Research Article

CHILDREN'S USE OF LANDMARKS: Implications for Modularity Theory

Amy E. Learmonth,[1] Lynn Nadel,[1] and Nora S. Newcombe[2]

[1]University of Arizona and [2]Temple University

Abstract—*Previous studies have shown that disoriented children use the geometric features of the environment to reorient, but the results have not consistently demonstrated whether children can combine such information with landmark information. Results indicating that they cannot suggest the existence of a geometric module for reorientation. However, results indicating that children can use geometric information in combination with landmark information challenge the modularity interpretation. An uncontrolled variable in the studies yielding conflicting results has been the size of the experimental space. In the present studies, which tested young children in spaces of two different sizes, the size of the space affected their ability to use available landmark information. In the small space, the children did not use the landmark to reorient, but in the large space they did. The ability of children to use landmarks in combination with geometric information raises important questions about the existence of an encapsulated geometric module.*

In two related sets of studies, Cheng (1986) and Hermer and Spelke (1996) and other researchers (e.g., Gouteux & Spelke, 2001; Wang, Hermer-Vazquez, & Spelke, 1999) explored the means by which disoriented rats, and humans, manage to reorient and search for hidden targets. It was claimed that both disoriented rats and disoriented humans utilized only the geometry of the test environment, completely ignoring local landmarks that could help them make better choices. These results led to the view that there exists a dedicated, informationally encapsulated, geometric module that is preferentially used for purposes of reorientation (Hermer & Spelke, 1996). These data seemed to provide strong support for the presence of Fodorian modules in both rats and young children. Hermer-Vazquez (Hermer-Vazquez, Moffet, & Munkholm, 2001) went on to argue that only with the advent of language can children aged 6 and older overcome this modular constraint to utilize nongeometric information in solving the reorientation problem.

The implications of this claim for theories of cognitive development are powerful. The discovery of a Fodorian module (Fodor, 1983) within development has implications for the structure of memory and the structure of the developing brain. Hence, our recent finding that children did combine geometric with landmark information during reorienting (Learmonth, Newcombe, & Huttenlocher, 2001) required closer examination, and led us to conduct studies aimed at clarifying how and when disorientation causes children to fail to use landmarks. We report the results of these studies here. As this domain of research depends on an understanding of how organisms orient themselves, some background on this process is important.

Spatial navigation allows people to find their way around the world, for example, to locate previously visited resources (e.g., a good restaurant), or to find their way home. A crucial part of this navigational capacity is the ability to know where one is in the world at any moment. In particular, it is essential that a person who becomes disoriented can quickly relocate him- or herself in space. There are a number of ways to reorient. Consider the uncomfortable feeling of coming out of a subway tunnel in an unfamiliar city and standing on the corner for a moment to figure out where one is and which way one should go. For adults, landmarks play an important role in these situations. In that moment just after emerging from the subway tunnel, one may look for a street sign or a building that will indicate where one is and what direction one is facing.

Landmarks are not the only source of information used in reorientation. Another source that provides orienting information to a disoriented animal is the geometric shape of the space it is in. The geometry of the space is that aspect of the space that can be described completely in terms of the relative position of points and lines and angles within the space. Geometric information can be provided by a river, a wall, or a mountain, but not by a street sign or a light fixture.

In navigating through the world, people encounter spaces with varying geometric properties. The ability to use these properties in everyday navigation allows for a means of knowing where one is that is not dependent on landmarks or an internal sense of direction and location. Both humans and other animals use the shape of the space they are in to provide information about where they are and which direction they are facing (Gallistel, 1990).

Research into the use of landmarks and geometry to reorient started with studies on reorientation in rats. The finding of interest from this research is that rats seem to use the geometric configuration of a space in isolation, even when other spatial information is readily available to them. This is the result that led to the claim that rats have a geometric module for reorientation (Cheng, 1986), and to the study of similar behavior in young children (Gouteux & Spelke, 2001; Hermer & Spelke, 1994, 1996; Learmonth et al., 2001; Wang et al., 1999). The initial study conducted with children, by Hermer and Spelke (1994), provided data supporting the existence of a geometric module in the young child. Subsequently, we (Learmonth et al., 2001) obtained contradictory results. Instead of finding that children, like rats, failed to combine geometric information with any other spatial information to reorient, we found that children needing to reorient were quite successful at combining the geometric features of a room with other spatial information provided by a variety of different landmarks.

These contradictory findings concerning whether children can or cannot use landmarks as well as geometry to reorient bear closer scrutiny, given the theoretical weight placed on these data. One possibility is that some difference in the procedures or apparatus used in the different studies was responsible for the disparate findings. An uncontrolled variable in the research to date has been the size of the experimental space. In those studies consistently finding evidence that geometry and landmarks do not mix, very small spaces were used (e.g., a 4- × 6-ft rectangular space and a 1.87-m square). In those studies finding evidence that geometry and landmarks can mix, an 8- × 12-ft square (quadruple the size of the small rectangular space used in the original study) was used. Thus, one difference between the studies that could account for the different findings is the size of the experimental space.

Address correspondence to Amy Learmonth, Rutgers University, Department of Psychology, 152 Frelinghuysen Rd., Piscataway, NJ 08854; e-mail: amyel@rci.rutgers.edu.

Consideration of how the size of the experimental space might influence navigation started in the late 1970s. Several studies investigated children's performance in large and small navigable spaces (Herman & Siegel, 1978; Kosslyn, Pick, & Fariello, 1974; Siegel, Herman, Allen, & Kirasic, 1979; Weatherford, 1982), showing that there was some effect of the size of the space on estimations of distance and the ability to take the perspective of another (Herman & Coyne, 1980; Weatherford & Cohen, 1980). This research suggests that the disparate findings in the reorientation studies could be related to the different room sizes used. To explore the role of differences in the size of the experimental space, we tested children for reorientation in spaces of two sizes, 4 ft × 6 ft and 8 ft × 12 ft.

Experiment 1 was designed to replicate the earlier findings that children use the geometric features of rooms of both sizes when there are no other cues available. The second purpose of the experiment was to see if children use an available landmark in the large room, but not in the small room. This experiment used a within-subjects design in which each subject was tested in both the small and the large room. Experiment 2 repeated the landmark condition of Experiment 1, but in older subjects. According to some previous work (Hermer-Vazquez et al., 2001), disoriented children begin to use landmarks in a 4- × 6-ft space once they are around 6 years old. Our goal in this experiment was to extend that finding and to see if there was a gradual shift or a sharp change in the ability to use the landmark.

EXPERIMENT 1

In this experiment, we sought to replicate the earlier findings for rooms of the two sizes used in the initial studies with children. The critical difference between this study and the previous work is that it used a within-subjects design in which each child was tested in a room of each size.

Method

Participants

Initially, 48 children participated in this study, but the data for 8 were discarded either because they refused to close their eyes or because they refused to complete eight trials. The average age for the remaining 40 subjects was 46 months 25 days (range: 36 months 8 days–59 months 27 days). Sixteen male and 24 female children participated. Half of the children were in the landmark group, and the other half were in the no-landmark group.

Apparatus

The equipment used in this study was a room that was constructed such that two of the walls could move, while the other two were stationary. One of the moving walls was constructed of plywood with metal supports and moved along a set of tracks on the ceiling. The other movable wall was a curtain hanging from a rod. A curtain that served as the roof to the experimental space hid the tracks for the plywood wall. All of the walls were of the same height and reached this second curtain. The curtain rod was held in place by hooks that were attached to one of the permanent walls and the plywood wall. The hooks themselves could be moved, allowing the curtain to hang at different distances from the opposite wall. All of the walls were covered by off-white curtains that matched the curtained wall. For the landmark group, one of the short walls had a blue curtain that covered the lower 5 ft of the wall.

Lighting came from above the ceiling curtain. For the small room, a large fluorescent light (5 ft × 2 ft) was hung centrally and directly above the room. For the large room, a round fluorescent light (12 in. in diameter) hung in each corner. The light diffused through the curtain such that in the small room it was impossible to tell where the light was above the curtain, and in the large room all four corners were equally bright and slightly brighter than the center of the room. The experimental room was located in a laboratory space within a large university building. With the door to the laboratory closed, there was no direction-specific noise.

In each corner of the experimental room there was a laminated 8.5-in. square of paper. All the squares were blue on one side; three of the squares were white on the other side, and the fourth was green.

Procedure

After each child was brought into the lab that contained the experimental room, parental consent was obtained, and the child was allowed to get comfortable with the experimenter. The child was then brought into the experimental room. For half the children, the experimental space was 4 ft × 6 ft to start, and for the other half it was 8 ft × 12 ft. The parent was allowed to come and look, and if the child was uncomfortable with the experimenter more time was spent with the parent in the experimental room. In most cases, the parent then left, and the experimenter and child completed the experiment alone. With some of the children, the parent was included in the large-room part of the experiment and simply followed the experimenter around when she changed position during the study. With 2 children, the parent stayed in the experimental room throughout the experiment, following the experimenter when she moved.

First getting the child's attention, the experimenter pointed out the four laminated squares. The child was shown that one was green on the other side and was then told to remember the location of the green square. While the child watched, the experimenter turned all of the squares blue side up. The child then spun around in a circle with eyes closed. Most of the children did this readily, but a few were helped to turn by the experimenter, and one 3-year-old was picked up and spun by the experimenter. During the spinning, the experimenter moved around the room, ending up at the center of a different wall on each trial. After making four or more rotations, the child was told by the experimenter to stop and open his or her eyes. The experimenter then asked the child to find the green square. The child's first choice was recorded; if it was incorrect, the experimenter showed the child where the green square was. There were four trials for each room size, all of which were the same except that the experimenter's location changed on each trial.

Results

The results of this study (see Table 1) indicate that in both the small and the large rooms, children in the no-landmark condition used the geometric configuration of the space to reorient. They visited the correct and congruent corners on 42% and 39% of the trials, respectively (large room: 45% and 36%; small room: 40% and 41%), and responded to the other two, geometrically different, corners much less often. The children went to the incorrect corner nearest the correct corner (on the other end of the short wall) on 9% of the trials, and to the far corner (on the other end of the long wall) on 11% of the trials (large room: 9% and 11%; small room: 10% and 10%).

In the landmark condition, the children went to the correct and congruent corners in the smaller room on 35% and 41% of the trials, respectively. They made errors to the near corner on 11% of the trials and to the far corner on 13% of the trials. In the larger room, the children went to the correct corner on 57% of the trials and to the congruent corner 23% of the time. They made errors to the near corner on 11% of the trials and to the far corner on 9%.

The size of the space the child was navigating in had an impact on the use or nonuse of available landmarks for the purpose of reorientation. In the no-landmark condition, all the children used the shape of the space to localize their search to the two geometrically appropriate corners, whereas in the landmark condition, the children used the landmark in the large room, but not the small room.

Planned contrasts showed a significant effect of room size, $F(1, 78) = 6.15$, $p = .0195$, but no interaction between room size and condition (landmark or no landmark), $F(1, 156) = 2.33$, $p = .1445$. There were no effects of age, $F(1, 78) = 0.60$, $p = .4459$, or sex, $F(1, 78) = 0.38$, $p = .5433$.

Following our previous research (Learmonth et al., 2001), we conducted a second analysis, which consisted of a number of t tests comparing responses to the correct and congruent corners; the only one that showed a significant difference was the comparison of the number of responses to the correct corner and the number of responses to the congruent corner for the landmark group in the large room, $t(19) = 3.025$, $p = .0070$. The landmark group did not search the correct corner more often than the opposite corner in the smaller room, $t(19) = 0.529$, $p = .6029$. The group with no landmark searched the correct corner and the opposite corner equally often in both the large and the small rooms, $t(19) = 1.099$, $p = .2856$, and $t(19) = -0.125$, $p = .9020$, respectively. When a landmark was available, the children did not use it in the smaller space but did use it in the larger space. The case that the size difference in the two spaces was crucial to this finding is strengthened by the within-subjects design. The same children who did not use the landmark in the smaller space did use it in the larger one. However, the difference in the number of correct responses between the landmark and no-landmark group was not quite significant in the large room, $t(38) = 1.726$, $p = .0925$.

EXPERIMENT 2

The finding that 3- and 4-year-olds did not use the landmark in the smaller space led us to question when children become able to use the landmark in the smaller space. In Experiment 2, the procedures of Experiment 1 were repeated with subjects who were 5 and 6 years old.

Method

Participants

The children in this study were 5 and 6 years old. No children's data had to be discarded. The 21 subjects included 13 males and 8 females, with an average age of 69 months and 25 days. There were ten 5-year-olds (average age = 62 months 23 days; range: 60 months 6 days–69 months 4 days) and eleven 6-year-olds (average age = 75 months 6 days; range: 72 months 2 days–78 months 14 days).

Apparatus and procedure

This experiment used the same apparatus and procedure as the landmark condition of Experiment 1.

Results

As in Experiment 1, the results were different for the two rooms (see Table 2). There was also a difference between the 5-year-olds and the 6-year-olds. In the smaller room, the 5-year-olds went to the correct and congruent corners on 35% and 38% of the trials, respectively. They made error responses to the near corner on 12% of the trials and to the far corner on 15%. The 6-year-olds went to the correct and congruent corners on 71% and 11% of the trials, respectively. They made error responses to the near corner on 11% of the trials and to the far corner on 7%.

In the larger room, the 5-year-olds went to the correct corner on 63% of the trials and to the congruent corner 15% of the time. They made error responses to the near corner on 12% of the trials and to the far corner on 10% of the trials. The 6-year-olds went to the correct corner on 84% of the trials and to the congruent corner 7% of the time. They made error responses to the near corner on 6% of the trials and to the far corner on 3% of the trials.

The older children were more successful than the younger children in Experiment 1 at finding the target in both the large and the small rooms. Their errors decreased between ages 5 and 6, and their ability to use the blue wall as a landmark increased with age. The 6-year-olds still made errors, but the number of errors decreased dramatically.

Planned contrasts showed a significant effect of room size, $F(1, 40) = 11.07$, $p = .0035$, and age, $F(1, 40) = 8.85$, $p = .0078$. There were no ef-

Table 1. *Difference scores, expressed as the proportion of correct responses minus the proportion of responses to the opposite corner, for the four groups in Experiment 1*

	Room size	
Condition	Large	Small
Landmark	.34*	−.06
No landmark	.09	−.01

*Responses to the correct corner significantly more frequent than responses to the opposite corner, $p < .05$.

Table 2. *Difference scores, expressed as the proportion of correct responses minus the proportion of responses to the opposite corner, for the four groups in Experiment 2*

	Room size	
Age group	Large	Small
6-year-olds	.77*	.60*
5-year-olds	.48*	−.03

*Responses to the correct corner significantly more frequent than responses to the opposite corner, $p < .05$.

fects of sex, $F(1, 40) = 0.92$, $p = .3505$, and the age-by-room-size interaction was not significant, $F(1, 80) = 1.30$, $p = .2692$.

Again following our previous research (Learmonth et al., 2001), we conducted *t* tests for each group to compare the number of correct responses and the number of responses to the opposite, but geometrically relevant corner. The *t* tests for the 5-year-olds showed a significant difference between responses to the correct and congruent corners in the large room, $t(9) = 3.353$, $p = .0080$, but there was no difference for the small room, $t(9) = -0.183$, $p = .8589$. The *t* tests for the 6-year-olds showed a significant difference between responses to the correct and congruent corners in both rooms: small room, $t(10) = 5.469$, $p = .0003$; large room, $t(10) = 7.455$, $p < .0001$. The significant difference between the number of correct choices and the number of congruent choices in the small room indicates that these older children were using the blue wall as a landmark. The experimenter noted that one of the 6-year-olds spontaneously reported that finding the target was easy because the blue part told her where to look. In the small room, the 5- and 6-year-olds made significantly different numbers of correct responses, $t(19) = -3.161$, $p = .0051$. This experiment shows that the inability of young children to use a colored wall as a landmark in a small room disappears as the children move beyond their 5th year.

GENERAL DISCUSSION

This study was designed to clarify an apparent conflict in the existing literature concerning the use of landmarks in combination with geometric features in a spatial reorientation task. The findings indicate that young children can use a landmark such as a blue wall in combination with the geometric information available when the experimental room is large enough. The children in this study were quite good at using the blue wall in the larger space, but could not use the blue wall in the smaller space if they were under 6 years of age. These findings raise the obvious question of why landmark use would be dependent on the size of the experimental space. Several possible explanations suggest themselves. One possibility is that older children have more experience than younger children navigating in general and have learned that color is a useful landmark in any space. Younger children use color as a landmark in large spaces, but not small ones. According to this explanation, the children under about age 5 failed to generalize what they knew about the usefulness of color as a landmark from larger, more natural spaces to the unnaturally small experimental space. In this case, the change that occurs between 5 and 6 years is one that allows children to generalize from their knowledge about larger spaces to a small space.

Another possible explanation is that the demands of the two spaces are somehow different. For example, one might ask if the smaller room engaged navigational ability at all. The 4- × 6-ft space was so small that with the experimenter and the child in the room, the space was crowded; in the larger room, there was plenty of space. Yet another possibility is that children treated the landmark differently in the two spaces. In the larger, but not the smaller, space it could be used as a heading cue, permitting appropriate reorientation. According to this view, a heading cue and a parallel geometric cue interacted in generating behavior.[1]

Hermer-Vazquez et al. (2001) suggested that the emergence of landmark use in 6-year-olds could reflect the advent of spatial language. Although the shift that allowed the children in the present experiments to use a landmark to reorient in the smaller space coincided with the advent of spatial language, the ability to use landmarks in the larger space long preceded spatial language. To say that spatial language was important in the small space only raises the new question of why spatial language would be necessary in a small space, but not in a large one. Furthermore, Thinus-Blanc and Gouteux (2000) have reported that monkeys can use a landmark to reorient in a space that is about the size of the larger space in the experiments we have reported here. Although this result demonstrates that language need not be involved in the successful use of landmarks in the larger room, the monkeys were not tested in a space small enough to rule out the possibility that it is spatial language that allows human children to overcome the special difficulty presented by a small space.

We think these findings indicate that the modularity explanation proposed by Hermer and Spelke (1994, 1996) cannot account for the data. The children in the studies presented here, and in some of the previous studies (Learmonth et al., 2001), succeeded in using the landmark in the large space even at 18 months. Although it remains possible that geometric and other modules are, in Fodor's terms, informationally encapsulated, our results indicate that information from multiple modules can be simultaneously brought to bear on reorienting behavior. Thus, at the level of behavior, there is no encapsulated module.

What these experiments do suggest is a fragility in the ability of young children to use landmarks. The same blue wall was available in both the large and small rooms in these experiments. The size of the landmark was proportionally the same in both rooms, yet the children under 6 used the landmark in the large room only, not in the small room. In the studies (Cheng, 1986) that found rats unable to use landmarks to reorient, the space was small in proportion to the size of the rat. The short wall was about twice the body length of the rat.

Thus, the studies to date indicate that human children (Learmonth et al., 2001) and monkeys (Thinus-Blanc & Gouteux, 2000) can use landmarks to reorient in large spaces, but that young human children (Hermer & Spelke, 1994, 1996) and rats (Cheng, 1986) cannot use landmarks to reorient in a small space.

The young children's failure to combine landmark and geometric information in the small space is in need of explanation. Given that the same children who could not use the landmark to reorient in the small space could do so in the larger space, a simple modularity explanation seems unlikely. Explanations will have to account for why the ability to use landmarks in a small space changes with age. This study, by demonstrating the crucial role of the size of the experimental space, sets the stage for a closer examination of the reasons why young subjects behave differently in small and large spaces.

Acknowledgments—This research was supported by grants from the Flinn Foundation and the McDonnell-Pew Cognitive Neuroscience Program awarded to Lynn Nadel. We would like to thank Josh Baker, Ryan Hendrix, and Amy Kaminski for help working with the parents and children participating in this research, and the parents and children themselves for their participation. We would also like to thank Elizabeth Spelke and an anonymous reviewer for their helpful and insightful comments.

1. This possibility was suggested by Elizabeth Spelke.

REFERENCES

Cheng, K. (1986). A purely geometric module in the rat's spatial representation. *Cognition*, *23*, 162–171.

Fodor, J.A. (1983). *Modularity of mind: An essay on faculty psychology.* Cambridge, MA: MIT Press.
Gallistel, C.R. (1990). *The organization of learning.* Cambridge, MA: MIT Press.
Gouteux, S., & Spelke, E. (2001). Children's use of geometry and landmarks to reorient in an open space. *Cognition*, *81*, 119–148.
Herman, J.F., & Coyne, A.C. (1980). Mental manipulations of spatial information in young and elderly adults. *Developmental Psychology*, *16*, 537–538.
Herman, J.F., & Siegel, A.W. (1978). The development of cognitive mapping of the large scale environment. *Journal of Experimental Child Psychology*, *26*, 389–406.
Hermer, L., & Spelke, E. (1994). A geometric process for spatial reorientation in young children. *Nature*, *370*, 57–59.
Hermer, L., & Spelke, E. (1996). Modularity and development: A case of spatial reorientation. *Cognition*, *61*, 195–232.
Hermer-Vazquez, L., Moffet, A., & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition*, *78*, 263–299.
Kosslyn, S.M., Pick, H.L., & Fariello, G.R. (1974). Cognitive maps in children and men. *Child Development*, *45*, 707–716.
Learmonth, A.E., Newcombe, N.S., & Huttenlocher, J. (2001). Toddlers' use of metric information and landmarks to reorient. *Journal of Experimental Child Psychology*, *80*, 225–244.
Siegel, A.W., Herman, J.F., Allen, G.L., & Kirasic, K.C. (1979). The development of cognitive maps of large and small scale space. *Child Development*, *50*, 582–585.
Thinus-Blanc, C., & Gouteux, S. (2000, December). *The encoding of geometry in primates: A comparison with children.* Paper presented at the International Conference for Spatial Cognition, Rome, Italy.
Wang, R., Hermer-Vazquez, L., & Spelke, E. (1999). Mechanisms of reorientation and object location by children: A comparison with rats. *Behavioral Neuroscience*, *113*, 475–485.
Weatherford, D.L. (1982). Spatial cognition as a function of size and scale of the environment. In R. Cohen (Ed.), *Children's concepts of spatial relations* (pp. 5–18). San Francisco: Jossey-Bass.
Weatherford, D.L., & Cohen, R. (1980). Influence of prior activity on perspective taking. *Developmental Psychology*, *16*, 239–240.

(RECEIVED 6/8/01; REVISION ACCEPTED 10/9/01)