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What Counts as *By*? Young Children's Use of Relative Distance to Judge Nearbyness

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The authors investigated how 3- and 4-year-old children and adults use relative distance to judge nearbyness. Participants judged whether several blocks were *by* a landmark. The absolute and relative distance of the blocks from the landmark varied. In Experiment 1, judgments of nearbyness decreased as the distance from the landmark increased, particularly for 4-year-olds and adults. In Experiment 2, 4-year-olds and adults were more likely to judge objects at an intermediate distance as *by* the landmark when intervening objects were absent than when intervening objects were present. In Experiment 3, participants of all ages were more likely to judge objects at a short distance as *by* the landmark when intervening objects were absent. Reliance on relative distance to judge nearbyness becomes more systematic and applicable to larger spatial extents across development.

Keywords: spatial language, spatial cognition, cognitive development, proximity, landmarks

The ability to communicate about location is a universal human phenomenon, occurring in all languages and cultures. Clearly, learning to talk about location constitutes a significant language milestone for young children. In English, speakers use prepositions or prepositional phrases to convey spatial information (e.g., "on top of the refrigerator," "by the sink"). Much of the early work on the development of spatial language focused on the order in which children acquire spatial terms (e.g., Clark, 1973, 1980; Dromi, 1979; Johnston & Slobin, 1979). For example, Johnston and Slobin (1979) examined the production of spatial terms among children between the ages of 24 and 56 months whose native languages were English, Italian, Serbo-Croatian, and Turkish. In general, a similar order of acquisition of spatial terms emerged across these languages. Children first produced terms such as *in*, *on*, and *under* and only later produced terms such as *beside*, *by*, *near*, and *next to*. Although such studies have provided valuable information about when children begin to use spatial terms, researchers know very little about whether children's understanding of these spatial terms changes with development. In particular, do young children and adults understand spatial terms in the same way? The purpose of the present investigation was to examine how children's understanding of one spatial preposition—*by*—changes during early childhood.

The term *by* is based on the notion of relative proximity to a reference object (Herskovits, 1986; Landau & Jackendoff, 1993). According to Herskovits (1986), an object is said to be near another object if the distance between the two is less than or equal to some threshold; this threshold "is an implicit variable whose value is contextually determined" (p. 16). What contextual factors might influence people's decisions about whether one object is near another object? One factor may be relative distance. Thus, when deciding whether a target object is near a reference object, children might consider not only how far the target object is from the reference object (i.e., absolute distance) but also how far the target is from the reference object in relation to other nontarget objects (i.e., relative distance). Without an appreciation of the importance of relative distance in judging nearbyness, young children may have difficulty determining how close two objects must be to be classified as near one another. For example, a decision as to whether Park A is near one's home depends not only on the distance between home and the park but also on the distance between home and the other parks in town (e.g., Park B). If Park B is closer to home than is Park A, then Park A might not be judged as near one's home. Another contextual factor that may influence decisions about nearbyness is relative size (i.e., scale; for integrative discussions of the importance of scale, see Acredolo, 1981; Liben, 1988). People may judge two locations that are separated by a particular distance as near each other when the scale of the space is large (e.g., a big city) but not when the scale of the space is small (e.g., a small town). Likewise, people may judge that an object is near a landmark when the two are similar in size (e.g., two buildings) but not when the two are radically different in size (e.g., a pencil and a building). Although there are other contextual factors that influence judgments of nearbyness (e.g., familiarity, stability), it seems likely that relative distance and relative size play major roles when people are deciding whether

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two objects or places are near each other. In fact, these two factors often work together. For example, locations that are a mile apart in a small town are likely to have many more intervening than nonintervening locations (making them seem far apart), whereas in a big city, locations that are a mile apart are likely to have many more nonintervening than intervening locations (making them seem close together). Thus, although it is possible to separate these factors experimentally, they often overlap in everyday environments.

Given the complexity of making judgments of nearbyness on the basis of relative information, the term *by* might present a challenge to young language learners. In fact, Piaget and Inhelder (1948/1967) proposed that children's understanding of relative information (i.e., proportional reasoning) emerges during the formal operational stage. More recently, researchers have challenged this notion, suggesting instead that young children can use relative coding in rudimentary ways but that this ability becomes more sophisticated with age (Huttenlocher, Duffy, & Levine, 2002; Huttenlocher, Newcombe, & Vasilyeva, 1999; MacDonald, Spetch, Kelly, & Cheng, 2004; Vasilyeva & Huttenlocher, 2004). For example, Huttenlocher et al. (1999) asked 3- and 4-year-old children to use a dot marked on a map to find a disk hidden in a long, narrow sandbox. Overall, the 4-year-olds were quite successful in finding the hidden disk. In contrast, only about half of the 3-year-olds were successful. The remaining 3-year-olds were unable to find the disk, instead responding randomly or perseveratively. More recently, Vasilyeva and Huttenlocher (2004) investigated the development of relative coding involving a 2-D space. Four- and 5-year-olds saw a dot on a rectangular map and were asked to place a toy at the corresponding location on one of two larger rectangular rugs. The rugs differed in size to allow for assessment of the effects of scale on relative coding abilities. In this more complex 2-D space, 5-year-olds were more successful than 4-year-olds at placing the objects in the correct locations. In fact, one third of the 4-year-olds responded randomly. Moreover, preschoolers were less accurate when placing the toy on the larger rug than they were when placing it on the smaller rug. Together, these findings suggest that young children's ability to code relative extent undergoes change during the preschool years. Whereas only some 3-year-olds appreciate relative distance and use it to locate objects along one dimension, 4-year-olds consistently use relative distance to locate objects along a single dimension. Furthermore, 5-year-olds consistently use relative information in a more challenging task involving two dimensions, though they are more successful when the scale difference between the map and the space is smaller.

The idea that young children might have difficulty with the terms *by* and *nearby* also is consistent with research on young children's referential communication. This work has shown that preschool children have difficulty using proximity terms to disambiguate identical hiding locations even after they can produce the terms successfully (Plumert, Ewert, & Spear, 1995; Plumert & Hawkins, 2001). For example, Plumert and Hawkins (2001) compared young children's uses of *in* and *by* to disambiguate identical hiding locations. In one experiment, 3- and 4-year-olds described the location of a miniature mouse hidden in a one-room model house. Several pairs of identical small objects (e.g., bags, pillows, hats) served as hiding locations. These small objects were always placed either *in* or *next to* (and touching) a piece of furniture (e.g., a crib). Thus, to unambiguously describe the location of the mouse, children needed to refer to the relation between the mouse and the small object and to the relation between the small object and the furniture landmark (e.g., "The mouse is *under* the pillow *in* the crib"). Both 3- and 4-year-olds' descriptions almost always included a reference to the small object (e.g., "The mouse is under the pillow"), but children were more likely to provide a reference to the furniture landmark when the small object was *in* the furniture item than when the small object was *by* the furniture item. In a similar experiment, 3- and 4-year-old children searched for the hidden mouse using a description provided by the experimenter (e.g., "The mouse is in the bag next to the dresser"). Three-year-olds took longer to find the mouse when it was hidden in a small object next to a landmark than when it was in a small object that was in a landmark. Search latencies did not differ across spatial relations for the 4-year-olds (Plumert & Hawkins, 2001). Together, these findings suggest that children's use of proximity terms such as *by* is undergoing change during early childhood.

The goal of the present investigation was to examine how the use of relative distance in judgments of nearbyness changes during the preschool years. Previous research has demonstrated important differences in the ways in which 3- and 4-year-olds make use of relative information and communicate about nearbyness (e.g., Gentner & Ratterman, 1991; Huttenlocher et al., 1999; Plumert et al., 1995; Plumert & Hawkins, 2001; Vasilyeva & Huttenlocher, 2004). Thus, we expected to find developmental differences in young children's use of relative distance in their judgments of nearbyness. In particular, we expected that 3-year-olds would use relative distance less systematically and across a narrower scale than would 4-year-olds. We included adults in this investigation to provide a benchmark for mature understanding of the term *by*.

In Experiment 1, 3- and 4-year-old children and adults were asked to judge whether several small blocks surrounding a larger box (i.e., a landmark) were *by* the box. The blocks were arranged in three roughly concentric circles, designated as the *inner*, *middle*, and *outer* blocks. We expected that participants of all ages would be less likely to judge blocks as *by* the landmark as the distance between the blocks and the landmark increased. Thus, participants would be most likely to judge the blocks nearest to the landmark (i.e., the inner blocks) as *by* the landmark and least likely to judge the blocks farthest away from the landmark (i.e., the outer blocks) as *by* the landmark. This demonstration was an important first step in our systematic examination of young children's use of relative distance in their judgments of nearbyness.

The second and third experiments directly examined the influence of relative distance on judgments of nearbyness. The task was identical to that used in the first experiment, with the exception that only a subset of the blocks was used in each condition. We focused on participants' responses to a target set of blocks that were always at the same absolute distance from the landmark but were at different relative distances from the landmark. In one condition, we included additional blocks closer to the landmark, making the target blocks relatively far from the landmark. In the other condition, we included additional blocks further from the landmark, making the target blocks relatively close to the landmark. We expected that the older children and adults would systematically use relative distance to interpret the proximity term *by*. That is, we expected that 4-year-olds and adults would judge the target blocks as *by* the landmark when other blocks did not intervene but would not judge the target blocks as *by* the landmark when other blocks intervened. In contrast, we expected that 3-year-olds would use distance less systematically when making nearbyness judgments, leading to less differentiation across distances. In other words, they would be less likely than older children and adults to judge the target blocks as *by* the landmark when these blocks were relatively close to the landmark and also more likely to judge target blocks as *by* the landmark when the blocks were relatively far from the landmark.

Experiment 1

Method

Participants. Twenty-four 3-year-olds (mean age = 3 years 8 months, range = 3 years 6 months to 3 years 9 months; 11 girls, 13 boys), twenty-four 4-year-olds (mean age = 4 years 8 months, range = 4 years 8 months to 4 years 9 months; 13 girls, 11 boys), and twenty-four adults (mean age = 19 years 2 months, range = 18 years 2 months to 22 years 1 month; 13 women, 11 men) participated. Children were from primarily middle- to upper-middle-class Caucasian families and were recruited through a child participant database maintained by the Department of Psychology at the University of Iowa. Most adults were from primarily middle- to upper-class Caucasian families. They were recruited from an introductory psychology course at the University of Iowa and received course credit for their participation.

Apparatus and materials. Twenty-one small wooden blocks (1.13 in. tall × 2.5 in. wide × 2.5 in. deep [2.87 cm × 6.35 cm × 6.35 cm]) were arranged on a 78-in. long × 48-in. wide (198.1 cm × 122 cm) piece of plywood covered with paper. The board was laid on the floor of the testing room. A short, blue box (5 in. on all sides [12.7 cm]) or a tall, red box (15 in. tall × 5 in. wide × 5 in. deep [38 cm × 12.7 cm × 12.7 cm]) stood at the center of the blocks and served as a landmark. The blocks were arranged so that 7 blocks were 6 in. (15.2 cm) from the edge of the box, 7 blocks were 12 in. (30.5 cm) from the edge of the box, and 7 blocks were 18 in. (45.7 cm) from the edge of the box. These sets of blocks were classified as the inner blocks, middle blocks, and outer blocks, respectively. The blocks were oriented in such a way as to minimize the appearance that they created concentric circles around the landmark (see Figure 1).

Design and procedure. Participants were randomly assigned to one of two conditions: *tall landmark* or *short landmark*. In the tall landmark condition, a tall, red box served as a landmark in the center of the blocks. In the short landmark condition, a short, blue box served as a landmark in the center of the blocks. This manipulation was designed to explore whether landmark size would influence the distance described as *by* the landmark. We predicted that children and adults might use *by* to describe a broader area when the landmark was tall than when the landmark was short (see Sadalla, Burroughs, & Staplin, 1980, for similar ideas). As it turned out, this variable did not affect performance in any of the analyses below and, therefore, is not discussed further.

Participants were tested individually in the laboratory. They were seated on a chair approximately 28 in. (70 cm) from the edge of the board. Participants were asked to make a judgment about the proximity of each block to the box. The experimenter first marked the location by placing a small (4-cm) flat disk on the target block. She then asked, “Do you think this block is *by* the box or *not by* the box?” Participants were asked this question for each of the 21 blocks. The order of blocks was randomized for each participant.

Coding and measures. The experimenter recorded the participants' judgments for each block. For each participant, we then calculated the proportion of blocks at each distance (i.e., inner, middle, and outer) that were judged to be *by* the landmark.

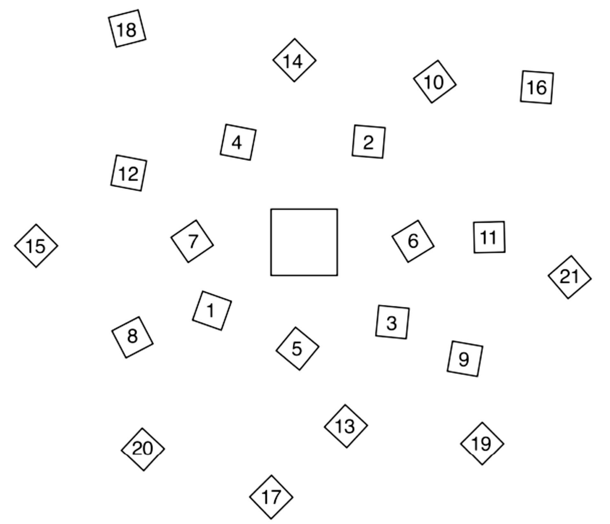

Figure 1. Diagram of the block layout and landmark used in Experiment 1. Blocks 1–7 constituted the inner blocks, Blocks 8–14 constituted the middle blocks, and Blocks 15–21 constituted the outer blocks. (Block numbers are for illustration only.)

Results: Mean Proportion of By Responses

The primary question of interest was how judgments of nearbyness varied with distance from the landmark. To address this question, we entered the mean proportions of *by* responses into an Age (3 years vs. 4 years vs. adult) × Distance (inner blocks vs. middle blocks vs. outer blocks) repeated measures analysis of variance (ANOVA) with the first factor as a between-subjects factor and the second as a within-subject factor.[1] There was a significant effect of distance, $F(2, 138) = 340.15$, $p < .01$, $\eta^2 = .62$, and a significant Age × Distance interaction, $F(4, 138) = 9.43$, $p < .01$, $\eta^2 = .03$. Simple effects tests revealed a significant effect of distance on the proportion of *by* responses for 3-year-olds, $F(2, 23) = 40.31$, $p < .01$, $\eta^2 = .33$; for 4-year-olds, $F(2, 23) = 109.50$, $p < .01$, $\eta^2 = .68$; and for adults, $F(2, 23) = 361.75$, $p < .01$, $\eta^2 = .90$ (see Figure 2). Fisher's protected least significant difference (PLSD) follow-up tests revealed that 3-year-olds judged that a significantly larger proportion of the inner than the middle and outer blocks were *by* the box (see Figure 2). The proportions of middle and outer blocks judged to be *by* the box did not differ significantly, however. Like the 3-year-olds, 4-year-olds and adults judged that a significantly larger proportion of the inner than the middle and outer blocks were *by* the box. However, 4-year-olds and adults also differentiated between the middle and outer blocks. They judged that a significantly larger proportion of middle than the outer blocks were *by* the box (see Figure 2).

Additional simple effects tests examining age differences for each distance revealed a significant effect of age on the proportion of *by* responses for the inner blocks, $F(2, 69) = 4.79$, $p < .05$, $\eta^2 = .12$, and for the outer blocks, $F(2, 69) = 5.67$, $p < .01$, $\eta^2 =$

[1] Preliminary analyses revealed no differences that were due to landmark condition (tall box vs. short box), so results were collapsed across this factor in all analyses.

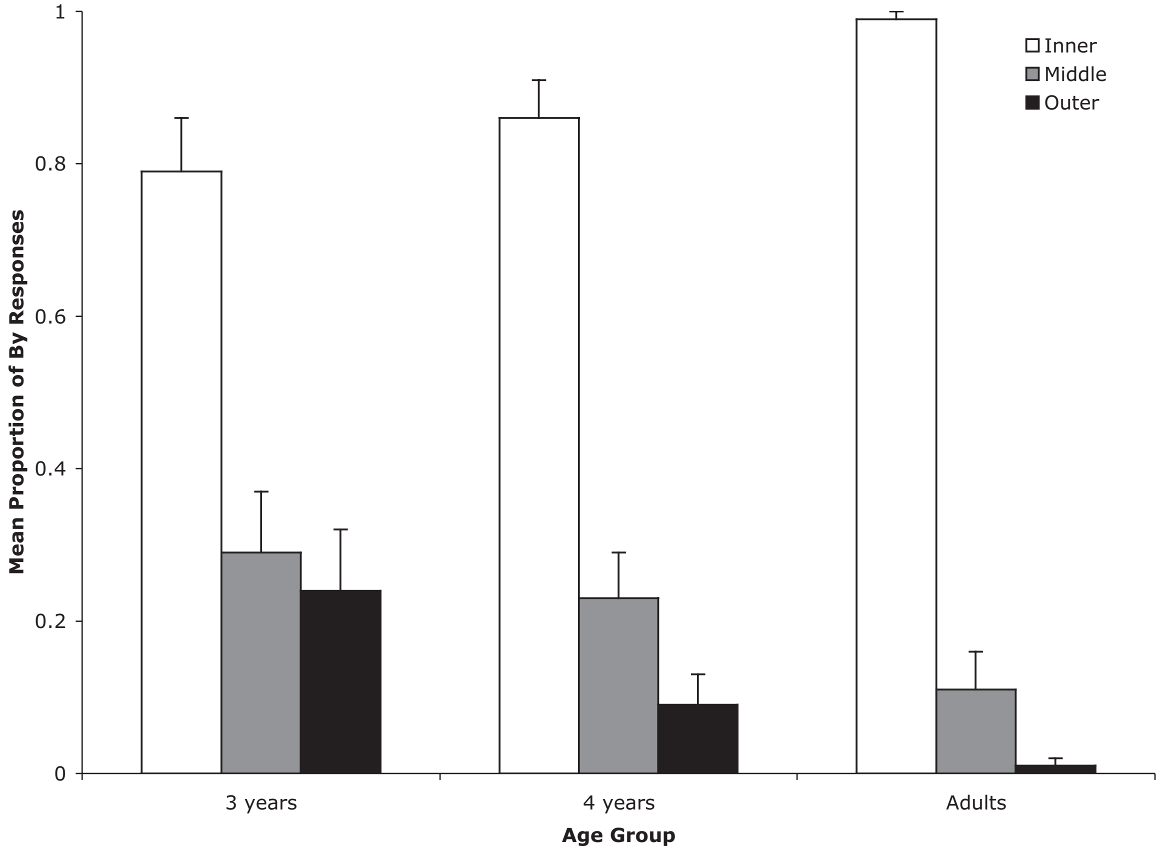

Figure 2. Mean proportions of *by* responses to the inner, middle, and outer blocks for each age group in Experiment 1. Error bars represent standard errors.

.14, but not for the middle blocks, $F(2, 69) = 2.22$, *ns*, $\eta^2 = .06$ (see Figure 2). Fisher's PLSD follow-up tests revealed that the 3-year-olds judged that a significantly smaller proportion of the inner blocks were *by* the box than did the adults. The judgments of 4-year-olds and adults did not differ significantly. Follow-up tests also revealed that 3-year-olds judged that a significantly larger proportion of the outer blocks were *by* the box than did the 4-year-olds and adults. Again, the judgments of 4-year-olds and adults did not differ significantly.

Discussion

The goal of the present experiment was to examine how 3- and 4-year-old children and adults interpret the term *by* when it is used to describe proximity relations. In particular, does the distance between an object and a landmark affect the interpretation of the term *by*? As expected, the likelihood of describing a block as *by* the landmark box decreased as the blocks got further from the box. Children and adults were much more likely to judge the blocks closest to the landmark as *by* the box than they were to judge the blocks at the middle and farthest distances as *by* the box. These findings indicate that distance affects judgments of nearbyness for both children and adults.

There were also developmental differences in the ways in which participants interpreted the relation between the blocks and the landmark box. In general, the 3-year-olds' judgments regarding nearbyness were less differentiated than were those of the 4-year-olds and adults. That is, although all age groups were significantly more likely to judge the closest blocks to be *by* the box relative to the middle and outer blocks, the 3-year-olds' judgments of the middle and outer blocks did not differ. In contrast, 4-year-olds and adults were significantly more likely to judge the middle blocks as *by* the box relative to the outer blocks. Comparisons across age groups also supported this conclusion. The 3-year-olds were significantly less likely than were the adults to judge that the inner blocks were *by* the landmark. Moreover, the 3-year-olds were significantly more likely to judge that the outer blocks were *by* the landmark than were the 4-year-olds and adults. Together, these findings suggest that 3-year-olds were less systematic about what counted as *by* than were the 4-year-olds and adults.

What might account for the differences in judgments across distances? It is possible that the absolute distance between each block and the landmark influenced the likelihood of describing it as *by* the box. According to this interpretation, the blocks at the closest distance were judged to be *by* the box because they were less than some threshold distance from the landmark. A more likely possibility is that the relative distances between the blocks and the landmark influenced responding. That is, perhaps children and adults were most likely to judge the closest set of blocks as *by* the landmark, regardless of their absolute distance from the box. This would suggest that the absence of intervening blocks between the inner blocks and the landmark, rather than the absolute distance from the landmark, determined *by* judgments. In support of this latter interpretation, the proportion of *by* responses for all three age groups dropped precipitously from the inner blocks to the middle blocks.

The goal of Experiment 2 was to investigate whether young children and adults use relative distance when making judgments of nearbyness. As in the first experiment, 3- and 4-year-old children and adults judged whether several blocks were *by* a landmark. In the *intervening* condition, participants judged blocks that were 15.2 cm and 30.5 cm from the landmark. In the *nonintervening* condition, participants judged blocks that were 30.5 cm and 45.7 cm from the landmark. (Note that the 30.5-cm blocks were the “middle” blocks in Experiment 1). Of particular interest was how children and adults in the two experimental conditions judged the blocks that were at the target 30.5-cm distance. If nearbyness depends on the relative locations of the blocks and the landmark, then participants’ judgments for the blocks 30.5 cm from the landmark should differ across conditions. We expected that the older children and adults would systematically use relative distance to interpret the proximity term *by*. That is, we expected that 4-year-olds and adults would judge the middle blocks as *by* the landmark when other blocks did not intervene. In contrast, we expected that they would not judge these blocks as *by* the landmark when other blocks intervened, indicating that relative distance influences *by* judgments. We expected that the 3-year-olds’ judgments would rely less heavily on relative distance and would be less systematic overall.

Experiment 2

Method

Participants. Twenty-four 3-year-olds (mean age = 3 years 9 months, range = 3 years 7 months to 3 years 11 months; 13 girls, 11 boys), twenty-four 4-year-olds (mean age = 4 years 9 months, range = 4 years 0 months to 4 years 11 months; 12 girls, 12 boys), and twenty-four adults (mean age = 19 years 3 months, range = 18 years 1 month to 22 years 2 months; 13 women, 11 men) participated. Children and adults were from primarily middle- to upper-middle-class Caucasian families. Participants were recruited in the same manner as in Experiment 1.

Apparatus and materials. The apparatus was identical to that used in Experiment 1, except only the short, blue landmark was used.

Design and procedure. Participants were randomly assigned to one of two conditions: intervening and nonintervening. In the intervening condition, the 7 inner blocks (those 15.2 cm from the box) and the 7 target blocks (those 30.5 cm from the box) were present. In the nonintervening condition, the 7 target blocks and the 7 outer blocks (those 45.7 cm from the box) were present (see Figure 3). Thus, only 14 of the 21 blocks from Experiment 1 were used for each participant.

As in Experiment 1, participants were asked to respond to the following question for each of the 14 blocks: “Do you think this block is *by* the box or *not by* the box?” The order of blocks was randomized for each participant.

Coding and measures. The coding and measures were identical to those used in Experiment 1.

Results

Mean proportions of by responses to the target blocks. The primary question of interest was whether children and adults were more likely to judge the target blocks (i.e., those 30.5 cm from the box) as *by* the box when no intervening blocks were present than they were when intervening blocks were present. The proportion of *by* responses for the target blocks was entered into an Age (3 years vs. 4 years vs. adult) × Condition (intervening vs. nonintervening blocks) ANOVA. If the relative position of blocks influences judgments of nearbyness, we would expect to find differences in responding across conditions. Indeed, there was a significant effect of condition, $F(1, 66) = 49.21$, $p < .01$, $\eta^2 = .37$, and a significant Age × Condition interaction, $F(2, 66) = 6.44$, $p < .01$, $\eta^2 = .10$. The proportions of *by* responses to the target blocks for each age group and condition can be seen in Figure 4. Simple effects tests indicated that the difference across conditions was significant for the 4-year-olds, $F(1, 22) = 12.60$, $p < .01$, $\eta^2 = .36$, and for the adults, $F(1, 22) = 89.58$, $p < .01$, $\eta^2 = .80$, but not for the 3-year-olds, $F(1, 22) = 2.52$, *ns*, $\eta^2 = .10$. Four-year-olds and adults in the nonintervening condition were significantly more likely to judge that the target blocks were *by* the landmark than were their counterparts in the intervening condition: for 4-year-olds, $M = .50$, $SD = .33$ (nonintervening), and $M = .11$, $SD = .19$ (intervening); for adults, $M = .91$, $SD = .29$ (nonintervening), and $M = .06$, $SD = .11$ (intervening). Judgments of 3-year-olds in the nonintervening and intervening conditions did not differ significantly—$M = .54$, $SD = .36$ (nonintervening), and $M = .29$, $SD = .41$ (intervening)—though the difference was in the same direction as for the older age groups.

To further determine the source of the Age × Condition interaction, we examined the pattern of age differences for each condition. Simple effects tests revealed significant age differences in the proportion of *by* responses in the nonintervening condition, $F(2, 33) = 5.67$, $p < .01$, $\eta^2 = .26$, but not in the intervening condition, $F(2, 33) = 2.32$, *ns*, $\eta^2 = .12$. Fisher’s PLSD follow-up tests revealed that in the nonintervening condition, adults judged that a significantly larger proportion of the target blocks were *by* the box than did the 3- and 4-year-olds. The children’s judgments did not differ significantly (see Figure 4).

Mean proportions of by responses to the inner and target blocks. How systematically did children and adults respond to the intervening (i.e., inner) blocks versus the target blocks? As in Experiment 1, we expected that participants’ *by* responses would decrease as the distance between the blocks and the landmark increased. Thus, we expected that children and adults would be more likely to judge that the inner than the target blocks were *by* the landmark. The mean proportion of *by* responses to the inner and target blocks for participants in the intervening condition was entered into an Age (3 years vs. 4 years vs. adult) × Distance (inner blocks vs. target blocks) repeated measures ANOVA with the first factor as a between-subjects factor and the second as a within-subject factor. There was a significant main effect of age, $F(1, 33) = 180.64$, $p < .01$, $\eta^2 = .67$, and a significant Age × Distance interaction, $F(2, 33) = 5.63$, $p < .01$, $\eta^2 = .04$. Simple effects tests yielded a significant difference across distance for 3-year-olds, $F(1, 11) = 14.29$, $p < .01$, $\eta^2 = .32$; for 4-year-olds, $F(1, 11) = 76.06$, $p < .01$, $\eta^2 = .82$; and for adults, $F(1, 11) = 418.00$, $p < .01$, $\eta^2 = .94$. As expected, the proportion of *by*

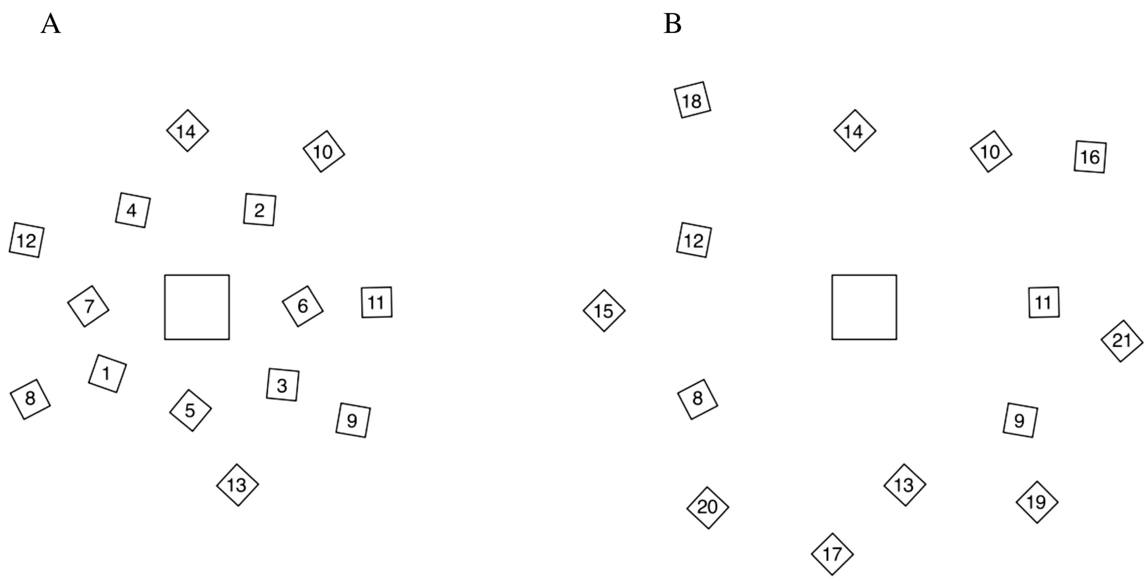

Figure 3. A: Diagram of the block layout used in the intervening condition in Experiment 2. B: Diagram of the block layout used in the nonintervening condition in Experiment 2. (Block numbers are for illustration only.)

responses to the inner blocks (3-year-olds: $M = .76$, $SD = .30$; 4-year-olds: $M = .88$, $SD = .19$; adults: $M = .96$, $SD = .12$) was significantly greater than the proportion for the target blocks (3-year-olds: $M = .29$, $SD = .41$; 4-year-olds: $M = .11$, $SD = .19$; adults: $M = .06$, $SD = .11$) for all three age groups. Additional simple effects tests revealed no significant differences across age groups for responses to the inner blocks, $F(2, 33) = 2.62$, *ns*, $\eta^2 = .14$. (Parallel analyses for the target blocks are not

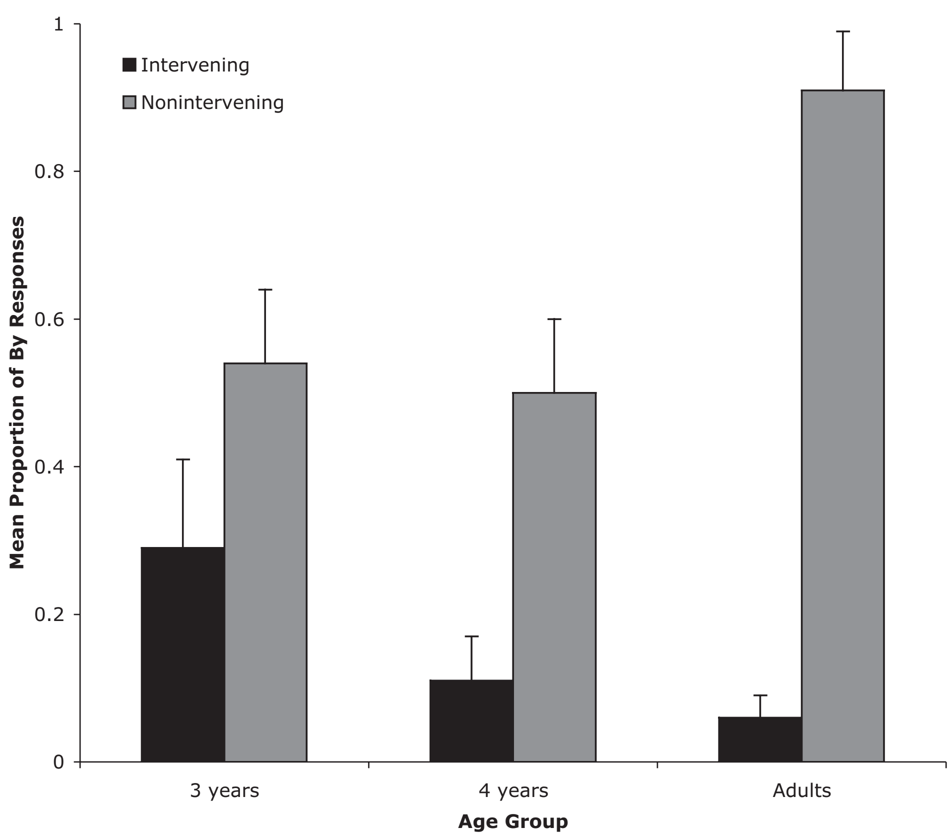

Figure 4. Mean proportions of *by* responses to the target blocks for each age group and condition in Experiment 2. Error bars represent standard errors.

reported here because they are redundant with analyses reported above.)

Mean proportions of by responses to the target and outer blocks. How systematically did children and adults respond to the target versus the nonintervening (i.e., outer) blocks? Consistent with the findings of Experiment 1, we predicted that participants would be more likely to judge that the target than the outer blocks were *by* the landmark. The mean proportion of *by* responses to the target and outer blocks for participants in the nonintervening condition was entered into an Age (3 years vs. 4 years vs. adult) $\times$ Distance (target blocks vs. outer blocks) repeated measures ANOVA with the first factor as a between-subjects factor and the second as a within-subject factor. The analysis revealed a significant main effect of distance, $F(1, 33) = 92.79$, $p < .01$, $\eta^2 = .39$, and a significant Age $\times$ Distance interaction, $F(2, 33) = 15.59$, $p < .01$, $\eta^2 = .13$. Simple effects tests yielded a significant difference across distance for 3-year-olds, $F(1, 11) = 8.05$, $p < .05$, $\eta^2 = .08$; for 4-year-olds, $F(1, 11) = 13.30$, $p < .01$, $\eta^2 = .39$; and for adults, $F(1, 11) = 116.53$, $p < .01$, $\eta^2 = .84$. The proportion of *by* responses to the outer set of blocks (3-year-olds: $M = .33$, $SD = .35$; 4-year-olds: $M = .10$, $SD = .18$; adults: $M = .01$, $SD = .04$) was significantly lower than the proportion for the target blocks (3-year-olds: $M = .54$, $SD = .36$; 4-year-olds: $M = .50$, $SD = .33$; adults: $M = .91$, $SD = .29$) for all three age groups. Additional simple effects tests revealed significant differences across age groups for responses to the outer blocks, $F(2, 33) = 6.56$, $p < .01$, $\eta^2 = .28$. As in Experiment 1, 3-year-olds were significantly more likely than were the 4-year-olds and adults to judge that the outer blocks were *by* the landmark. Responses to the outer blocks did not differ significantly for the 4-year-olds and adults. These findings indicate that 3-year-olds' responses were less systematic than were the responses of the older participants. (Parallel analyses for the target blocks are not reported here because they are redundant with analyses reported above.)

Individual patterns of responding. We also examined individual patterns of responding in the two conditions to provide further information about the systematicity of children's judgments. We were particularly interested in how many children and adults exhibited highly differentiated patterns of responding on the basis of relative distance. We classified participants in the intervening condition as systematic users of relative distance if they said "yes" to at least 6 out of 7 inner blocks and "no" to at least 6 out of 7 target blocks. Likewise, we classified participants in the nonintervening condition as systematic users of relative distance if they said "yes" to at least 6 out of 7 target blocks and "no" to at least 6 out of 7 outer blocks. We also classified participants as having a yes (or no) bias if they said "yes" (or "no") to at least 13 out of 14 blocks. The results are shown in Table 1. Only 6 3-year-old children were systematic users of relative distance, whereas 12 4-year-olds and 20 adults used relative distance systematically.

Discussion

The primary goal of Experiment 2 was to investigate whether judgments of nearbyness depend on relative distance. To determine whether the relative distance between the blocks and the landmark influenced judgments, we compared judgments for a target set of blocks across two conditions in which other blocks were present in intervening locations or in nonintervening locations.[2] *By* judgments differed significantly across conditions for the 4-year-olds and the adults, suggesting that the relative position of the target blocks in relation to the landmark affected judgments of nearbyness. These judgments did not differ significantly across conditions for the 3-year-olds, implying that they were less strongly influenced by relative distance than were the older children and adults. Inspection of individual patterns of responding provided additional support for this notion: six 3-year-old children were systematic users of relative distance, whereas twelve 4-year-olds and twenty adults used relative distance systematically.

One question these findings raise is why 3-year-olds' responses to the target blocks in the two conditions did not differ significantly. One possible explanation for this finding is that 3-year-olds have more difficulty using relative distance to make judgments about nearbyness at larger distances. This hypothesis is consistent with previous work showing that young children more successfully use relative coding in smaller than in larger spaces (Vasilyeva & Huttenlocher, 2004). This hypothesis also is consistent with the results of Experiment 1 showing that 3-year-olds were more likely to judge the inner blocks as *by* the landmark than the middle and outer blocks. In our third experiment, we examined whether 3-year-olds were more likely to use relative distance to make judgments about nearbyness when the distances were smaller. Experiment 3 was identical to Experiment 2 except that the target blocks were very close to the landmark. Thus, the blocks were either 7.6 cm and 15.2 cm or 15.2 cm and 30.5 cm from the landmark. (Note that the 15.2-cm blocks were the "inner" blocks in Experiment 1.) We expected that all age groups would be more likely to judge that the 15.2-cm blocks were *by* the landmark when no blocks intervened than when blocks intervened, suggesting they use relative distance to make nearbyness judgments when distances are smaller.

Experiment 3

Method

Participants. Twenty-four 3-year-olds (mean age = 3 years 6 months, range = 3 years 0 months to 3 years 12 months; 14 girls, 10 boys), 24 4-year-olds (mean age = 4 years 7 months, range = 4 years 1 month to 4 years 11 months; 12 girls, 12 boys), and 24 adults (mean age = 24 years 5 months, range = 19 years 2 months to 44 years 7 months; 18 women, 6 men) participated. Children were from primarily middle- to upper-middle-class Caucasian families. They were recruited through community advertising and child care centers. Most adults were from primarily middle- to upper-middle-class Caucasian families. They were recruited from psychology courses at Illinois State University and received extra credit for participation.

Apparatus and materials. The apparatus was identical to that used in Experiment 2 except for the layout of blocks. In the *intervening* condition,

[2] Previous findings have suggested that the perception of distance between two objects may be distorted when an intervening object is introduced, either "lengthening" the overall distance (e.g., Kosslyn, Pick, & Fariello, 1974; Newcombe & Liben, 1982) or "shortening" the distance (e.g., Piaget, Inhelder, & Szeminska, 1960). Thus, it is possible that the inclusion of intervening blocks increased the perception of the absolute distance between the target blocks and the landmark in our study. These claims regarding how the inclusion of intervening objects distort distance perception are broadly consistent with our main argument that the overall layout of blocks and the scale of the space affect judgments of nearbyness.

Table 1
Individual Patterns of Responding in Experiment 2

Age and condition	Number of participants showing each pattern of responding			
	Systematic	Mixed	Yes bias	No bias
3-year-olds				
Intervening	6	3	2	1
Nonintervening	0	8	2	2
4-year-olds				
Intervening	9	3	0	0
Nonintervening	3	7	0	2
Adults				
Intervening	9	3	0	0
Nonintervening	11	0	0	1

Note. Classification of individual participants is based on the proportion of *yes* responses (see text for details).

the 5 inner blocks were 7.6 cm from the box, and the 7 target blocks were 15.2 cm from the box. In the *nonintervening* condition, the 7 target blocks were 15.2 cm from the box, and the 7 outer blocks were 30.5 cm from the box (see Figure 5).

Design and procedure. The design and procedure were identical to those used in Experiment 2.

Coding and measures. The coding and measures were identical to those used in Experiments 1 and 2.

Results

Mean proportions of by responses to the target (15.2-cm) blocks. The primary question of interest was whether children and adults were more likely to judge the target set of blocks as *by* the box when no intervening blocks were present than they were when intervening blocks were present when the distance between the target blocks and the landmark was small. The proportion of *by* responses for the target blocks was entered into an Age (3 years vs. 4 years vs. adult) × Condition (intervening vs. nonintervening) ANOVA. There was a significant effect of condition, $F(1, 66) = 93.03$, $p < .01$, $\eta^2 = .55$, and a significant Age × Condition interaction, $F(2, 66) = 4.16$, $p < .01$, $\eta^2 = .05$. Simple effects tests indicated that the difference across conditions was significant for 3-year-olds, $F(1, 22) = 13.46$, $p < .01$, $\eta^2 = .38$; for 4-year-olds, $F(1, 22) = 15.49$, $p < .01$, $\eta^2 = .41$; and for adults, $F(1, 22) = 198.55$, $p < .01$, $\eta^2 = .90$. Unlike in Experiment 2, participants of all ages in the nonintervening condition were significantly more likely to judge that the target blocks were *by* the landmark than were their counterparts in the intervening condition. To further examine the source of the Age × Condition interaction, we examined the pattern of age differences for each condition. Simple effects tests revealed no significant age differences in the proportion of *by* responses in the intervening condition, $F(2, 33) = 2.29$, *ns*, $\eta^2 = .12$, or in the nonintervening condition, $F(2, 33) = 1.99$, *ns*, $\eta^2 = .11$. The proportion of *by* responses to the target blocks for each age group and condition can be seen in Figure 6.

Mean proportions of by responses to the inner and target blocks. How systematically did children and adults respond to the intervening (i.e., inner) blocks versus the target blocks? As in the

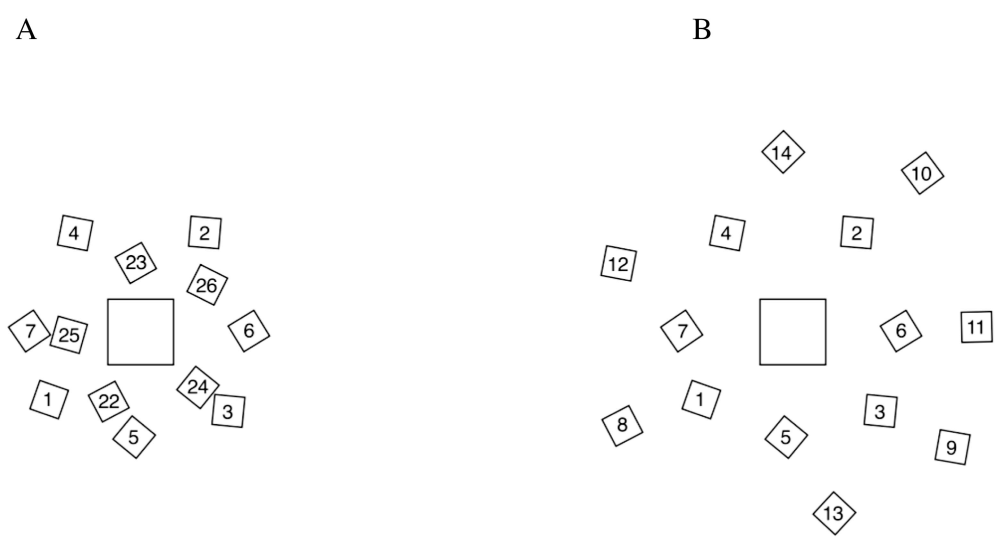

Figure 5. A: Diagram of the block layout used in the intervening condition in Experiment 3. B: Diagram of the block layout used in the nonintervening condition in Experiment 3. (Block numbers are for illustration only.)

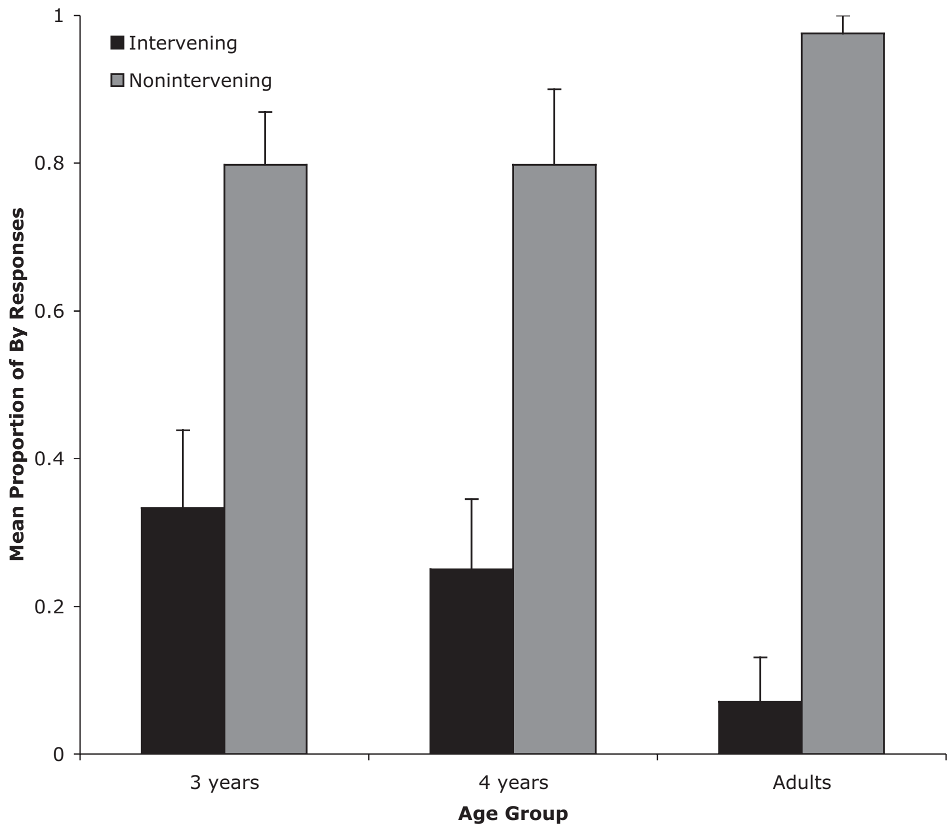

Figure 6. Mean proportions of *by* responses to the target blocks for each age group and condition in Experiment 3. Error bars represent standard errors.

previous experiments, we expected that children and adults in the intervening condition would be more likely to judge that the inner than the target blocks were *by* the landmark. The mean proportion of *by* responses to the inner and target blocks for participants in the intervening condition was entered into an Age (3 years vs. 4 years vs. adult) × Distance (inner blocks vs. target blocks) repeated measures ANOVA with the first factor as a between-subjects factor and the second as a within-subject factor. The analysis revealed a significant main effect of distance, $F(1, 33) = 103.81$, $p < .01$, $\eta^2 = .56$, and an Age × Distance interaction, $F(2, 33) = 7.01$, $p < .01$, $\eta^2 = .08$. Simple effects tests revealed a significant difference across distance for 3-year-olds, $F(1, 11) = 7.96$, $p < .05$, $\eta^2 = .22$; for 4-year-olds, $F(1, 11) = 25.02$, $p < .01$, $\eta^2 = .61$; and for adults, $F(1, 11) = 242.48$, $p < .01$, $\eta^2 = .92$. The proportion of *by* responses to the inner blocks (3-year-olds: $M = .68$, $SD = .34$; 4-year-olds: $M = .90$, $SD = .20$; adults: $M = 1.0$) was significantly greater than the proportion for the target blocks (3-year-olds: $M = .33$, $SD = .36$; 4-year-olds: $M = .25$, $SD = .33$; adults: $M = .07$, $SD = .21$) for all three age groups. Additional simple effects tests yielded significant differences across age groups in responses to the inner blocks, $F(2, 33) = 6.19$, $p < .01$, $\eta^2 = .27$. Three-year-olds were significantly less likely than were 4-year-olds and adults to judge that the inner blocks were *by* the landmark. Judgments did not differ significantly for the 4-year-olds and adults. Again, these findings indicate that 3-year-olds' judgments were less systematic than were those of participants in the older age groups. (Parallel analyses for the target blocks are not reported here because they are redundant with the analyses reported above.)

Mean proportions of by responses to the target and outer blocks. We also compared responses to the target and responses to nonintervening (i.e., outer) blocks to examine the systematicity of responding. That is, to what extent did children and adults in the nonintervening condition systematically reject the outer blocks as *by* the landmark? As in the previous experiments, we predicted that participants in the nonintervening condition would be less likely to judge that the outer than the target blocks were *by* the landmark. The mean proportion of *by* responses to the target and outer blocks for participants in the nonintervening condition were entered into an Age (3 years vs. 4 years vs. adult) × Distance (outer blocks vs. target blocks) repeated measures ANOVA with the first factor as a between-subjects factor and the second as a within-subject factor. The analysis revealed a significant main effect of distance, $F(1, 33) = 199.93$, $p < .01$, $\eta^2 = .66$, and an Age × Distance interaction, $F(2, 33) = 8.35$, $p < .01$, $\eta^2 = .06$. Simple effects tests revealed a significant difference across distance for 3-year-olds, $F(1, 11) = 15.45$, $p < .01$, $\eta^2 = .34$; for 4-year-olds, $F(1, 11) = 59.60$, $p < .01$, $\eta^2 = .73$; and for adults, $F(1, 11) = 1415.12$, $p < .01$, $\eta^2 = .98$. As expected, the proportion of *by* responses to the outer set of blocks (3-year-olds: $M = .35$, $SD = .39$; 4-year-olds: $M = .01$, $SD = .04$; adults: $M = .01$, $SD = .04$) was significantly lower than the proportion for the target blocks

(3-year-olds: $M = .80$, $SD = .25$; 4-year-olds: $M = .80$, $SD = .35$; adults: $M = .98$, $SD = .08$) for all three age groups. Additional simple effects tests yielded significant differences across age groups in responses to the outer blocks, $F(2, 33) = 8.48$, $p < .01$, $\eta^2 = .34$. Three-year-olds were significantly more likely than were 4-year-olds and adults to judge that the outer blocks were *by* the landmark. Judgments did not differ significantly for the 4-year-olds and adults. Again, these findings show that judgments by 3-year-olds were less systematic than were judgments by the older participants. (Parallel analyses for the target blocks are not reported here because they are redundant with the analyses reported above.)

Individual patterns of responding. We again examined individual patterns of responding in the two conditions to provide further information about systematicity in children's judgments. We were particularly interested in how many children and adults exhibited highly differentiated patterns of responding on the basis of relative distance. We used the same criteria as in Experiment 2 to classify participants.[3] The results are shown in Table 2. Seven 3-year-olds, fifteen 4-year-olds, and twenty-two adults were systematic users of relative distance.

Discussion

The goal of Experiment 3 was to examine the influence of spatial scale on judgments of nearbyness. In particular, we hypothesized that young children (especially 3-year-olds) would use relative distance more systematically when the distances involved were smaller than those in the previous study. As in Experiment 2, we compared judgments for blocks at a given distance across two conditions in which other blocks were present in intervening locations or in nonintervening locations. Unlike in Experiment 2, the distance between the landmark and the target blocks was very small. *By* judgments for the target blocks differed significantly across conditions for all three age groups, suggesting that the relative distance between the target blocks and the landmark affected judgments of nearbyness. Moreover, there were no age differences in *by* judgments in either the intervening or the nonintervening condition. Children and adults were equally willing to reject the target blocks as *by* the landmark when they were relatively far from the landmark, and they were equally willing to accept the target blocks as *by* the landmark when they were relatively close to the landmark. These findings are consistent with the idea that children first use relative distance to make judgments of nearbyness for smaller distances and gradually extend its use to larger distances. Implications of these results are discussed in detail below.

The present findings revealed that 3-year-olds' judgments were less systematic than were the judgments of the 4-year-olds and adults. In particular, the 3-year-olds were less willing to say that the inner blocks were *by* the landmark and more willing to say that the outer blocks were *by* the landmark than were the participants in the older age groups. These findings lend further support to the notion that young children's judgments about relative nearbyness become more differentiated with development.

General Discussion

The results of this investigation clearly show that both young children and adults use relative distance to make judgments about nearbyness. Nonetheless, there are developmental changes in the use of relative distance to guide judgments of nearbyness. Adults systematically used relative distance when making *by* judgments. Thus, they almost always judged blocks as *by* the landmark when no intervening blocks were present, and they almost never judged blocks as *by* the landmark when intervening blocks were present. In contrast, 3- and 4-year-olds were less systematic in their use of relative distance to make judgments of nearbyness. At the intermediate distance (i.e., 30.5 cm), 4-year-olds, but not 3-year-olds, were significantly more likely to judge the target blocks as *by* the landmark when no intervening blocks were present than when intervening blocks were present. However, both 3- and 4-year-olds were less willing than adults to judge the target blocks as *by* the landmark when no intervening blocks were present. There were no age differences in willingness to reject the target blocks as *by* the landmark when intervening blocks were present. At the short distance (i.e., 15.2 cm), both 3- and 4-year-olds were significantly more likely to judge the target blocks as *by* the landmark when no intervening blocks were present than when intervening blocks were present. Moreover, both the 3- and 4-year-olds and the adults were quite willing to accept the target blocks as *by* the landmark when no intervening blocks were present. Likewise, there were no significant age differences in willingness to reject the target blocks as *by* the landmark when intervening blocks were present. These patterns of responding across Experiments 2 and 3 underscore two points about the developmental trajectory of nearbyness judgments: (a) Children and adults use relative distance to make judgments of nearbyness, and (b) there are developmental changes in the use of relative distance during the preschool years. In particular, judgments based on relative distance become more differentiated and extend to larger distances over development. Moreover, the overall pattern of results provides important details about the factors that shape judgments of nearbyness. These points are discussed in turn below.

Why were young children more reluctant than adults to consider blocks that were relatively close but somewhat distant from the landmark as *by* the landmark? One possibility is that young children's verbal judgments about proximity mirror their nonverbal coding of location. A number of studies over the last 25 years have documented a *proximal-to-distal shift* in young children's coding of location (Acredolo, 1978, 1990; Acredolo & Evans, 1980; Allen & Kirasic, 1988; Bushnell, McKenzie, Lawrence, & Connell, 1995; see also Craton, Elicker, Plumert, & Pick, 1990; Newcombe & Huttenlocher, 2000; Newcombe, Huttenlocher, Drummey, & Wiley, 1998; Sluzenski, Newcombe, & Satlow, 2004). In other words, younger children rely almost exclusively on proximal landmarks to remember locations, whereas older children and adults tend to rely more on distal landmarks to remember locations. For example, Acredolo and Evans (1980) found that 11-month-olds used colorful markings around a window where an interesting event occurred to remember the location of the event, but they did not use the same markings around a window *opposite* to where the interesting event occurred to remember the location of the event.

[3] Note that participants in the intervening condition needed to respond "yes" to at least 4 out of 5 blocks to be considered systematic and "yes" (or "no") to at least 11 out of 12 blocks to be considered biased in their responding.

Table 2
Individual Patterns of Responding in Experiment 3

Age and condition	Number of participants showing each pattern of responding			
	Systematic	Mixed	Yes bias	No bias
3-year-olds				
Intervening	4	5	2	1
Nonintervening	3	7	2	0
4-year-olds				
Intervening	6	5	1	0
Nonintervening	9	1	0	2
Adults				
Intervening	11	1	0	0
Nonintervening	11	1	0	0

Note. Classification of individual participants is based on the proportion of *yes* responses (see text for details).

Likewise, Bushnell et al. (1995) found that 12-month-olds could find an object if it was hidden under a distinctive landmark but had great difficulty finding the object if it was hidden under something *next to* a distinctive landmark. Other studies have shown that even 5-year-olds are more likely to rely on proximal than on distal landmarks to remember a starting location (Acredolo, 1976; see also Overman, Pate, Moore, & Peuster, 1996). Likewise, Craton et al. (1990) found that 4-year-olds were more likely to refer to proximal landmarks than to more distal landmarks when communicating about the location of a hidden object. Together, these studies suggest that young children prefer landmarks that are very close to target objects. As a result, they may have difficulty using relative distance to classify objects as near or far at larger distances.

A second, somewhat speculative explanation for young children's reluctance to consider blocks that were relatively close but somewhat distant as *by* the landmark stems from these children's linguistic experience (see Bowerman & Choi, 2003, for ideas about how linguistic experience shapes young children's spatial lexicon). Many spatial terms in English map onto discrete, rather than continuous, spatial information. Although there are some ambiguous cases (e.g., a book partly under a couch), objects are usually described as *in* or *out*, *on* or *off*, *under* or *not under*. Because the terms *in*, *on*, and *under* are usually acquired first, children may come to expect that all spatial terms refer to discrete spatial categories. Thus, young children may initially think that the term *by* refers only to objects that are touching or nearly touching a landmark. Parents may reinforce these notions by using the term *by* only in such cases. In other words, parents may quickly learn that young children have difficulty following directions involving the term *by* unless the missing object is touching or nearly touching a landmark. Young children may broaden their use of relative distance to larger distances as they start to experience the term *by* used in contexts in which the missing object is relatively, but not absolutely, close to the landmark. The finding that 3-year-olds' use of relative distance to make judgments about nearbyness depended on the distance between the target objects and the landmark suggests that young children start by using relative distance at smaller distances and gradually move to using relative distance at larger distances. Naturalistic or seminaturalistic studies of parents' use of the term *by* are clearly needed to determine whether young children's linguistic experience emphasizes the use of relative distance at small distances before larger distances.

A third explanation for young children's reluctance to consider blocks that were relatively close but somewhat far from the landmark as *by* the landmark comes from research on young children's analogical reasoning. According to Gentner (1988), children between the ages of 3 and 5 years become increasingly likely to use relational similarity to solve analogical reasoning tasks (see also Gentner & Ratterman, 1991; Goswami, 1989; Ratterman & Gentner, 1998). For example, when shown two arrays of objects that differ in size and identity (e.g., a small car, a medium mug, and a large house; a small mug, a medium house, and a large flower pot) and asked to select the object that is the same as the marked one in the first array (e.g., the medium mug), 3-year-olds have difficulty choosing the relational match (i.e., the *medium* house), preferring to use object-identity matches instead (i.e., the small *mug*). When object similarity and relational similarity are not in conflict, 3-year-olds are much more likely to succeed in making relational matches. In contrast, 5-year-olds are likely to use relational similarity in analogical reasoning tasks regardless of other available cues. In the present investigation, 4-year-olds were more likely to use relational information than were 3-year-olds when absolute and relative distance information were in conflict (though less so than adults; see Experiment 2). When absolute and relative distance were consistent with each other, both 3- and 4-year-olds used relative distance to make judgments about nearbyness (see Experiment 3). These findings suggest that domain-general developmental changes in relational thinking may underlie the increased systematicity in the use of relative distance observed here (for a discussion of the general role of relational complexity in children's reasoning, see Andrews & Halford, 2002; Halford, Andrews, Dalton, Boag, & Zielinski, 2002; Halford, Wilson, & Phillips, 1998; see Gentner & Ratterman, 1991, for a domain-specific view).

We want to emphasize that the explanations given above are not meant to be mutually exclusive. Changes in spatial-coding abilities and linguistic experiences may contribute simultaneously to more systematic and widespread use of relative distance to interpret the term *by*. How might this work? We speculate that as children's spatial attention broadens, parents may begin to use the term *by* to describe objects that are increasingly distant yet relatively close to landmarks. More varied linguistic experiences with the term *by* may help young children extract a statistical regularity converging on relative distance. Note that in turn, linguistic experience with relational information in the spatial domain may lead to improvements in relational thinking in general (see Gentner & Loewenstein, 2002) and to increased flexibility in how children use landmarks. Further research is clearly needed, however, to determine how these increases in the use of relative distance information occur during the late preschool years.

In addition to highlighting the mechanisms underlying developmental changes in young children's use of relative distance to make judgments of nearbyness, the present results add to a growing body of literature specifying the factors that influence how adults interpret spatial terms. Previous research has shown that adults use vertical and horizontal reference axes (Coventry & Prat-Sala, 2001; Crawford, Regier, & Huttenlocher, 2000; Hayward & Tarr, 1995; Meints, Plunkett, Harris, & Dimmock, 2002) and functional relations between objects (Carlson-Radvansky, Covey, & Lattanzi, 1999; Carlson-Radvansky & Tang, 2000) to interpret spatial terms such as *above* and *below* and *left* and *right* (see also Logan & Sadler, 1996; Manning, Sera, & Pick, 2002). For example, Hayward and Tarr (1995) examined how reference axes influence the direction and extent of spatial regions denoted by the prepositions *above*, *below*, *left*, and *right*. On each trial, adults viewed two objects (e.g., a computer and a circle) and were asked to rate the acceptability of a linguistic description of the spatial relation between the objects (e.g., "The circle is above the computer"). Acceptability for *above* and *below* was highest when the circle was directly above or below the computer (i.e., along the vertical axis). Similarly, acceptability for *left* and *right* was highest when the circle was directly to the left or right of the computer (i.e., along the horizontal axis). These findings suggest that reference axes play an important role in adults' judgments about spatial prepositions (see also Crawford et al., 2000). Our results extend these findings by examining how relative distance influences adults' understanding of another spatial term—*by*. An important next step is to examine similarities and differences across spatial terms. For example, the present findings contrast with work by Carlson and Logan (2001) showing that the presence of distractor items has little effect on adults' judgments of the spatial term *above*. Although adults were slower to verify relations (e.g., "L is above X") when distractors were present than when they were absent, the location of the distractor relative to the target object did not affect responses. In contrast, the location of "distractor" objects in our task had a major impact on how adults interpreted the term *by*. Clearly, additional research is needed to investigate how particular factors influence people's interpretation of different spatial terms.

A final issue concerns whether there are any limits on people's use of relative distance to interpret the term *by*. Although the present results support the notion that children's use of relative distance extends to larger distances across development, it is possible that there is an outer limit for nearbyness judgments, even for adults. In our task, the largest distance between the target blocks and the landmark was 30.5 cm (12 in.). Although adults were willing to reject these target blocks as *by* the landmark when there were intervening blocks, it is not known whether adults would be willing to accept more distant target blocks as *by* the landmark when there are no intervening blocks. We suspect that relative distance plays a primary role in adults' judgments of nearbyness even when the distance between the object and the landmark is quite large. In other words, provided that there are no other nearer landmarks, an object would be judged as *by* a landmark even when the distance between the object and the landmark is quite large. For example, a remote cabin may be considered *by* the nearest town even if that town is 40 miles away. Clearly, this example illustrates the importance of spatial scale in proximity judgments. Further research is needed to determine what, if any, boundaries exist in people's use of relative distance to judge nearbyness.

In conclusion, the results of the present investigation clearly show that young children and adults use relative distance to make judgments of nearbyness. Nonetheless, their judgments on the basis of relative distance become increasingly systematic across development. In addition, children extend the use of relative distance to greater distances between 3 and 4 years of age. These findings underscore the idea that young children's understanding of spatial prepositions undergoes developmental change even after they begin to produce such words.

References

Acredolo, L. (1976). Frames of reference used by children for orientation in unfamiliar spaces. In G. Moore & R. Golledge (Eds.), *Environmental knowing: Theories, research, and methods* (pp. 299–302). Stroudsburg, PA: Dowden, Hutchinson & Ross.

Acredolo, L. (1978). Development of spatial orientation in infancy. *Developmental Psychology, 14,* 224–234.

Acredolo, L. (1981). Small- and large-scale spatial concepts in infancy and childhood. In L. S. Liben, A. H. Patterson, & N. Newcombe (Eds.), *Spatial representation and behavior across the lifespan: Theory and application* (pp. 63–81). New York: Academic Press.

Acredolo, L. (1990). Behavioral approaches to spatial orientation in infancy. In A. Diamond (Ed.), *The development and neural bases of higher cognitive functions: Annals of the New York Academy of Sciences* (Vol. 608, pp. 596–607). New York: New York Academy of Sciences.

Acredolo, L., & Evans, D. (1980). Developmental changes in the effects of landmarks on infant spatial behavior. *Developmental Psychology, 16,* 312–318.

Allen, G. L., & Kirasic, K. C. (1988). Young children's spontaneous use of spatial frames of reference in a learning task. *British Journal of Developmental Psychology, 6,* 125–135.

Andrews, G., & Halford, G. S. (2002). A cognitive complexity metric applied to cognitive development. *Cognitive Psychology, 45,* 153–219.

Bowerman, M., & Choi, S. (2003). Space under construction: Language-specific spatial categorization in first language acquisition. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (pp. 387–427). Cambridge, MA: MIT Press.

Bushnell, E. W., McKenzie, B. E., Lawrence, D. A., & Connell, S. (1995). The spatial coding strategies of one-year-old infants in a locomotor search task. *Child Development, 66,* 937–958.

Carlson, L. A., & Logan, G. D. (2001). Using spatial terms to select an object. *Memory & Cognition, 29,* 883–892.

Carlson-Radvansky, L. A., Covey, E. S., & Lattanzi, K. M. (1999). "What" effects on "where": Functional influences on spatial relations. *Psychological Science, 10,* 516–521.

Carlson-Radvansky, L. A., & Tang, Z. (2000). Functional influences on orienting a reference frame. *Memory & Cognition, 28,* 812–820.

Clark, E. V. (1973). Non-linguistic strategies and the acquisition of word meanings. *Cognition, 2,* 161–182.

Clark, E. V. (1980). Here's the top: Nonlinguistic strategies in the acquisition of orientational terms. *Child Development, 51,* 329–338.

Coventry, K. R., & Prat-Sala, M. (2001). Object-specific function, geometry, and the comprehension of in and on. *European Journal of Cognitive Psychology, 13,* 509–528.

Craton, L. G., Elicker, J., Plumert, J. M., & Pick, H. L., Jr. (1990).

Children's use of frames of reference in communication of spatial location. *Child Development, 61,* 1528–1543.
Crawford, L. E., Regier, T., & Huttenlocher, J. (2000). Linguistic and non-linguistic spatial categorization. *Cognition, 75,* 209–235.
Dromi, E. (1979). More on the acquisition of locative prepositions: An analysis of Hebrew data. *Journal of Child Language, 6,* 547–562.
Gentner, D. (1988). Metaphor as structure mapping: The relational shift. *Child Development, 59,* 47–59.
Gentner, D., & Loewenstein, J. (2002). Relational language and relational thought. In E. Amsel & J. P. Byrnes (Eds.), *Language, literacy, and cognitive development: The development and consequences of symbolic communication* (pp. 87–120). Mahwah, NJ: Erlbaum.
Gentner, D., & Ratterman, M. J. (1991). Language and the career of similarity. In S. A. Gelman & J. P. Byrnes (Eds.), *Perspectives on language and thought: Interrelations in development* (pp. 225–277). New York: Cambridge University Press.
Goswami, U. (1989). Relational complexity and the development of analogical reasoning. *Cognitive Development, 4,* 251–268.
Halford, G. S., Andrews, G., Dalton, C., Boag, C., & Zielinski, T. (2002). Young children's performance on the balance scale: The influence of relational complexity. *Journal of Experimental Child Psychology, 81,* 417–445.
Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences, 21,* 803–864.
Hayward, W. G., & Tarr, M. J. (1995). Spatial language and spatial representation. *Cognition, 55,* 39–84.
Herskovits, A. (1986). *Language and spatial cognition: An interdisciplinary study of the prepositions in English.* New York: Cambridge University Press.
Huttenlocher, J., Duffy, S., & Levine, S. (2002). Infants and toddlers discriminate amount: Are they measuring? *Psychological Science, 13,* 244–249.
Huttenlocher, J., Newcombe, N., & Vasilyeva, M. (1999). Spatial scaling in young children. *Psychological Science, 10,* 393–398.
Johnston, J. R., & Slobin, D. I. (1979). The development of locative expressions in English, Italian, Serbo-Croatian, and Turkish. *Journal of Child Language, 6,* 529–545.
Kosslyn, S. M., Pick, H. L., Jr., & Fariello, G. R. (1974). Cognitive maps in children and men. *Child Development, 45,* 707–716.
Landau, B., & Jackendoff, R. (1993). "What" and "where" in spatial language and spatial cognition. *Behavioral and Brain Sciences, 16,* 217–265.
Liben, L. S. (1988). Conceptual issues in the development of spatial cognition. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial cognition: Brain bases and development* (pp. 167–194). Hillsdale, NJ: Erlbaum.
Logan, G. D., & Sadler, D. D. (1996). A computational analysis of the apprehension of spatial relations. In P. Bloom, M. A. Peterson, L. Nadel, & M. F. Garret (Eds.), *Language and space* (pp. 494–529). Cambridge, MA: MIT Press.
MacDonald, S. E., Spetch, M. L., Kelly, D. M., & Cheng, K. (2004). Strategies in landmark use by children, adults, and marmoset monkeys. *Learning and Motivation, 35,* 322–347.
Manning, C., Sera, M. D., & Pick, H. L., Jr. (2002). Understanding how we think about space. In K. R. Coventry & P. Oliver (Eds.), *Spatial language: Cognitive and computational perspectives* (pp. 147–163). Boston: Kluwer Academic.
Meints, K., Plunkett, K., Harris, P. L., & Dimmock, D. (2002). What is on and under for 15-, 18-, and 24-month-olds? Typicality effects in early comprehension of spatial prepositions. *British Journal of Developmental Psychology, 20,* 113–130.
Newcombe, N., & Huttenlocher, J. (2000). *Making space: The development of spatial representation and reasoning.* Cambridge, MA: MIT Press.
Newcombe, N., Huttenlocher, J., Drummey, A. B., & Wiley, J. G. (1998). The development of spatial location coding: Place learning and dead reckoning in the second and third years. *Cognitive Development, 13,* 185–200.
Newcombe, N., & Liben, L. S. (1982). Barrier effects in the cognitive maps of children and adults. *Journal of Experimental Child Psychology, 34,* 46–58.
Overman, W. H., Pate, B. J., Moore, K., & Peuster, A. (1996). Ontogeny of place learning in children as measured in the radial arm maze, Morris search task, and open field task. *Behavioral Neuroscience, 110,* 1205–1228.
Piaget, J., & Inhelder, B. (1967). *The child's conception of space* (F. J. Langdon & J. L. Lunzer, Trans.). New York: Norton. (Original work published 1948)
Piaget, J., Inhelder, B., & Szeminska, A. (1960). *The child's conception of geometry.* New York: Basic Books.
Plumert, J. M., Ewert, K., & Spear, S. J. (1995). The early development of children's communication about nested spatial relations. *Child Development, 66,* 959–969.
Plumert, J. M., & Hawkins, A. M. (2001). Biases in young children's communication about spatial relations: Containment versus proximity. *Child Development, 72,* 22–36.
Ratterman, M. J., & Gentner, D. (1998). More evidence for a relational shift in the development of analogy: Children's performance on a causal-mapping task. *Cognitive Development, 13,* 453–478.
Sadalla, E. K., Burroughs, W. J., & Staplin, L. J. (1980). Reference points in spatial cognition. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 516–528.
Sluzenski, J., Newcombe, N. S., & Satlow, E. (2004). Knowing where things are in the second year of life: Implications for hippocampal development. *Journal of Cognitive Neuroscience, 16,* 1443–1451.
Vasilyeva, M., & Huttenlocher, J. (2004). Early development of scaling ability. *Developmental Psychology, 40,* 682–690.

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