DeLoache, 1987, 1991; DeLoache & Marzolf, 1992; Uttal & Sheehan, 2014) have carried out an extensive set of studies on the earliest use of spatial symbols to locate hidden objects in a retrieval task. In this task, an experimenter indicates on a symbol (a scale model, a photograph or a map) the place where she or he has hidden a toy in a room; based on that information, children have to find the object in the corresponding location in the room. In one of these experiments (Marzolf & DeLoache, 1994) they examined the comprehension of a simple map by children of 2.5 and 3 years of age. The map consisted of an aerial view of the referent space and was extremely iconic: the depicted objects had distinctive shapes (e.g., square/circle), colors (green/red), and shared these properties and the spatial organization with their real counterparts. The objects on the map also varied in verbal labels (couch/chair) and the experimenter pointed out the overall correspondence between the symbol and the room, made the individual objects correspondences clear and explained to the children how to use the map in order to find the toy. While most 3-year-olds were able to find the hidden toy, no 2.5-year-olds used the map correctly.

This study raises the possibility that 3-year-olds were able to determine the location of the hidden object with the support of visual and linguistic cues. For example, recent work has shown that without the aforementioned explicit verbal instructions, children demonstrate a symbolic comprehension of the map-room relation later in development, at 4 years of age (Maita, Mareovich, & Peralta, 2014).

As a matter of fact, when the depicted objects are identical to each other, young children show difficulties at locating a hidden object (Blades & Cooke, 1994; Bluestein & Acredolo, 1979; Liben & Yekel, 1996). In a pioneering research, Bluestein and Acredolo (1979) presented children from 3 to 5 years of age with a map of a small room containing four identical green boxes. The map represented the referent space from an angular perspective and its figures had the same color as the real objects. The results revealed the fragility of 3-year-old children’s performance: half of the 3-year-olds but most of the 4- and 5-year-olds could find the hidden object based on the information about its location transmitted by the map.

The map used in Bluestein and Acredolo’s study can be considered an abstract, geometric map because it has no distinctive elements; it conveys little information about the appearance of the locations so they can only be determined by their spatial positions relative to one another (Dillon & Spelke, 2018; Huang & Spelke, 2015). In the absence of distinguishing visual and linguistic cues, this map provides a particularly stringent test of children's symbolic abilities: spatial relations are the unique cues to determine a location in the referent space. In other words, children have to focus on relational similarity, rather than on object similarity, to establish correspondences between the map and the space (Yuan, Uttal, & Gentner, 2017). The earliest evidence of comprehension of geometric maps was found at 2.5 years of age by Winkler-Rhoades, Carey and Spelke (2013). In this study, children could use an overhead map with three circles, representing the positions of three identical places in a cylindrical room, to successfully place an object in the room, without corrective feedback. These findings are relevant as they indicate that very young children can take advantage of the spatial properties of geometric maps and that doing so does not require extensive experience.

In summary, most of the focus of the research we have reviewed so far has been when and how children use iconic and geometric maps for the purpose of identifying locations in a space. Nevertheless, some experimental situations have demanded children to use these spatial symbols for a different purpose. In a series of studies, Liben and colleagues (Downs, Liben, & Daggs, 1988; Liben & Downs, 1989; Liben & Yekel, 1996; Myers & Liben, 2008) asked children to place stickers on a map to indicate their own location, the location of another person (who stood at various positions in a room) and/or the location of objects. Instead of being a tool to determine the location of a hidden target, as in the retrieval task, the map in this task (hereinafter called map making) functions as a tool to represent the location of the target. From 4 years on, children appeared able to indicate the positions in a room by placing stickers on iconic maps. Nevertheless, 4- and 5-year-olds had trouble to map making when the correct position could only be differentiated on the basis of spatial relations (Liben & Yekel, 1996).

The ability to use spatial symbols for different purposes may go through a developmental sequence in which difficulty is determined by the number of steps required to establish the relation of the symbol to the space (Huttenlocher, Vasilyeva, Newcombe, & Duffy, 2008). Following this assumption, in the retrieval task the target object is hidden out of the children’s sight, so two steps are required. The first step is to determine the target’s location shown in the map, the second step is to either recover the object or to point to its hidden place; because the object is hidden, representation of the target in working memory must be maintained until a response is made. In the map making task, the target object is visible, so it is only necessary to represent its location in the map.

Dalke (1998) directly compared 3-year-olds’ performance on the retrieval and map making tasks. In this research, she employed a one-room dollhouse and a map consisting of an aerial view of this space. Each piece of furniture was represented on the map by a rectangle of the same color (blue). Even the youngest group of 3-year-olds showed some ability to make the map and to use it in the retrieval trials, in both tasks with corrective feedback; however, correct performance was no higher than about 50%.

The purpose of the current study was to get a closer view of the onset of young children’s ability to use geometric maps as tools to determine and to represent the locations of objects using a single procedure. We asked 2.5, 3, 3.5, and 4-year-olds to solve a task with two phases in counterbalanced order: children were asked to find a hidden toy after the intended target was indicated on a map (retrieval) and to indicate on the map with a sticker the location of the hidden toy (map making). In other words, retrieval was a map-to-space phase and, conversely, map making a space-to-map phase. Both phases were carried out in the absence of explicit task instructions. This experimental design allowed us, from both an inter- and intra-individual perspective, to identify early starting points in children’s performance on each phase of the task and to examine the relationships between both map use skills within each age group.

Although the two phases of the task would demand a symbolic understanding of the map, our chief hypothesis was that using the symbol in order to locate an object (retrieval) or to represent its location (map making) would differ in difficulty in specific points of the development of map-reading abilities. We argued that children would be more successful at younger ages on the space-to-map phase than the map-to-space phase because a fewer number of processing steps are required to establish the symbolic relation.

We focused on children ages 2.5 through 4 years because we hoped to capture gaps as well as continuities in children’s emergent map knowledge. Moreover, we chose age groups separated by short periods of time motivated by the longstanding evidence that showed a relatively rapid progress in children’s mastering of spatial symbols (Callaghan & Corbit, 2015; DeLoache, 1987, 1991; DeLoache & Marzolf, 1994; Salsa & Peralta, 2007).

Research over the past two decades has revealed a remarkable sensitivity of young children to geometric properties of space (Cheng, Huttenlocher, & Newcombe, 2013; Cheng & Newcombe, 2005). In the present work, we used two geometric maps, each one representing three identical markings except for its spatial organization, a straight line or a right triangle (see Figure 1 for map examples). On the linear map, the object locations were distinguished by their distance relations (because the central object location was closer to one end than to the other), and the central location also was distinguished by the relation of betweenness. On the triangle map, the object locations were specified by their distance relations to the right angle (one long side, one short side).

Our hypothesis was that using two maps, and consequently changing the spatial distribution of the potential hiding places in the course of the task, would discourage perseverative errors (Kuhlmeier, 2005; Sharon & DeLoache, 2003; Suddendorf, 2003). This error consists of searching on trial *n* in the location where the toy was found on the preceding trial and it is the most common type of error in retrieval tasks, hindering young children’s performance with spatial symbols. Furthermore, even though there has been a body of evidence demonstrating children’s spontaneous use of relative distances along a line (Huttenlocher et al. 1999; Shusterman, Lee & Spelke, 2008) and within a shape (Izard, O’Donnell & Spelke, 2014; Shusterman et al., 2008; Spelke, Gilmore, & McCarthy, 2011; Vasilyeva & Bowers, 2006), sensitivity to relative distances has not been explored in interaction with different map uses.

**Method**

**Participants**

A total of 64 children participated, 16 (8 girls) in each of four age groups: 2.5-year-olds (*M*age =31 months, 15 days; age range: 30-32 months), 3-year-olds (*M*age = 36 months, 7 days; age range: 35-37 months), 3.5-year-olds (*M*age = 42 months, 9 days; age range: 41-43 months) and 4-year-olds (*M*age = 48 months, 24 days; age range: 48-50 months). Three additional children were tested but excluded from analyses due to incomplete data. The sample size (16 participants per age group) was chosen to match the sample size range reported in previous studies (*n* = 16-20 per condition, see Dalke, 1998 and Winkler-Rhoades et al., 2013).

All children were recruited from preschools in a large city (Rosario, Argentina), located in areas of medium socioeconomic status. Children had no history of special developmental issues, according to the records of the educational institutions. Participation in the study was voluntary and with the informed written consent of the parents.

**Materials**

The referent space was a 3D structure made of wood (95 x 80 x 65 cm), with three identical yellow boxes rectangular in shape (14 x 7 x 6.5 cm). The two maps, printed on laminated white A4 paper, consisted of three rectangular figures arranged in a line at unequal distances (2 and 13 cm) (Figure 1a) and in a right triangle (height 18 cm, base 5 cm) (Figure 1b). The maps were an aerial view of the referent space and their figures were simple black outline shapes. The scale factor of the representation on the map was 3:10 with respect to the actual structures. A divider separated the referent space from a low table on which the map was displayed, so that children could not see the space and the map simultaneously. We also used a plastic toy (Winnie the Pooh) and stickers (1.5 x 2 cm).

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Insert Figure 1 here

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**Design and Procedure**

Children were tested individually in a separated room at their preschools. To establish rapport, the experimental session began with a brief warm-up period in which the main experimenter chatted with the children about what they had been doing that day. When the children appeared to be comfortable, the task began; it lasted approximately 15 minutes and had two phases, retrieval and map making.

Using a within-participants design, half the children in each age group received the retrieval phase first and the other half the map making phase first. Within each phase, trials were blocked by map type (linear or triangle), with block order counterbalanced between participants. Within each map block, children received one test at a distant location and one test at a proximate location (the location farthest or closest to the right angle of the triangle and the center of the line). Each child received eight trials in total, four for retrieval and four for map making.

As an introduction to the task, the experimenter stated that they would play a hiding game. First, she introduced the toy (‘Winnie the Pooh’) and his room (referent space): “There’s one box, there’s the other one, and there’s the other one” (pointing out every box). Next she said: “Winnie the Pooh has some favourite places to hide when he plays with his friends. He is going to show us his favourite hiding places using a picture of his house”. The experimenter introduced one of the maps (according to the order previously assigned to the children) pointing out the depicted boxes: “There’s one box, there’s the other one, and there’s the other one”. The current design was a challenging test for young children’s map-reading abilities for at least three reasons. First, the map was located on a small table outside and to the left of the referent space, and it was always in the same orientation as the room; the symbol and its referent could not be seen together. Second, as shape, color and verbal labels were not available as cues to reference, only spatial information served to identify each target on the map and in the 3D array. Finally, the experimenter never explicitly drew children’s attention to the correspondence between the room and the map nor to how the symbol could be used to solve the task.

Immediately following the introduction, the children participated in the retrieval or map making trials (according to the order of phases previously assigned).

**Retrieval.** On each of the four retrieval trials, the experimenter hid the toy in the referent space outside of the view of the children (“I’m going to help Winnie the Pooh hide in his house. Then you can come to find him”). Children were asked to cover their eyes while the experimenter was hiding the toy to prevent them from peeking. Then, the experimenter returned and indicated the location of the toy by placing a sticker on the map (“This is where Winnie the Pooh is hiding in his room”) and the children were encouraged to search for it (“Can you find him?”). On each trial the sticker was removed from the map so the children always saw one marked hiding place. If the children were not successful, the experimenter retrieved the hidden toy without giving feedback (“I think Winnie the Pooh is hiding here”).

**Map making.** On each of the four trials, the experimenter hid the toy in the room while directing children’s attention to the event, making sure they were looking at the toy as it was placed in a target location (“Look! Winnie the Pooh is hiding right in here” [pointing at the toy and its hiding place]). Immediately after, the children and the experimenter approached to the table where the map was displayed and the children were asked to place a sticker on the map where the toy was hidden (“Can you show me on the map where Winnie the Pooh is hidden in his room?”). After each trial the experimenter removed the sticker from the map. Finally, the children were taken back to the room and asked to retrieve the toy hidden at the beginning of the trial (memory-based search). Children’s errors during the map making trials and the memory-based search were not corrected.

Children conducted the first two trials of each phase using one map (e.g., linear) and the remaining two with the other map (e.g., triangle). After the second trial of each phase, the spatial disposition of the boxes was changed to match with the new map and the two remaining trials took place. To that end, the experimenter said: “Winnie the Pooh also likes to play with his friends using the hiding places like this” (while changing the disposition of the boxes). Now, look at this picture of his house” (showing the other map to the children).

**Scoring**

 The experiment was videotaped by a second experimenter. Responses on the retrieval and map making phases of the task were coded from the video record by trained observers. A child was judged to have a correct response only if he or she searched at the correct hidden location (retrieval) or indicated the correct hidden location on the map (map making), on his or her first attempt. If the child’s only response consisted of verbalizing or pointing to a correct hidden location, that response was scored as correct. In addition, in the map making phase, as the child was taken back to the referent space in order to retrieve the toy hidden at the beginning of the trial, correct responses in this memory-based search were also coded. Children could score a maximum of four correct responses on each phase of the task and on the memory-based search.

Incorrect responses were classified in: (i) perseverative errors, when the child responded by selecting the location that had been correct on the immediately preceding trial; (ii) non-perseverative errors, when the child responded by selecting a location different from the one that had been correct on the preceding trial; and (iii) no responses. Self-corrections were recorded in both phases when children spontaneously corrected themselves following an incorrect first response.

We also analyzed patterns of individual performance. As in previous research (DeLoache, 2000; Troseth, Bloom Pickard, & DeLoache, 2007), a child was judged to be successful when he or she had three or four correct responses (75% - 100%) on the retrieval and map making phases of the task.

**Results**

Preliminary analyses of variance (ANOVAs) determined that there were no effects of gender, order of presentation of task phases (starting with the retrieval trials vs. the map making trials) and hiding locations (proximal vs. distant locations) on the performance variables of interest (all *p*s > .05), so the following analyses collapse across these variables.

A multivariate analysis of variance (MANOVA) was first performed to look for significant global differences between age groups (2.5, 3, 3.5, and 4 years) in their mean correct responses in the retrieval and map making phases of the task (dependent variables), *F*(6, 57) = 5.09, *p* < .001; Wilk's Λ = 0.63, ηp2  = .20. Following this finding on the effect of age, in order to get a clear picture of inter-individual and intra-task response patterns, we assessed developmental trends within each phase of the task and then the relations between the two phases within each age group.

**Retrieval (Map to Space) and Map Making (Space to Map)**

Figure 2 shows the developmental trajectories in each phase of the task. In the retrieval phase, a one-way ANOVA was performed with the number of correct responses as the dependent variable and age group as the between-subject variable (4). Results showed a significant main effect of age, *F*(3, 60) = 7.73, *p* = .001, ηp2 = .97. Post hoc tests (Bonferroni corrected) revealed a significant increase in correct responses in retrieval at 4 years of age (*M* = 3.43, *SD* = .89); the oldest children performed better than the 3.5-year-olds (*M* = 2.37, *SD* = 1.31) (*p* = .05), 3-year-olds (*M* = 2.37, *SD* = 1.08) (*p* =.05), and 2.5-year-olds (*M* = 1.56, *SD* = 1.09) (*p* = .001), with no significant differences between these three age groups (all *p*s > .05). Nevertheless, only the 2.5-year-olds’ group was markedly unsuccessful at locating the hidden object [performance was not significantly different from 33%, chance1, *t*(15) = .88, *p* = .389, *d* = .46]. Retrieval performance was above chance at 3 years [*t*(15) = 3.87, *p* = .001, *d* = 1.06], 3.5 years [*t*(15) = 3.22, *p* = .006, *d* = 1.06], and 4 years of age [*t*(15) = 9.49, *p* < .001, *d* = 2.12].

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Insert Figure 2 here

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Following the analysis of group performance, we analyzed individual performance using the success criterion. A chi-square test revealed a progressive developmental trend in the number of children who found the hidden object on three or four trials (at least 75%), *χ*2(3, *N* = 64) = 18.32, *p* = .001, *r* = .54. Only 2 of the 16 children (12.5%) of the 2.5-year-olds’ group, about half (7 and 8 children, 44% and 50%) of the 3- and 3.5-year-olds, and almost all (14 children, 87.5%) of the 4-year-olds’ group achieved the success criterion.

In the map making phase, the ANOVA also yielded a significant main effect of age group, *F*(3, 60) = 5.74, *p* = .002, ηp2 = .59 . However, as seen from Figure 2, pairwise comparisons (Bonferroni) revealed a significant increase of correct responses in map making earlier than in the retrieval phase, at 3 years of age. The youngest children (2.5-year-olds) had significant less correct responses (*M* = 1.75, *SD* =1.29) than the 3-year-olds (*M* = 2.87, *SD* = 1.20) (*p* = .05), 3.5-year-olds (*M* = 3.18, *SD* = 1.16) (*p* = .007), and 4-year-olds (*M* = 3.31, *SD* =1.07) (*p* = .003). Of most importance, 3-, 3.5-, and 4-year-olds showed no significant differences between them (all *p*s > .05). Again, only 2.5-year-olds’ performance was lower than chance, *t*(15) = 1.33, *p* = .203, *d* = .69; map making performance was above chance at 3 years [*t*(15) = 5.16, *p* < .001, *d* = 1.56], 3.5 years [*t*(15) = 6.40, *p* < .001, *d* = 1.87], and 4 years of age [*t*(15) = 7.39, *p* < .001, *d* = 1.99].

At the individual level, there were also significantly differences in the number of children who achieved the successful criteria across age groups, *χ*2(3, *N* = 64) = 16.9, *p* = .001, *r* = .51. Specifically, there was a clear gap between 2.5 and 3 years of age in children’s use of maps to represent the location of a hidden object. While only four (25%) 2-year-olds achieved the success criterion, 11 (69%) 3-year-olds, 14 (87.5%) 3.5-year-olds, and 13 (81%) 4-year-olds succeeded in at least the 75% of the map making trials. Finally, as expected, children in the four age groups were highly successful at remembering the location of the toy hidden in the room (between 89% and 98% of correct memory-based searches, *F*(3, 60) = 1.22, *p* = .307, ηp2 = .05).

With respect to the pattern across task phases within age groups, we used the success criterion in order to calculate the number of children who: (i) succeeded in both phases of the task; (ii) were unsuccessful on both phases; and (iii) were successful on only one phase of the task (retrieval or map making). Two patterns of results can be observed in Table 1. First, whereas the majority of children in the youngest age group (2.5 years) were not able to use the maps for any of the two proposed purposes (75%), most of the 4-year-olds were very successful on both (75%). Second, a discontinuity across task phases was found in 3.5-year-olds: the proportion of children who passed both phases, retrieval and map making (44%), was the same as the proportion of children who only passed the map making phase (44%) but different from the proportion who only passed the retrieval one (6%). In fact, in the four groups, very few children were successful on the retrieval but not on map making phase (between 6% and 12.5%). In consequence, in a specific point of the development of map-reading abilities, between 3 and 3.5 years of age, representing the location of a hidden object using a geometric map seems to be easier than using the symbol as a tool to determine the hidden location in space.

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Insert Table 1 here

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**Map Type**

An additional examination of the data was carried out to investigate the effect of map type, firstly in relation to perseverative errors. Previous research has shown that perseverative errors often hinder children’s performance in spatial symbol tasks (Kuhlmeier, 2005; Sharon & DeLoache, 2003; Suddendorf, 2003). Our hypothesis was that using two maps, and consequently changing the spatial distribution of the potential hiding places in the course of the task, would discourage selecting the location that had been correct on the immediately preceding trial. In order to examine perseverative errors, the data were collapsed across age and task phase. Sixty-three of the 173 incorrect responses (36%) consisted of perseverative errors; since the probability of making this type of error, given that an error occurred, was 0.33, this finding suggests that perseverative errors were not disproportionately frequent on this task. It should be noted that there was also a low frequency of children’s spontaneous error corrections (18%).

In regard to the relationships between the two maps and the proposed symbol uses, Table 2 presents children’s performance on each type of map as a function of task phase. Comparisons of means between the linear and the triangular map within each phase revealed no significant differences in the retrieval phase in any age group. However, in the map making phase, a paired-samples *t* tests showed that 2.5-year-olds were more likely to represent the correct hidden location with the linear (56% of correct responses) than the triangle map (31%), *t*(15) = -3.16, *p* = .006, *d* = -1.63. Conversely, 3.5-year-olds represent the correct hidden location on the 87.5% of the trials with the triangle map, which was better than the 71% of trials with the linear map, *t*(15) = 2.07, *p* = .05, *d* = 1.07. Finally, when we analyzed performance with each map type between task phases, the only significant comparison was found at 3.5 years of age: children’s use of the triangle map was better during the map making phase (87.5%) than the retrieval phase (53%), *t*(15) = -2.55, *p* = .022, *d* = -1.32.

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**Discussion**

The current study goes one step deeper into the research that has investigated children’s understanding of geometric maps (e.g., Shusterman et al., 2008; Spelke et al., 2011; Winkler-Rhoades et al., 2013) by examining the use of this spatial symbol for two different purposes and from both an intra- and inter-individual perspective. At an age in which map-reading abilities are just beginning to develop, the findings indicate that 3- and 3.5-year-old children can use geometric maps to represent the location of a hidden object but not to locate the object in a referent space. Children’s ability to do so is particularly striking in the context of the nature of our spatial symbol task: the map and the space were never visible at the same time and the total absence of adult’s demonstrations, practice trials, and corrective feedback. The differences between using maps to represent or to determine locations in space highlight the critical role functional use of spatial symbols plays in children’s developing map-reading abilities and symbolic understanding.

The employment of an intra-individual design allows us to suggest that children do not possess the skills to solve the two phases of the task (retrieval and map making) from the start. The combination with an inter-individual perspective shows that there is a clear developmental progression with 2.5-year-olds failing both phases, 3- and 3.5-year-olds only succeeding in map making, and 4-year-olds succeeding in both the map making and the retrieval phases. Similar to previous findings (e.g., Bluestein & Acredolo, 1979; Shusterman et al., 2008; Vasilyeva & Bowers, 2006), 4-year-olds’ performance was high (86% and 83% of correct responses in the retrieval and map making phases, respectively). Therefore, the most interesting results could be observed in the youngest age groups, in which gaps between the two proposed map uses were found.

Symbolic map use emerges early in development: around 3 years of age, children were able to use a map in order to represent the location of an object they had seen hiding in a referent space. If we take into account 3- and 3.5-year-olds’ relatively high success in the map making phase of the task (72% and 80% of correct responses), the present results extend prior findings of map making performance to younger children (Liben & Downs, 1989; Liben & Yekel, 1996; Myers & Liben 2008) and to higher scores of correct responses (Dalke, 1998), even without corrective feedback. In fact, children could use the maps despite the locations being uniquely distinguishable by their relative distance in a linear and right triangular array and, as we have noted above, in full absence of demonstrations and practice trials. This last characteristic of the task distinguishes our work from Winkler-Rhoades et al. (2013)’s study, where 2.5-year-olds could use similar maps but children were given warm-up trials and both the maps and the locations they depicted were described verbally.

Why might this developmental pattern emerge and what might it mean for early map-reading skills? We have hypothesized that the map making phase would demand fewer processing steps to establish the symbolic relation than the retrieval one. We have been able to demonstrate this assumption by providing new evidence, in comparison with Huttenlocher et al. (2008)’s study. This research, as well as Winkler-Rhoades et al. (2013), used a placement task in which children had to place an object in or on one of the locations in the referent space after the intended target was indicated on a map. The placement task, similar to the retrieval phase of our task, requires children to establish correspondences from the map to the space; however, retrieval seems more challenging than placement as it requires more actions to be conducted in the space to achieve a correct response.

On the contrary, we have made a direct comparison between retrieval and map making, a task which requires establishing correspondences from the space to the map. Children can see where the object is being hidden in the space and have to use the map to represent its particular location. The mental image the children have to use to guide their symbolic behavior is based on their direct experience with reality; that is, it is sustained in their observation of the actual concealing of the target object. On the other hand, in the retrieval phase, the map functions as a source of knowledge about a current unseen reality. In order to successfully use the symbol, the children have to form a mental model of the hidden object based on the map, determine its location in the space and, finally, recover the object. In map making, the starting point is a visible hiding event, so fewer steps are needed to relate the space and the map.

Moreover, whereas in both phases children need to keep the location of the object in memory, they get this information from two distinct sources: through direct experience in space (map making) or symbolic mediation (retrieval). Our findings thus clearly indicate that the difference in task difficulty, in terms of the steps required to interpret the map (Huttenlocher et al., 2008), may not be the only factor that could explain the observed developmental patterns. In fact, the mode of obtaining information about object locations may have affected how 3- and 3.5-year-olds understood the symbolic relation. This interpretation is consistent with the argument that young children do have difficulty in acquiring information from symbolic media, with studies showing, for instance, better learning from direct experience compared to visual media (DeLoache & Chiong, 2009; Strouse & Troseth, 2008). More broadly, research on event memory (Gobbo, Mega, & Pipe, 2002; Murachver, Pipe, Gordon, Owens, & Fivush, 1996) has also demonstrated an advantage of direct experience over mediated sources to obtain information in children’s abilities to recall and reenact.

Another, no less important, difference between the two map uses is their relationship with the experiences children have with spatial symbols and pictures, at least in Western cultures. In the retrieval phase, in spite of children viewing the map statically, they have to use it in a similar way to using maps for navigation in real life: viewing maps allows people to learn or plan routes and to anticipate spatial relations they will encounter when navigating in space. From this perspective, retrieval requires the ability to use a map to acquire very simple spatial facts about the world, basically the location of an individual object. Studies of the development of navigation skills (Newcombe & Huttenlocher, 2000) have found that it is not until age 4 that children can use maps to guide navigation in a simple situation, without demands on alignment or scaling as in the current study.

Nevertheless, map making, as it requires using the map as a tool to represent a simple fact about the world, is much more similar to the active experiences children have with pictures in daily life. Pictures in books are commonly used by parents, older siblings, and teachers as a means to communicate information to children under the age of 3 (Fletcher & Reese, 2005; Rideout, Vandewater, & Wartella, 2003). Adults usually ask children to identify people, animals or objects that they know or should recognize in photographs and picture books. They also frequently point out correspondences between real-world items and their pictured equivalents (Strouse, Nyhout, & Ganea, 2018), in many cases not just to the memories of such real-world references the children have experienced, but to things immediately present. Consequently, in addition to being less cognitively demanding than retrieval, map making would allow young children to make use of the spatial symbols in a familiar and meaningful way for them.

In summary, the overall pattern of performance indicates that the two proposed map uses posed a diverse complexity of problems for young children. The developmental gaps documented provide further evidence, as Newcombe and Huttenlocher (2000) have suggested, of a gradual, sequenced process of map-reading competence. This process would be guided by different skills that emerge gradually, rather than by a single general competence that would enable distinct symbolic uses.

An additional pattern of results was found in relation to the two geometric maps used. First, changing the maps and the spatial arrays of the hiding locations in the referent space was a simple and effective way of reducing perseverative errors as the dominant incorrect responses. Thus, the current research adds to previous studies that have managed to reduce the impact of perseverative errors (to return on trial *n* to the location that was correct on trial *n – 1*) in spatial symbol tasks (Sharon & DeLoache, 2003; Suddendorf, 2003).

Secondly, although the use of both types of maps demonstrates children’s sensitivity to objects’ relative distance, a differential map effect was only observed when the symbolic use proposed enhances children’s map-reading abilities, such as in the map making phase of the task. For example, although 2.5-year-olds’ performance was below chance, the use of a linear geometric map enhanced performance on the map making trials (56%), as opposed to the retrieval ones (31%), showing again that representing locations on a map could be a skill that arises earlier in development. The relationships between map types and map uses should be examined in future research by incorporating other kinds of spatial geometric information, such as sense relations, which may develop in the school-age years (Spelke et al., 2011).

Furthermore, the present study used geometric maps but very simple, with only three potential hiding locations in a small space, so children could inspect all the target locations in the layout at once, from a single point of view, without demands on alignment or scaling. Map-reading abilities undergo considerable changes throughout development: future studies should also address whether the developmental gaps between representing and determining locations remain when using maps with high levels of spatial complexities, for example maps misaligned with their referent spaces or with an increase in scaling disparity.

Finally, as we were interested in early spontaneous use, no verbal and/or nonverbal scaffolding were provided to enhance children’s performance. Variations in adult’s support, for instance including spatial language or explicit instructions on the map-space correspondences, could be a route to find differences between making use of maps for representing and determining the locations of hidden objects in the youngest age group, at 2.5 years of age.

**Conclusion**

The current results show a significant improvement between 2.5 and 4 years of age in children’s comprehension and use of geometric maps. Retrieval and map making are not similar in difficulty for children; therefore, understanding of maps is closely related to how children have to use the symbolic tools, whether to represent or to determine the location of objects in space. Investigating open questions regarding the relationships between these skills and the characteristics of the maps and/or the verbal support could provide more pieces to complete the developmental puzzle of map-reading competence.

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Footnotes

1The chance level of 33% was based on the number of potential hiding places in the room (the number of places that could fully conceal the toy).

Table 1

*Patterns of performance across task phases (retrieval and map making) within age groups.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Age group | *N* | Both phases*n* (%) | No phases*n* (%) | Retrieval*n* (%) | Map making*n* (%) | *χ*2, *p* |
| 2.5-year-olds | 16 | 2 (12.5) | 12 (75) | 0 | 2 (12.5) | 12.5\*\* |
| 3-year-olds  | 16 | 6 (37.5) | 4 (25) | 1 (6) | 5 (32.5) | ns |
| 3.5-year-olds | 16 | 7 (44) | 1 (6) | 1 (6) | 7 (44) | 9\* |
| 4-year-olds | 16 | 12 (75) | 1 (6) | 2 (12.5) | 1 (6) | 21.5\*\* |

\**p* < .05

\*\**p* < .01

Table 2

*Mean frequencies of correct responses for each type of map (linear and right triangular) by task phase and age group.*

|  |  |  |
| --- | --- | --- |
|  | Retrieval phase | Map making phase |
| Age group | Linear map | Triangle map | Linear map | Triangle map |
| 2.5-year-olds | .81 (.83) | .69 (.60) | 1.13 (.71) | .63 (.71) |
| 3-year-olds | 1.19 (.83) | 1.13 (.61) | 1.50 (.63) | 1.50 (.81) |
| 3.5-year-olds | 1.31 (.79) | 1.06 (.77) | 1.44 (.72) | 1.75 (.57) |
| 4-year-olds | 1.81 (.54) | 1.63 (.50) | 1.56 (.72) | 1.75 (.44) |

*Note*. Maximum score per map and task phase = 2. Standard deviations are in parentheses.



*Figure 1.* The two types of map used in the experiment: (a) linear; (b) triangle.

*Figure 2.* Correct responses by age group for the retrieval and map making phases of the task. The dotted line shows the success criterion of at least 75% of correct responses.

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