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Rooms Without Walls: Young Children Draw Objects But Not Layouts

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Drawing is the epitome of uniquely human expression, with few known limits beyond those of our perceptual and motor systems and the cultures in and for which we draw. The present study evaluates whether the drawings of young children nevertheless reveal an early emerging bias in the depiction of 2 different foundational spatial categories: layouts and objects. Across 2 experiments following preregistered designs and analysis plans, 4-year-old children either sat in a colorful "fort" or looked at a small "toy" version of the fort and were asked to draw exactly what they saw. Children's drawings often omitted the walls composing the fort's layout but included the corresponding object parts for the toy. Symbolic representations of space in young children's drawings thus privilege small-scale objects over large and fixed layout geometry. A distinction between the intuitive geometries of layouts and objects leads to their differential treatment in both humans and other animals during everyday navigation. This distinction may also underlie the differential treatment of layouts and objects in children's drawings.

Keywords: children's drawings, navigation, scenes, objects, spatial cognitive development

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As a form of human expression, drawing may seem limited only to that which we can see, whether in the world or in the mind's eye. Sure, our limited perceptual and motor systems must constrain our drawing in some ways, especially in children, and so do trends or traditions of culture and history (see Nadal & Chatterjee, 2018). But under these constraints, when asked to draw what we see, we should be otherwise free to do so. The present study evaluates whether the drawings of young children nevertheless reveal an early emerging bias in the depiction of layouts and objects.

Collections of children's spontaneous drawings suggest that young children tend to draw mostly individual objects or collections of objects, not the extended environment that constitute a scene's layout (e.g., Machón, 2013; Piaget & Inhelder, 1948/1967). Many studies aiming to understand trends in such drawing production nevertheless present children with only objects to draw (e.g., Bremner & Batten, 1991). It is thus unclear whether children's object-focused drawings in such experiments are a result of specific task demands. Even work aiming to examine children's depiction of layouts has sometimes relied on children's depictions of objects. For example, one representative study probing children's depiction of depth in the layout explored where children drew objects in an otherwise empty space: When 5- to 10-year-old children were asked to draw two apples, one behind the other, the youngest children tended to draw the apples side-by-side, while children who were slightly older drew them vertically, and the oldest children overlapped them (Freeman, Eiser, & Sayers, 1977). Although these kinds of experiments can chart development in children's use of spatial cues about objects in the layout, they do not bear on the question of whether and how children depict the layout itself.

Some studies have directly probed children's drawing of layout information, for example, by asking children to draw both layouts and objects: from memory (e.g., Kreindel & Intraub, 2017; Lewis, 1990); from photographs (e.g., Cox & Littleton, 1995); or from scale models (e.g., Ebersbach, Stiehler, & Asmus, 2011; Lange-Küttner, 2014). In these studies, layouts and objects nevertheless differed in a variety of visual features, such as shape, texture, and complexity. Of such different approaches to elicit layout drawings, moreover, only the use of scale models required children to perform the geometric translation of a 3D space on to a 2D piece of paper. Despite being contextualized as navigable spaces, the 3D model spaces were still not themselves navigable layouts. Their visual features were at least as consistent with small, manipulable objects as with large, navigable layouts, and prior work has shown that young children can treat such models either as objects or as layouts (e.g., DeLoache, Miller, & Rosengren, 1997).

The different approaches of such previous studies notwithstanding, they nevertheless suggest not only that children often omit layout information from drawings but also that, when drawn, layouts are much less geometrically rich than objects. For exam-

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The design, protocol, and analysis plan for this study were preregistered prior to data collection on the Open Science Framework (OSF). The procedural materials, data, and analysis code are publicly accessible on the OSF (osf.io/5wng2).

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ple, Ebersbach et al. (2011) found that in a group (N = 100+) of 5- to 9-year-old children who were asked to draw a table-top 3D model of a barn scene, more than 90% of children drew no elements composing the model's layout (e.g., its ground). Lange-Küttner (2014) found that in a group ($N \approx 60$) of 7- to 10-year-old children who were asked to draw several table-top 3D models of a field with five plastic figurines, a smaller but still significant percentage of children (around 22% on average) drew no layout elements (whereas only one child did not include all five figurines), and an additional 20% on average drew the field simply as a horizontal line on the paper.

Despite these clear and consistent trends, no studies have directly tested whether children prioritize their drawing of objects over layouts. Across two experiments, the present study thus evaluates whether children preferentially draw objects over layouts based on a difference in spatial category alone. Different groups of 4-year-old children were presented with either a 3D navigable "fort," with layout and object information matching in shape and complexity (Experiment 1), or a 3D manipulable "toy," a 1/20 model of the fort (Experiment 2). In both experiments, children were asked to draw exactly what they saw. By measuring the number and geometric richness of the walls and objects that children drew for the fort and by comparing these counts and spatial dimensions to those measured on drawings of the corresponding object parts of the toy, this study directly tests whether children prioritize objects over layouts in drawings. If children do, then such findings would raise a host of possible cognitive, cultural, or developmental factors that might be driving such a bias.

Experiment 1

Method

Participants. Thirty-two 4-year-old children (M_{age} = 4.50, range = 4.03–4.99; 15 girls) completed four drawings of a "fort" arranged in different configurations. One additional child participated but did not meet the preregistered inclusion criteria because of experimenter error during data collection. The sample size was chosen in advance of data collection, was based on pilot data in which patterns of responding were consistent across small numbers of children, and was preregistered on the Open Science Framework (OSF). Data collection stopped when the preregistered number of participants was determined to meet the inclusion criteria. Participants were recruited from the New York City area, and the use of human participants for this study was approved by the Institutional Review Board on the Use of Human Subjects at New York University.

Materials and procedures. Children were presented with four configurations of a colorful fort (see Figure 1). Two configurations included two rectangular side walls (1.68 m × 2.13 m) and one rectangular back wall (1.68 m × 1.60 m), with one rectangular object (60.96 cm × 45.72 cm) in front of each wall.

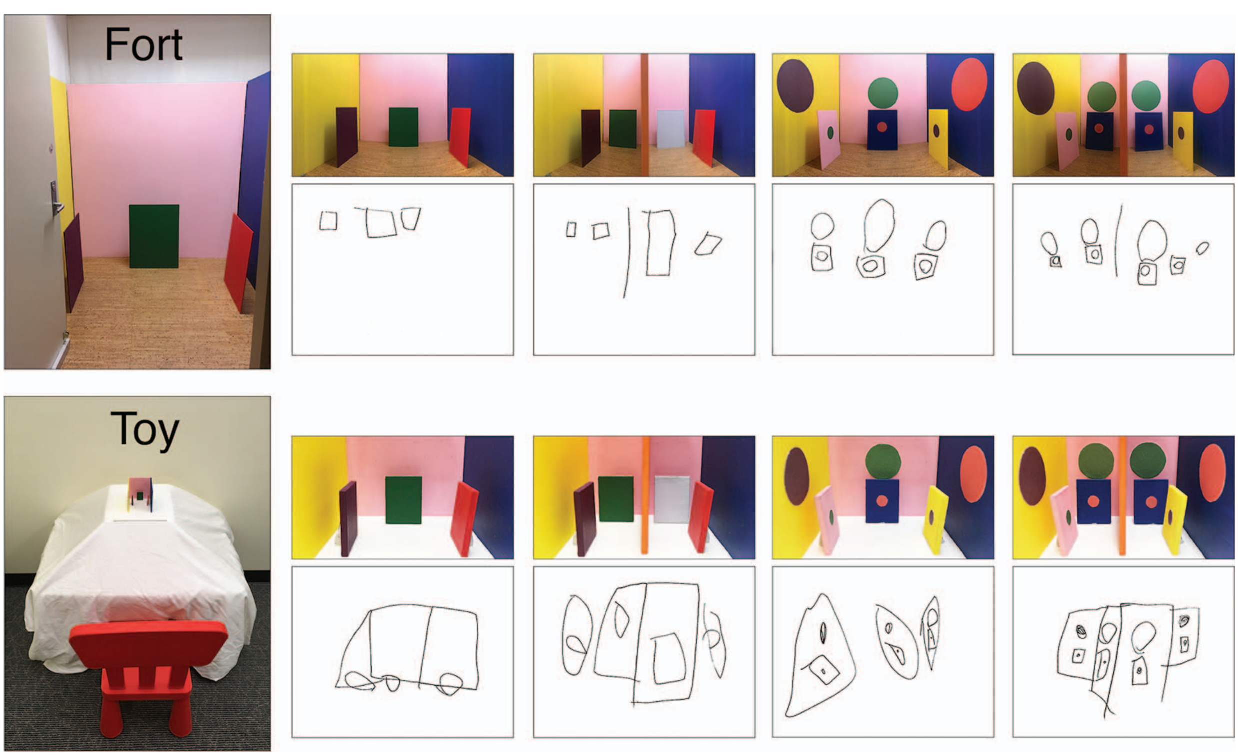

Figure 1. Photographs of the context and configurations for the fort (Experiment 1, top row) and toy (Experiment 2, bottom row). A sample set of one child's drawings from each experiment are included below each set of photographs to illustrate the study's main finding that children tend to leave out the layout information in their drawings but include all shape-defining features of objects in their drawings. See the online article for the color version of this figure.

Two configurations included an additional fourth wall (1.68 m × 1.07 m), orthogonally bisecting the back wall, with one rectangular object in front of each side wall and one on either side of the bisecting wall. This fourth, dividing wall was included for two main reasons. First, it allowed for multiple drawings from the same individual child across multiple fort configurations, leading to more statistical power for the analyses. Second, the dividing wall's position, as the front-and-center-most element, introduced configurations in which a wall was in front of all objects and was in the center (in the three-wall configurations, the objects were front-and-center). Pilot data revealed no effects of this dividing wall on the relative number of wall and object elements that children drew, and so the preregistered analysis treated these three-wall and four-wall configurations as all probing children's drawing of walls and objects in a layout more generally (see the online supplemental material for a post hoc analysis of the dividing wall; as in the pilot data, it also yielded no effects). One 3-wall and one 4-wall configuration also included flat circular "decals" placed in the center of each wall (diameter = 53.34 cm) and object (diameter = 15.24 cm). Configurations with decals were also included to allow for multiple drawings from the same individual child, increasing power, as well as to incorporate additional types of spatial elements against which to evaluate children's drawing of layout and object information. A planned analysis of the two configurations that did not include decals was consistent with the main analysis and so is reported in the online supplemental material.

Fort configurations were presented in a semicounterbalanced order to children: Configurations with or without decals were always paired, but order was otherwise fully counterbalanced. The exterior room in which the fort was set up was covered with opaque white fabric to block any of its salient attributes. In addition, a white drop ceiling was installed to cover all but a plain, central light fixture. Two cameras were mounted above the door.

Children sat on a black "X" on the floor, 15.24 cm from the fort's opening and centered. They viewed the fort from about 50 cm off the ground (the height of their eyes while sitting), and the back wall of the fort subtended 44.69 degrees of visual angle in the vertical direction and 44.12 degrees of visual angle in the horizontal direction. These visual properties of the fort and the child's position in it, along with the fort's size, which was large enough for the child to comfortably walk around in, thus presented visual cues consistent with it being a navigable space, its intended spatial category.

Children entered the fort with two experimenters (one primary experimenter and one coder) and first completed a practice trial in which they were asked to use a pencil and US-letter-sized piece of white paper (21.59 cm × 27.94 cm) to draw exactly what they saw (after Lewis, Russell, & Berridge, 1993), but nothing more, from a laminated US-letter-sized piece of paper that depicted 16 colorful forms of various shapes and sizes arranged in a quasi-symmetrical layout (for practice trial picture and full experimental script, see the online supplemental material). When children indicated that they had completed the practice drawing, they received instructive feedback: The experimenter went through every element in the practice picture and asked children to point to that element in their own drawing. If an element was missing, the experimenter asked children to add it to their drawing, reiterating that children should draw exactly what they saw. If there were extra elements, the experimenter reiterated to children that they should only draw what they saw and nothing more.

The first test trial began immediately after the practice trial. The experimenter waved their hand across the space and said, "See how we're in this super cool fort? I'm going to give you another piece of paper, and your job is to draw exactly what you see." Children were given a clipboard with US-letter-sized piece of white paper and a pencil to complete their drawing. As in the practice trial, children were asked to indicate when they were done, and there was no time limit. Unlike the practice trial, children received no informative feedback.

After children indicated that the drawing was complete, the coder took a photograph of the drawing with an iPad and followed the preregistered coding procedure. First, the experimenter asked children to point to each individual element in their drawing, and the coder outlined each element on the corresponding iPad photograph with a stylus. If there were isolated lines or closed shapes that children did not point out, the experimenter asked, "Is there anything else?" If children did not indicate any further elements, the experimenter pointed to the missing element(s), saying, "Is this something else?" If children indicated that the missing element was not an element or was a mistake, the element was not outlined or included as part of the final drawing. Second, the experimenter asked children to identify each of the outlined elements by touching it in the fort. To do so, the experimenter touched one element directly on the drawing and asked, "Can you go touch it to show me what it was you drew?" The experimenter repeated this procedure for each outlined element. The coder recorded the element in the fort that children touched by annotating the photograph (see the online supplemental material for the full set of coded drawings). If children at that point indicated an element that they had already individuated was a mistake, then that element was coded as having an indeterminate referent. If children wanted to add something to their drawing after the coding had begun, they could, but such elements were not coded. After this procedure, children exited the testing space, and the room was reconfigured for the next test trial. This procedure was repeated for the next three test trials.

Analysis. All analyses were specified prior to data collection and preregistered on the OSF with one change: Some analytic models had initially been specified with random-effects slopes as well as random-effects intercepts (see the online supplemental material); however, several of these models failed to converge, and so random-effects slopes were dropped from all analyses. Two primary dependent variables were defined. The first was the number of spatial elements that children drew according to four categories: walls; objects; wall decals; or object decals. Counts are bounded at zero, only take on integer values, and are often heavily skewed. Mixed-model Poisson regressions were thus planned and conducted. The findings were also robust to a mixed-model linear regression framework; these regressions were conducted post hoc and are reported in the online supplemental material. There were three additional categories of elements, which were coded but not included in the analysis: miscellaneous elements in the room (e.g., door handle); miscellaneous elements not in the room (e.g., ice cream cone); and elements with an indeterminate referent (e.g., scribbles). The second dependent variable was the dimensionality (1D, 2D, or 3D) of the spatial elements. Dimensionality is on an ordinal scale and was thus analyzed with mixed-model ordinal logistic regressions. The count and dimensionality variables were considered separately because they focused on two different questions. The count variable focused on whether a child included a particular element, and the dimensionality variable focused on how they depicted that element, once included.

The data coding was also preregistered. The live-coding procedure, detailed above, was the primary coding scheme. To determine the element count for each drawing, the coder simply enumerated the total number of elements of each type per drawing. To determine the dimensionality of each element, the coder judged whether each element was indicated by a single line (1D), a closed frontoparallel figure (2D), or a closed figure with any judged amount of perspective/recession of that figure into the picture plane, even if only the front surface of the element was depicted (3D). Because both the wall and object elements of the fort appeared mostly or entirely flat (see Figure 1), their additional 3D surfaces were unlikely to ever be drawn. Because inclusion of elements in perspective is typically not observed until children are much older (see Lange-Küttner, 2014 for a review), moreover, few to no characterizations of elements being drawn in 3D were expected.

Two additional coding schemes were implemented to evaluate the reliability and robustness of the results. First, a second coder used the experimental videos to recode 25% of children's drawings for their spatial element counts. The planned model for calculating coder reliability was misspecified (see the online supplemental material), and so the reliability of these count data was calculated using a measure of intraclass correlation (see Shrout & Fleiss, 1979). The coding reliability was high: intraclass correlation (ICC) [1, 1] = .97, 95% CI [.96, .98]. Second, two hypothesis-naïve coders also coded the drawings (Coder 1 did all the drawings; Coder 2 did 25%). These naïve coders used photographs of the fort from children's seated perspective to make their best guess as to the identity and dimensionality of each spatial element in the original drawings. The planned analyses for both element count and dimensionality were repeated on the entire set of naïve Coder 1's drawings, and the count reliability analysis evaluated how well naïve Coder 2's coding reflected naïve Coder 1's. The results from this analysis are convergent with the main analysis, so they are reported in the online supplemental material.

Results

Element count. The primary analysis examined the number of spatial elements that children drew. Figure 2 presents the raw distributions of wall and object element counts across all four fort configurations as well as the wall decal and object decal element counts across the two fort configurations that included them. A mixed-model Poisson regression with spatial element (wall or object) and configuration (each of the four configurations) included as predictor variables and participant included as a random-effects intercept revealed main effects of both spatial element (Wald test, $\chi^2[1] = 45.90$, $p < .001$) and configuration (Wald test, $\chi^2[3] = 12.76$, $p = .005$). As predicted, children drew significantly more objects than walls (see Figure 2; see Figure S1 in the online supplemental material), and children varied their drawings based on the number of spatial elements present in each configuration (configurations included 6, 8, 12, or 16 total elements; see Figure 1). A second mixed-model Poisson regression with spatial element (wall, object, wall decal, or object decal) included as a predictor variable and participant included as a random-effects intercept, but considering only the two configurations that included decals (see Figure 1), again revealed a main effect of spatial element (Wald test, $\chi^2[3] = 25.45$, $p < .001$). Planned Holm-corrected pairwise contrasts also revealed that children drew significantly more objects than walls ($p < .001$; see Figure 2 and Figure S1 in the online supplemental material).

Dimensionality. The dimensionality of the spatial elements was then evaluated. A mixed-model ordinal logistic regression with spatial element (wall or object) included as a predictor variable and participant included as a random-effects intercept revealed that children drew objects with more dimensionality than walls. The odds of children's drawing objects with greater dimensionality were 270% more likely than the odds of children's drawing walls with greater dimensionality (95% CI [112, 544], $p < .001$; see Figure 3). For the two configurations with decals, the odds of children's drawing objects with greater dimensionality were 247% more likely than the odds of children's drawing walls with greater dimensionality (95% CI [58, 661], planned Holm-corrected pairwise contrast, $p = .002$; see Table S1A in the online supplemental material).

Discussion

When told to draw exactly what they saw while sitting in a colorful fort, young children primarily drew the objects in the fort, not the walls that composed its layout. This result was particularly striking because the walls and objects were matched on many visual properties: all elements were colorful, the same shape, the same texture, and presented in the same or similar configurations. Nevertheless, children may have considered the walls to be mere background, and children may, in general, prioritize figural as opposed to ground elements in their drawings, regardless of whether those ground elements are or are not part of the navigable layout.

Experiment 2 thus evaluates whether such figure-ground relations might explain children's omission of layouts in their drawings of the fort. In this experiment, children are asked to draw a toy object that has the exact same figure-ground relations as the fort. If children draw the toy without the object parts that correspond to the walls of fort, then selective drawing of figural versus ground elements may also explain children's performance in Experiment 1. If, in contrast, children draw the toy with the object parts that correspond to the walls of the fort, then selective omission of layouts versus objects better explains children's performance in Experiment 1.

Experiment 2

Method

Participants. A different group of 4-year-old children (N = 32; M_{age} = 4.49, range = 4.02–4.98; 21 girls) from those children who completed Experiment 1 completed four drawings of a "toy" arranged in exactly the same ways as the fort from Experiment 1. No children were excluded. As in Experiment 1, the sample size and stopping rule were chosen in advance and preregistered on the OSF. Participants were recruited from the New York City area, and the use of human participants was approved by the Institu-

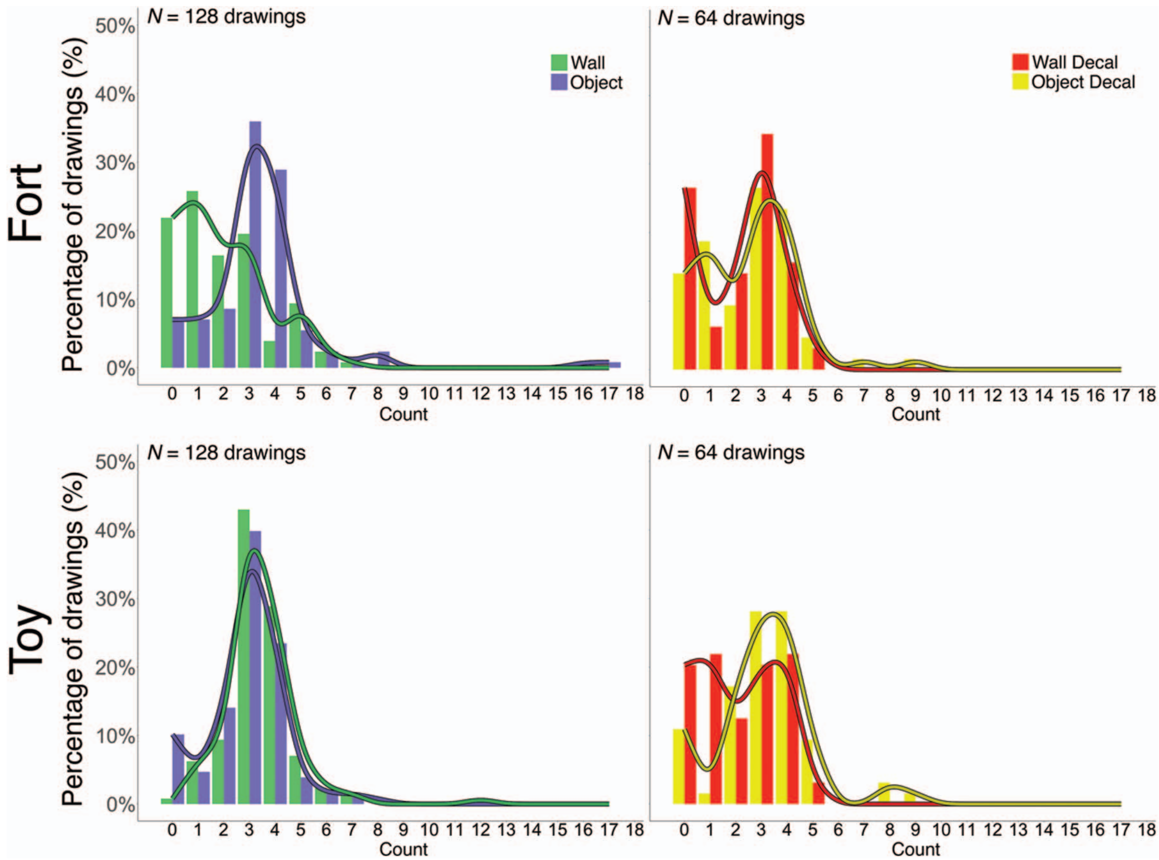

Figure 2. The raw counts of spatial elements for the fort (Experiment 1, top) and toy (Experiment 2, bottom) for the four configurations in which there were walls and objects (left) and for the two configurations in which there were also wall decals and object decals (right). To illustrate the distribution of these counts, overlaid on each set of counts is a smooth curve, generated by a kernel regression on Count and Percentage. Across all configurations of the fort, the count distribution for walls is strikingly different from the count distributions for all of the other spatial elements, with wall counts peaking at 0–1 and other element counts peaking at 3–4. In contrast, across all configurations of the toy, the count distribution for walls is strikingly similar to those for all other spatial elements, with element counts peaking at 3–4. See the online article for the color version of this figure.

tional Review Board on the Use of Human Subjects at New York University.

Materials and procedures. The toy in Experiment 2 mimicked the fort in Experiment 1 in materials and procedures. A 3D-printed, plastic scale model of the fort at 1/20 the size, matching the fort exactly in color and configuration, was created (see Figure 1). Although all the parts of the toy were now "objects" and the toy was always described as a toy (never as, e.g., a "model fort"), for ease of comparison, the parts of the toy that correspond to the walls of the fort are referred to as "walls" and the parts of the toy that correspond to the objects in the fort are referred to as "objects" throughout the remainder of this paper.

Children entered the testing room with two experimenters (one primary experimenter and one coder) and sat in a child-sized chair at a small table. The experimenter sat at the table, orthogonal to the children, and the coder stood behind children to one side. The toy was on top of the table, positioned 30.48 cm from children and at their eye level, with the back wall of the toy subtending 11.46 degrees of visual angle in the vertical direction and 10.89 degrees of visual angle in the horizontal direction. These visual properties of the toy and the child's position outside of it, along with the toy's size, which was small enough for the child to comfortably grasp with their hands, thus presented visual cues consistent with it being a manipulable object with different parts, its intended spatial category. The toy was covered with opaque white fabric as children entered and left the room so that they did not see the toy from an overhead perspective. The table, as well as the side walls of the room, were also covered with opaque white fabric to cover any of the room's salient features. One camera was placed behind children, and one was placed next to the experimenter.

Children completed the same practice trial as in Experiment 1 and then moved on to the test trials, which were presented in the same semicounterbalanced order as in Experiment 1. For the test trials, the experimenter waved their hand in front of the toy and said, "Do you see this super cool toy? I'm going to give you another piece of paper, and your job is to draw exactly what you see." The coder and experimenter followed the preregistered coding procedure from Experiment 1. The only difference was that in

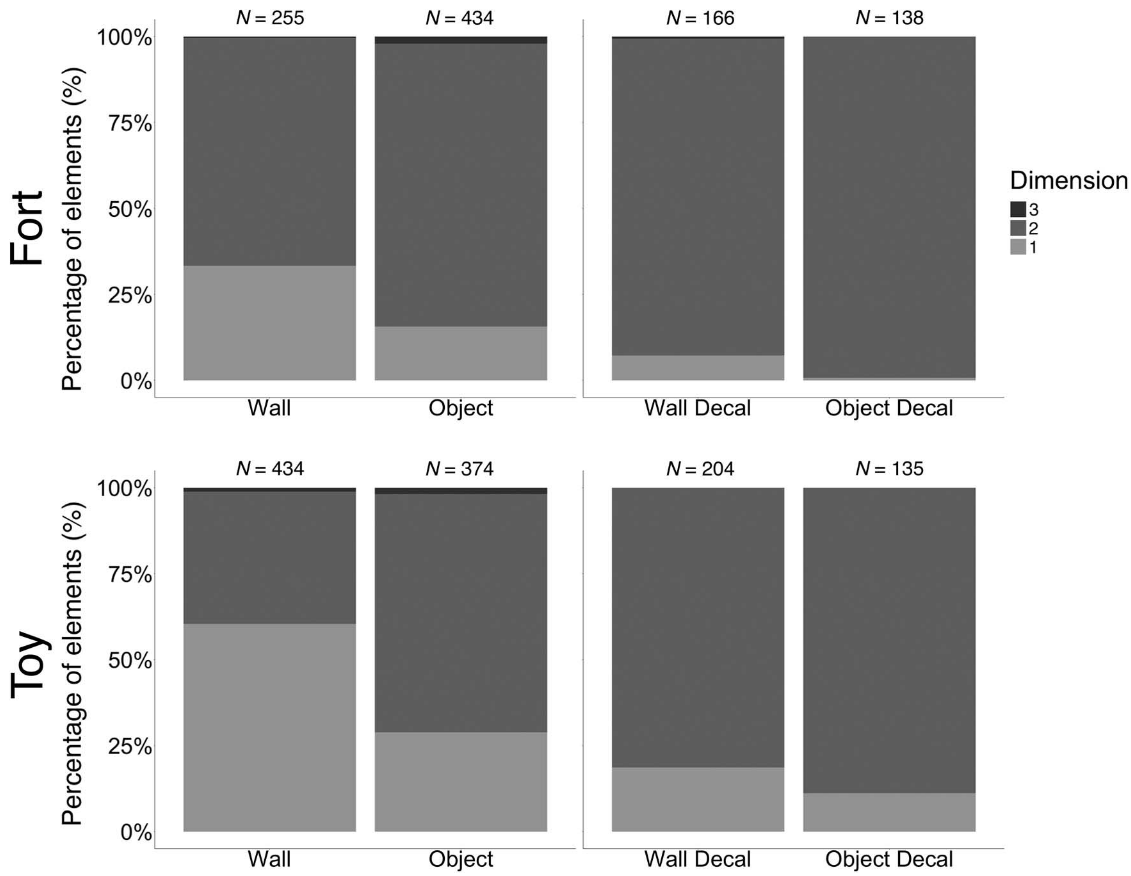

Figure 3. The percentages of spatial elements drawn at different dimensionalities for the fort (Experiment 1, top) and toy (Experiment 2, bottom) for the four configurations in which there were walls and objects (left) and for the two configurations in which there were also wall decals and object decals (right). For both the fort and toy, children drew the walls with less dimensionality than the objects. The *N*s indicate the number of elements reflected in each bar.

Experiment 2 children used a long plastic pointer, instead of their hands, to indicate the identity of each element of their drawing because the setup was small.

Analysis. All analyses were specified prior to data collection and preregistered on the OSF. As in Experiment 1, random-effects slopes were dropped from all analytic models. Reliability of the coding of the number of spatial elements that children drew was calculated as an intraclass correlation coefficient, and reliability was high: ICC(1,1) = .89, 95% CI [.85, .92]. As in Experiment 1, the dependent variables included the number of spatial elements that children drew and the dimensionality of those elements. Additional analyses directly compared the results of the two experiments to evaluate whether children drew more objects versus walls for the fort versus toy.

Results

Element counts. Figure 2 presents the raw distributions of wall and object elements across all four toy configurations as well as the wall decal and object decal elements across the two toy configurations that include them. In a first mixed-model Poisson regression examining wall and object counts across all four configurations of the toy, there were main effects of both spatial element (Wald test, $\chi^2[1] = 4.45$, $p = .035$) and configuration (Wald test, $\chi^2[3] = 12.41$, $p = .006$). Although there was a prediction of no difference in the spatial element count, children showed the opposite pattern for the toy in Experiment 2 compared with the fort in Experiment 1: Children drew more walls than objects (see Figure 2 and Figure S1 in the online supplemental material). In the regression considering the configurations with all four element types, there was also a main effect of spatial element (Wald test, $\chi^2[3] = 25.93$, $p < .001$), and planned Holm-corrected pairwise contrasts also revealed that children drew more walls than objects ($p = .005$; see Figure 2 and Figure S1 in the online supplemental material). Indeed, whereas children clearly drew more objects than walls in the fort condition, their drawing counts in the toy condition may have roughly reflected the relative real-world sizes of each of the element types. That said, in the analysis of the configurations without decals and the analysis of the data coded by the naïve coder, the greater counts for walls versus objects was less consistent than in the main analysis (see Figures S2 and S3 in the online supplemental material), so this size-based effect may be weak.

Dimensionality. The next analysis measured the dimensionality of the spatial elements. Unexpectedly, children drew objects with more dimensionality than walls, as in the fort condition. The odds of children's drawing objects with greater dimensionality were 1824% more likely than the odds of children's drawing walls with greater dimensionality (95% CI [982, 3321], $p < .001$; see Figure 3). This effect persisted when just examining the two configurations with decals: The odds of children's drawing objects with greater dimensionality were 897% more likely than the odds of children's drawing walls with greater dimensionality (95% CI [446, 1723], planned Holm-corrected pairwise contrast, $p < .001$; see Figure 3 and Table S1B in the online supplemental material).

Comparing children's drawings of the fort and toy.

Element counts. To directly examine the differences in children's drawings across the two experiments, the same mixed-model regressions were conducted as above, but with experiment as an additional predictor variable. First, for element count, including walls and objects across all four configurations, there were main effects both of spatial element (children drew more objects than walls; Wald test, $\chi^2[1] = 8.55$, $p = .003$) and of experiment (children drew more elements for the toy versus fort; Wald test, $\chi^2[1] = 7.44$, $p = .006$). Critically, these results were further characterized by a significant spatial element by experiment interaction (Wald test, $\chi^2[1] = 41.44$, $p < .001$): Children drew significantly more walls than objects for the toy versus fort. Planned Holm-corrected pairwise contrasts revealed that children did not draw significantly more objects for the toy versus fort ($p = .082$), but they did draw significantly more walls for the toy versus fort ($p < .001$). The second regression, examining element counts in the two configurations with four spatial elements also revealed main effects of both spatial element (Wald test, $\chi^2[3] = 17.79$, $p < .001$) and experiment (Wald test, $\chi^2[1] = 5.06$, $p = .024$) as well as an interaction between these variables (Wald test, $\chi^2[3] = 33.40$, $p < .001$). Again, planned Holm-corrected pairwise contrasts revealed that children did not draw significantly more objects for the toy versus fort ($p = .188$), but they did draw significantly more walls for the toy versus fort ($p < .001$).

Dimensionality. Finally, a mixed-model ordinal logistic regression examining element dimensionality for walls and objects across all four configurations revealed that, across experiments, children drew objects with more dimensionality than walls (change in odds ratio: 211%, 95% CI [106, 369], $p < .001$). Children also drew elements with greater dimensionality for the fort versus toy (change in odds ratio: 77%, 95% CI = [65, 84], $p < .001$), and children drew objects versus walls with greater dimensionality for the toy versus fort (change in odds ratio: 127%, 95% CI [32, 288], $p = .003$). The model including all four element types was convergent with these results. Children drew objects with greater dimensionality than walls (change in odds ratio: 201%, planned Holm-corrected pairwise contrast, 95% CI [60, 466], $p < .001$), and their drawings had greater dimensionality for the fort versus toy (change in odds ratio: 82%, 95% CI [68, 89], $p < .001$). Children also drew objects versus walls with greater dimensionality for the toy versus fort (change in odds ratio: 170%, planned Holm-corrected pairwise contrast, 95% CI [19, 512], $p = .053$).

Discussion

In this experiment, children were asked draw exactly what they saw while sitting in front of a colorful toy with figure and ground elements that matched the fort from Experiment 1. Young children drew the toy's parts that corresponded both to the fort's objects and to the fort's walls. These results suggest that children's omission of layout information from their drawings in Experiment 1 was not attributable to the more general spatial phenomenon that children include figural but not ground elements in their drawings.

Children's drawings in Experiment 2 did nevertheless shed light on some additional spatial phenomena that might affect children's drawings, like the real-world sizes of what is being drawn and the arrangements of the parts of what is being drawn (e.g., whether the background elements form a concave shape). Children's inclusion of spatial elements for the toy roughly corresponded to the elements' relative real-world sizes: The toy's walls, its largest elements, were drawn most frequently, while the toy's object decals, its smallest elements, were drawn least frequently. This size effect was not present in Experiment 1, however, so it is not generalizable across spatial contexts (otherwise children would have drawn the fort's walls most frequently as well). When children did draw the walls of the fort, their depictions showed some similarities to children's depictions of the walls of the toy: In both experiments, children tended to draw the walls with less dimensionality than the objects. While this result was not predicted, it may have been due to the more general challenge of drawing concave backgrounds, present in both spatial contexts. Indeed, these results (with background information being depicted with less dimensionality) are consistent with other studies using 3D toy models as tests of children's layout depictions (e.g., Lange-Küttner, 2014). The results of Experiment 2 thus suggest that while there may have been some limited effects of more general spatial phenomena such as real-world size and background concavity on children's drawing, the predominant effect is that children often omitted the walls composing the fort's layout but included the corresponding object parts for the toy.

General Discussion

Decades of work exploring young children's drawings suggest a prevalence of object depictions (e.g., Cox, 2005; Gardner, 1980; Machón, 2013; Piaget & Inhelder, 1948/1967). The present study tested this suggestion across two experiments by comparing in young children's drawings the frequency and richness of large, fixed layout information and small, manipulable-object information using stimuli matched on shape, complexity, and spatial arrangement. When drawing a layout, children tended to juxtapose objects and omit extended boundaries. When drawing a toy replica of the layout, in contrast, children captured all the elements, including those in the background. These findings are based on a difference in spatial category alone and so are the first to show clearly that young children's drawings prioritize objects over layouts.

Why do children draw objects but not layouts? One possibility is that basic differences in the way not only children, but also adults and nonhuman animals, attend to layouts and objects for everyday navigation might affect what and how children draw. While humans and other animals use layout information automatically to determine their position in space (e.g., Cheng & Gallistel, 1984; Cheng & Newcombe, 2005; Hermer & Spelke, 1994, 1996; Spelke & Lee, 2012), they must attend to and learn associations between their position in space relative to distinct landmark objects (e.g., Barry & Muller, 2011; Doeller & Burgess, 2008; Doeller et al., 2008; Shusterman, Lee, & Spelke, 2011; Twyman, Friedman, & Spetch, 2007). This same dissociation of automaticity and attention to layouts and objects is also evident in children's symbol-guided navigation, like their navigation by maps and pictures (Dillon, Huang, & Spelke, 2013; Dillon & Spelke, 2015, 2017). Objects also elicit attention in many everyday contexts (e.g., Evans, Rotello, Li, & Rayner, 2009; Scholl, 2001) and heightened attention to objects as individuated entities as opposed to mere spatial extents is present from infancy (e.g., Feigenson & Carey, 2005; Feigenson, Carey, & Hauser, 2002). Moreover, objects serve as the referents for infants' earliest symbolic learning: language. Infants first learn the names for objects (Gentner, 1982; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), and they use language to generalize object categories based on shape and function from as early as 6 months of age (Fulkerson & Waxman, 2007; Futó, Téglás, Csibra, & Gergely, 2010). Because drawings, like language, are symbolic, intentional, and communicative (see Callaghan & Corbit, 2015), children may prioritize in their drawings those elements in the environment that naturally elicit explicit attention.

Another, not mutually exclusive possibility, is that children prioritize objects over layouts in drawings because layouts pose unique geometric challenges to drawing. In particular, the geometry of a scene's large-scale layout may be more difficult to draw than the shapes of small-scale objects. Layout navigation tends to rely on the distances and directions of large boundary surfaces (e.g., Julian, Keinath, Marchette, & Epstein, 2018; Lee, Sovrano, & Spelke, 2012; O'Keefe & Burgess, 1996; Persichetti & Dilks, 2016), while recognition of objects tends to rely on the relative lengths and angles that define small object parts (e.g., Biederman & Cooper, 1991; Smith, 2009). Drawing distance or depth information on a 2D surface is difficult in general (e.g., Kosslyn, Heldmeyer, & Locklear, 1977), as perhaps exemplified in the present study by children's tendency to depict the concave shape formed by the walls of the fort and the corresponding object parts of the toy using only single lines. Because distance information is primary for layout navigation but not object recognition, however, the difficulty in capturing large-scale layout distances as small-scale shapes on a 2D surface may be particularly challenging. For objects, in contrast, the very same small-scale shape information is used both to recognize objects in everyday life and to draw them on a 2D surface (Fan, Yamins, & Turk-Browne, 2018; Sayim & Cavanagh, 2011). Indeed, though by age 3 to 4 years children can capture object shape information in their drawings (e.g., Cox, 2005; Drake & Winner, 2012; Villarroel & Ortega, 2017), they have difficulty incorporating receding depth information into their drawings through early adolescence (e.g., Freeman, 1980; Willats, 1995). To most easily convey the layout of a scene, children may thus merely juxtapose objects in drawings, giving a nevertheless reasonable sense of the layout's general arrangement. Future studies might explore whether there are differences in the difficulty of drawing depth information that describes layouts versus objects or whether, if children are asked to construct 3D models instead of making 2D drawings, they still leave out layout elements. Future studies might also explore whether, when children do draw layouts, they use other spatial cues to indicate depth, like size, position, or overlapping, differently for layouts versus objects (e.g., Freeman et al., 1977; Lange-Küttner, 1997).

Differences between the fort and the toy's spatial categories in the present study were also reinforced in two different ways, through both visual cues and verbal descriptions: The fort was a large navigable space that children could go inside, and the experimenter always referred to it that way; the toy was small and manipulable by children's hands, and the experimenter always referred to it that way. It may be that either of these methods of conveying spatial category—through visual cues or through language—led to the observed pattern of results. Future studies might examine the individual effects of these two manipulations by using different language applied to the exact same visual stimulus (i.e., referring differently to the same 3D space, 3D model, or even 2D photograph).

While drawings reflect complex causal interactions among cognition, culture, and development, the aforementioned possibilities as to why children prioritize objects over layouts in drawings suggest that intuitive geometries, shared by humans with other animals, may play a previously unrecognized role in what and how humans draw. Such geometries may be an additional cognitive constraint that informs a cultural expression. The tools and technologies we humans have developed to aid our drawing of layout geometry might thereby belie the initial cognitive challenge of intuitively drawing layouts (e.g., Gombrich, 1960/2000). The effects observed in the present study might thus be especially evident in the drawings of young children, who have been exposed to less formal art instruction and fewer examples of their culture's artistic traditions, such as instruction to draw horizon lines in specific ways (Nand, Masuda, Senzaki, & Ishii, 2014) or technological innovations, such as visual aids like predrawn spatial axes that highlight the geometry of layouts for drawing (Lange-Küttner, 2009, 2014). Moreover, anthropologists and art historians alike have noted the puzzling absence of explicitly drawn layout information in adult human drawings from around the world dating from prehistory (Clottes, 2008; Fritz, 2017; White, 2003). And even today, in the wake of cultural and technological innovations that have facilitated our depiction of layouts, objects may still be prioritized in the drawings of skilled adults. For example, an analysis of around 500 drawings from children's books recently awarded the Caldecott Medal (for their illustrations) revealed that only 2.5% of drawings included just layout information, while 7.2% of drawings included just object information (a statistically significant difference; Dillon & Spelke, 2017). To examine the host of factors that might be driving children to prioritize objects over layouts in drawings in the present study, future studies could examine how both development and culture affect human drawings of layouts and objects.

Finally, if intuitive spatial categories for layouts and objects shared with other animal species affect human drawing, then other such basic categories might as well. For example, are we more likely to pay attention to potential social partners over objects, and so depict people more often than objects? Or are objects more likely to be drawn because we use drawings to communicate to people about the properties and functions of objects? Might the shapes of people and other biological kinds be easier to draw than the shapes of some objects because their 3D geometry is easily recoverable from a set of skeletal exes (Feldman & Singh, 2006)?

Future studies varying the content and geometry of drawing subject matter may begin to address these questions. Likewise, varying the communicative intent of drawings, including what information is important to the purpose of the drawing (e.g., to show someone where something is or what something does), may shed light on what attentional hierarchies are present in everyday life and translate to our picture-making.

While drawing may seem like an epitome of relatively unconstrained human expression, especially in young children, the present study has revealed a clear, early emerging bias in human drawing. Drawings prioritize a scene's small-scale objects over its large-scale and fixed layout geometry. Among the complex interactions of cognition and culture that explain this bias in children's drawings, a previously unrecognized cognitive constraint deriving from phylogenetically ancient but distinct cognitive domains for navigating layouts and recognizing objects may also shape our art. To better understand an individual's artistic development or even the history of art, we must better understand the cognitive constraints that frame human drawings.

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